MBTOC Update

Control of Pests of Walnuts by Irradiation

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Method of Control: Ionizing radiation

This method uses electromagnetic radiation of energy levels sufficient to control or kill pests. The source of ionizing radiation for food irradiation is primarily the radioactive isotope ^{60}cobalt, although ^{137}cesium, x-rays and electron accelerators could be used with electron beam being more likely. The method is rapid, effective and leaves no product residue.

Crop/Commodity: Postharvest walnuts. Approximately 540,000 metric tons are produced world-wide. The United States produces the largest share, about 42% of the world crop, with China producing about 32.5%. Other producers include Chile, France, India, Italy, and Turkey (USDA, 1994).

Target Pest(s):

- Indianmeal moth (*Plodia interpunctella*)
- navel orangeworm (*Amyelois transitella*)
- codling moth (*Cydia pomonella*)

Summary of Viability:

Ionizing radiation, either from isotope or machine generated sources, has been suggested as an alternative to chemical fumigation for various dried fruit and nut commodities, including walnuts. Both domestic applications to disinfest harvested product or control storage insects and quarantine treatments have been considered. While the method was determined to be efficacious, there are, however, implementation issues.

Some treated insects may survive for some time after treatment. Required doses may be close to those causing adverse effects on product quality. With walnuts, large amounts of product must be handled over a short harvest period; this problem could be resolved more economically through the use of accelerators, or with gamma contract irradiation facilities where sufficient other commodities are available to the facility during the off season. The current US-FDA approved maximum dose for disinfestation may be too low given current storage container size and product density if walnuts are to be irradiated in the container; this problem might not an issue in other countries if containers are smaller. Since irradiation at doses higher than the current limit may negatively affect walnuts, accelerator applications with the walnuts removed from the storage containers might be more effective. Major changes to existing processing facilities and product handling procedures, and the high initial capital cost of irradiators, make the treatment more costly than fumigation. The problem of having to retreat stored product because of reinfestation is likely to occur with current storage proceedures.

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Pest Efficacy and Consistency:

General mode of action and efficacy: Much work has been done on the general effects of ionizing radiation on insects (Tilton and Brower, 1983; Nation and Burditt, 1994). Because the high dosages necessary to cause immediate mortality in mature larvae, pupae or adults may reduce product quality, the criteria used for evaluation of efficacy is often based on reduction of product damage and preventing pest population growth. Relatively low doses (less than 100 Gy) have been found to be effective in preventing emergence of viable adults and preventing damage by feeding stages, although irradiated insects may survive for some time after treatment. Eggs are normally the least tolerant stage because undifferentiated, mitotically active tissues are most sensitive to ionizing radiation. The insect midgut includes undifferentiated epithelium and so is quite sensitive to radiation. For this reason irradiated insects often stop feeding soon after treatment. Gonadal tissue is also sensitive, thus insects surviving radiation treatments should be sterile at recommended treatment doses. Efficacy of radiation for control of three major postharvest walnut pests was summarized in Rhodes (1986).

Viability Evaluation Factors:

a. Tested under full laboratory and field conditions including field tests in Article 5 countries

1. Additional research and field development needed (time and resources) for full evaluation of the control method.

Few developing countries market significant amounts of walnuts. While the United States produces the largest share of the world's walnuts (about 225,000 metric tons each year), China is second with 175,000 metric tons in 1994 (USDA, 1994). Much has been done on use of irradiation for food preservation in developing countries (Khan, 1993, Al-Bachir et al, 1993; Mahlous, 1993; Nketsia-Tabiri et al, 1993) but most of this work has been done on other commodities. Basic work on irradiation of walnuts has been done, but for developing countries considering this method, pilot scale studies would be necessary to determine the cost and efficacy for their specific situation.

