Gamma Irradiation as a Quarantine Treatment for Sweet Cherries Against Queensland Fruit Fly

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Abstract. The quality of 'Ron's Seedling', 'American Bing', and 'Lambert' sweet cherry drupes was not affected by irradiation doses up to 300 to 1000 gray. Peduncle discoloration increased in 'Ron's Seedling' cherries when irradiated at 600 and 1000 gray. A dose of 75 gray prevented adult eclosion of more than 1300 Queensland fruit fly (*Dacus tryoni*, Froggatt). Larvae treated at the third instar were the least susceptible to gamma irradiation. The results indicated that gamma irradiation is a feasible quarantine treatment against *D. tryoni* without impairment to the quality of cherries.

Australian cherries can be host to insect pests and are subject to strict quarantine regulations that restrict their movement both interstate and overseas. Japan bans the importation of cherries from Australia due to possible infestation by several pests, including Queensland fruit fly (All-Japan Union of Plant Quarantine Association, 1979). Australian cherries may gain U.S. entry, providing they have been treated with cold storage or a combination of cold storage and methyl bromide fumigation (U.S. Department of Agriculture Animal and Plant Health Inspection Service, 1985). The fruit from most cultivars are tolerant of methyl bromide, although some researchers cite deleterious effects on flavor and external appearance (Claypool and Vines, 1956; Jessup, 1988).

The major drawback of treatments involving cold storage, either alone or in combination with fumigation, is the time required to complete the treatment. This concern is important to trade with Japan, as produce from Australia must be treated before departure from Australia (Higgs, 1987), resulting in a reduction in shelf life, as, on average, shipping time from Australia to most Asian ports is 20 days.

Gamma irradiation can sterilize quarantine pests in just a few hours in many food products with little or no adverse effects on quality (Loaharanu and Urbain, 1982; Dentener et al., 1988). Quarantine security against *D. tryoni* is assured at a dose of 75 gray (Gy) (Rigney and Wills, 1984), while the International Consultative Group on Food Irradiation has stated that a dose of 300 Gy would sterilize any insect infesting fruit (Food and Agricultural Organization/International Atomic Energy Agency, 1986).

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This paper reports studies on the effects of irradiation, normal refrigerated storage, plastic film wrapping, and an ethylene absorbant on the appearance and quality of Australian-produced 'Ron's Seedling', 'American Bing', and 'Lambert' cherries, three of the most important cherry cultivars grown in Australia, and on treatment efficacy against eggs and larvae of *D. tryoni*.

All fruit was harvested at Young in southern New South Wales from Dec. 1987 to Feb. 1988. They were cooled overnight to 10C to remove field heat then packed in 5-kg-capacity cardboard retail display cartons. The fruit was transported to Gosford the next day and sorted into treatment units comprised of 50 fruit each, stored at 10C overnight, and transported 85 km by road to the Australian Nuclear Science and Technology Organization (ANSTO) to be irradiated. At ANSTO, the fruit were irradiated in air at 21C using a 100-kCi (1 Ci = 37 GBq) Cobalt-60 source emitting gamma irradiation at a dose rate of 9.25 Gy/min. Upon return to Gosford, the fruit was stored at 10C for 10 days or at 1C for 20 days and then assessed for evidence of damage.

In the first experiment, 'Ron's Seedling' fruit were divided into five replicates of two groups of six plastic containers (50 fruit per

container). The fruit in the first group were covered with commercial plastic wrap (Cryovac v925, 50,000 nm thickness), and in the second, 50 g of vermiculite impregnated with potassium permanganate was placed in a mesh bag under the wrap. The wrap and potassium permanganate were used to determine if increasing relative humidity or reducing ethylene concentrations would reduce peduncle discoloration (Sharkey and Pegg, 1984). Fruit for each storage treatment were irradiated, in their plastic containers, at 0, 75, 150, 300, 600, or 1000 Gy. For each dose, the five replicates were irradiated separately. After irradiation, fruit were placed for 10 days in a cold room equilibrated to 10C. Ferrous ammonium sulphate (FAS) dosimetry was conducted on one plastic container from each replicate dosed at 300 Gy. The maximum to minimum ratio of dose received was <2:1.