2. Tested in developing countries (identify countries)

As of yet, little work has been done on irradiation of walnuts in developing countries. Pakistan reports use of irradiation to inhibit insect infestation of walnuts (Khan, 1993), along with several other dried fruits and nuts.

b. Efficacy with respect to crops and targeted pests

1. Pest efficacy and variability

Indianmeal moth: The major pest of postharvest walnuts, this insect infests the product while it is in storage. Much work on the effect of radiation on this insect has been done, both as a possible disinfestation technique and in developing a sterile insect release program. Because Indianmeal moth has a wide host range and is cosmopolitan in distribution, this work includes a number of commodities. Generally, minimal dosages of 200 to 250 Gy have been suggested to prevent continued development of populations (Brower and Tilton, 1970, 1971, 1972), although to reduce female longevity a dose of 300 Gy may be more practical (Johnson and Vail, 1987). Such a dose will not prevent feeding of late instar larvae (Johnson and Vail, 1988) but does reduce product damage considerably (Johnson and Vail, 1989).

Walnuts often undergo multiple fumigations due to the ability of Indianmeal moth to reinfest current storage systems. Currently, US regulations regarding food irradiation do not allow for multiple treatments. Without a change to this policy, disinfestation of California walnuts with radiation must be combined with other measures to prevent reinfestation. Temperatures ≤ 10°C prevent Indianmeal moth populations from developing in walnuts (Johnson et al, 1995). Because walnuts are often stored at 7-10°C in order to preserve quality, the use of low temperature storage to prevent reinfestation after irradiation may be an option.

Navel orangeworm: This insect is a common pest of California tree nuts. Infestations of walnuts by navel orangeworm commonly originate in the field and are carried into storage. Newly harvested walnuts are fumigated to prevent further damage by feeding larvae. Although adults do not normally reproduce under storage conditions, processors are also concerned about the possibility of adult moths reinfesting product. Husseiny and Madsen (1964) showed that dosages of ≥ 300 Gy applied to eggs or larvae prevented emergence of viable adults, but dosages of ≥ 500 Gy applied to pupae were need to obtain sterile adults. Johnson and Vail (1988, 1989) showed that feeding and damage caused by navel orangeworm larvae could be reduced with dosages of ≥ 300 Gy.

Codling moth: Similar to navel orangeworm, codling moth infests walnuts in the field and may be brought into storage. Although widespread in distribution, codling moth is not found in Japan or Korea, and is under quarantine in these countries. Research on use of radiation to control codling moth has concentrated on the development of quarantine treatments. Burditt and Moffitt (1985) showed that nondiapausing codling moth larvae were more resistant than diapausing larvae to irradiation, and determined that a dose of 145 Gy should be an adequate quarantine treatment for apples. Burditt (1986) determined that 156 Gy prevented emergence of normal adults from nondiapausing larvae in walnuts. A dose of 230 Gy was necessary to completely prevent emergence of adults.

A major consideration for use of radiation as a quarantine treatment is the possibility of live insects being found during inspections by the importing country. Currently, there is no simple method to determine if such an insect has been irradiated. This issue is being addressed internationally and will make quarantine irradiation treatments viable.

2. **Crop impact (yield/quality/storage life) and consistency**

While radiation doses required for insect disinfestation of most dried fruits and nuts generally cause little quality damage, walnuts are considerably more sensitive to radiation treatments because of their high oil content. Taste panel studies conducted by Rhodes (1986) found that radiation doses of up to 900 Gy did not cause immediate deterioration in quality of walnuts, but, with storage, some quality damage occurred at 600 and 900 Gy. It was recommended that irradiation of walnuts be done at less than 600 Gy, preferably 300-450 Gy.

Jan et al (1988) evaluated the changes in lipids in walnuts irradiated at doses of 0.5 and 10 kGy, finding no radiation induced change either directly after treatment or after storage. Khan (1993) noted that doses of up to 1 kGy had no adverse effect on several food items, including walnuts. Wilson-Kakashita et al (1995) irradiated walnuts at 5 to 20 kGy and found no change in free fatty acids, iodine values or 2-thiobarbituric acid levels immediately after treatment, but noted that peroxide levels were much higher. Walnuts were not evaluated after storage.

Because of the conflicting results presented above, additional work at the pilot scale level should be done to evaluate product quality under industry standard storage conditions and durations.

3. **Potential for methyl bromide emission reductions**

Should radiation be used as a substitute for all methyl bromide on postharvest walnuts, emissions from this application would be eliminated. Should radiation be used only for certain specific applications, such as packaged product or quarantine treatments, then methyl bromide emissions would be reduced proportionately.

c. Ease of application

1. **Type and ease of application (logistics)**

When a commodity is irradiated, it passes through an irradiator producing ionizing radiation either from an isotope source or machine generated (X-rays or electron beam). In order to ensure the safety of workers, the unit requires large amounts of shielding, and a way to move the commodity past the source. Irradiators require a certain level of training and understanding of technology. Given that about 180 commercial gamma irradiators and over 450 commercial electron beam accelerators currently operate in over 40 countries, including many developing countries, it is obvious these operational and safety issues are manageable.

California processors of walnuts normally use methyl bromide to fumigate incoming product and for as long as a year during bulk storage. Use of irradiation as a substitute for this application would require passage of all commodity through an irradiator, either at a remote location or at the processing plant. This may require massive changes in normal handling practices. If radiation is used only for packaged products or for quarantine treatments, then changes in product handling practices may be minor.

2. **Safety (grower, worker, consumer)**

   Irradiators must be carefully designed to prevent accidental exposure of workers, operated by trained and licensed personnel, and inspected regularly. Medical product irradiators have been operated for years with a good safety record.

   The safety of irradiated foods has been researched for years. In 1980, the Joint Food and Agriculture Organization/International Atomic Energy /World Health Organization Expert Committee on the Wholesomeness of Irradiated Food recommended general approval of foods treated with doses of up to 10 kGy as unconditionally wholesome (Sapp, 1995). The committee based this recommendation on research involving microbiological, nutritional, and food chemistry studies, as well as long-term feeding studies. The U. S. Food and Drug Administration has determined that food irradiation is safe and has approved general use of up to 1 kGy in addition to certain applications at higher doses.

3. **Special requirements and restrictions on use**

   Irradiators must be approved and licensed by the appropriate governmental agency, and must be inspected regularly. The Codex Alimentarius Commission General Standard for Irradiated Foods recommends that foods only be irradiated once, but allows for reirradiation under certain circumstances. Within the United States, food stuffs may not be irradiated more than once, and irradiated food must be clearly labeled. Should the method be used for quarantine purposes, the necessary clearances with the importing countries would be required.

4. **Potential non-target impacts**

   This method will only directly effect insects that occur within the commodity. Because any insect within the product is undesirable, all may be considered as target species.

d. Relevance to climatic conditions, soil and cropping patterns

1. **Geographical areas (acres and climatic conditions)**

   Climatic variation has little effect on efficacy or practicality. Lack of irradiation equipment in the geographic area where the product is continues to be a problem in many regions.

2. **Soil types**

   Not applicable.

3. **Cropping patterns, rotations, and/or land use**

   Not applicable.

e. Commercial availability

1. **Registration potential/requirements/status**

   Food irradiation is a well established treatment method in many countries. Within the United States, commercial food irradiation is allowable under current regulations. On a limited basis, produce, poultry and spices have been irradiated and sold within the United

States. U. S. Animal Plant Health Inspection Service has developed policies and guidelines for use of radiation as a quarantine treatment.

2. **Commercial availability (materials/engineering)**

Several companies build and maintain irradiation facilities. While both Co^{60} and Cs^{137} may be used in food irradiators, all commercial facilities use Co^{60}. Currently, the supply of Co^{60} meets the needs of planned irradiators.

3. **Technology readily transferable**

Currently there are about 450 electron beam irradiators and 180 gamma irradiators operated by industries throughout the world (Leemhorst, 1993). Used primarily for applications other than food processing, this demonstrates that the technology has already been transferred to commercial users.

4. **Public/consumer acceptance**

Public acceptance is possibly the most debated issue associated with this method. Within the United States, a small but vocal number of consumer advocacy and environmental groups have expressed concern over the issue of safety (Sapp, 1995). While safety concerns are unfounded, the fear of public outcry has caused the food industry to be reluctant to adopt radiation as a processing technique. Nevertheless, irradiated produce is currently sold in about 40 stores in mid-western United States.

Besides this record of continued consumer purchases of irradiated foods consumer acceptance studies seem to indicate that the majority of consumers will eventually accept irradiated foods. Marcotte (1995) summarized work done on consumer attitudes and market studies on food irradiation. Market tests of irradiated foods worldwide have all been successful and attitudes of the majority of consumers are often positive. Consumers are more interested to know the price and quality of foods rather than the method of treatment. Other work indicates that acceptance increases when consumers are provided with information about specific advantages of the process (Bruhn, 1995). Thus, education of the public and legislative sectors concerning the safety of irradiated foods needs to be pursued vigorously.

f. **Economic viability**

1. **Direct effects**

Irradiation equipment capable of processing large volumes of commodities such as California walnuts is very capital intensive, with facility costs in the range of $4-7 million (Leemhorst, 1993). A recent note on the costs of treating dried fruit with accelerator equipment or X-rays indicates costs could vary between $1.40/ton if all California commodities were irradiated at one plant to $5-10/ton if 5-10 facilities were built (AECL Application Note, November 1996). Increased handling costs were not included in the analysis. Irradiation is more expensive than fumigation, but given the high value of walnuts, irradiation costs might not be prohibitive.

The only in-depth economic analysis of the use of radiation specifically for walnut disinfestation was done by Rhodes (1986). Although this report is 10 years old, and costs for irradiation have changed, the work is still relevant in that it compares costs of other alternative methods, and looks at the costs of combination treatments. Costs of using radiation as a substitute for methyl bromide were estimated at $8.32-71.89 per ton handled annually. Costs varied with plant size, with per ton estimates being lower for larger plants. An alternative plan used radiation in combination with controlled atmosphere, where costs were estimated at $6.52-66.96 per ton handled annually. Cost for controlled atmosphere alone was $4.28-10.97 per ton handled annually. Normal control costs using methyl bromide fumigation was only $0.78-1.54 per ton handled annually, regardless of plant size.

Radiation processing and equipment has changed in the time since Rhodes (1986). Additional analysis should be done on the basis of current commercial practices and fumigation costs, investigating options for irradiation at different stages of product storage and marketing and including scenarios for improved storage that prevents reinfestation of the product. Comparison of radiation costs with use of phosphine should be included.

2. Indirect effects

In the analysis by Rhodes (1986) for the control scenario where radiation was the sole method, the assumption was made that product could be reirradiated. U.S. regulations do not allow retreatment, thus, without a regulatory change, walnuts would only be irradiated one time. In any case, given the quality affects of irradiation on walnuts, they might not withstand re-irradiation. Because other control measures would be needed throughout storage, the cost estimates for radiation combined with modified atmosphere is more realistic. Another possible method to prevent reinfestation is refrigeration to temperatures below insect developmental thresholds (10°C). Walnuts are often stored at low temperatures to preserve product quality, so some refrigerated storage is available. However, large, bulk storage silos are not chilled, and retrofitting these for refrigerated storage would be costly.

While logistic, regulatory and economic problems reduce the likelihood of irradiation being used as the single substitute for methyl bromide in postharvest walnuts, there are applications where the speed and penetration of the method may be useful. Where these applications are for only a portion of the walnut crop, contract irradiators may be more economically acceptable (Leemhorst, 1993). These applications include quarantine treatments and disinfestation of finished packaged material.