Ten fruit per replicate from each of the six plastic containers per treatment were assessed for the following variables: total soluble solids ($^{\circ}$ Brix), firmness (determined by the distance each fruit was deformed under a weight of 100 g for 15 sec), peduncle discoloration and external damage (scored from 1 to 10, where 1 = 0% to 10% discoloration or damage and 10 = 90% to 100% discoloration or damage), and average fruit weight. External damage (i.e., skin pitting, browning, or splitting) was also noted. Fruit with a peduncle discoloration score >5 (40% to 50% of the peduncle was brown or dried out) were classed as unmarketable.

In the second experiment, five replicates each of 'American Bing' and 'Lambert' cherries were irradiated at 0, 75, 150, or 300 Gy and then stored at 1C for 20 days to study the effects of a combination irradiation and cold storage treatment. Ten fruit per replicate were assessed for degree of peduncle abscission using a clamping device that held the fruit while the peduncle was removed. The force required to remove the peduncle was measured in grams. External damage and degree of skin browning were scored on 20 fruit per replicate using the same method as in the first experiment. Skin color was also assessed for these fruit and scored from 1 = completely black to 5 = completely red. Data

Table 1. Effects of gamma irradiation and subsequent storage at 1C for 20 days on quality attributes of 'American Bing' and 'Lambert' cherries.

Attribute	Dose (Gy) ^z			
	0	75	150	300
<i>American Bing</i>				
Peduncle discoloration ^y	2.05 b	2.28 a	2.27 a	2.37 a
Skin color ^x	1.83 a	1.84 a	1.72 b	1.76 b
External damage	1.52	1.39	1.57	1.47
Force to remove peduncle (g)	10.7	10.3	10.4	10.1
<i>Lambert</i>				
Peduncle discoloration ^y	2.34 a	2.17 b	2.21 ab	2.12 b
Skin color ^x	1.77 a	1.63 b	1.68 b	1.67 b
External damage	1.31	1.27	1.49	1.40
Force to remove peduncle (g)	7.1 a	5.7 b	6.6 ab	6.7 ab

^zMean separation in each row by Duncan-Waller Bayesian k ratio test (k = 100). Each figure represents the mean of five replicates of 50 fruit each.

^yScored from 1 (completely green) to 10 (completely brown).

^xScored from 1 (completely black) to 5 (completely red).

Table 2. Pupal formation from immature stages of *D. tryoni* in 'Ron's Seedling' cherries after gamma irradiation.

Stage	Dose (Gy) ^{a,b}		
	0	75	300
Egg	460	0 (100)	0 (100)
First instar	389	0 (100)	1.3 (97.7)
Second instar	577	430 (25.5)	419 (27.7)
Third instar	505	458 (9.3)	495 (2.1)

^aEach datum represents the mean number of pupae formed from five replicates of 160 fruit each.

^bNumbers in parentheses represent percent mortality and are based on pupal formation from nonirradiated (0 Gy) 'Ron's Seedling' cherries infested with immature lifestages of *D. tryoni*.

Table 3. Survival of third instar *D. tryoni* to adult eclosion in 'Ron's Seedling' cherries after gamma irradiation.

Dose (Gy)	Pupae formed ^a (no.)	Emergent adults ^b (no.)	Emergence (%)
0	1450 ^b	1389	95.8
75	1080	0	0
100	1238	0	0

^aTotal number of pupae from five replicates of 100 fruit each.

^bTotal number of emergent adults from five replicates of 100 fruit each.

from both experiments were tested by analysis of variance (Alvey et al., 1983). Where differences between treatment means were significant ($P < 0.05$), K-LSD values were calculated at $k = 100$ using the Duncan-Waller Bayesian k ratio test (Chew, 1977).

To test the efficacy of irradiation against *D. tryoni*, five replicates each of 160 'Ron's Seedling' cherries were infested in the laboratory with *D. tryoni* eggs (Rigney and Wild, 1975) by placing the fruit on mesh cages housing 3- to 5-week-old adult flies and allowing oviposition through the mesh. Infested fruit were stored at 26C and 70% RH, the optimum conditions for the development of *D. tryoni*, until larvae had attained first, second, and third instars. Infested fruit were then irradiated when insects were at the egg stage and the three larval stages, separately. Doses received were 0 (nonirradiated control), 75, and 100 Gy. Dosage was confirmed using FAS dosimeters on the 75-Gy fruit. After irradiation, the infested fruit were stored at 26C over dry sand in which surviving larvae pupated. Pupae were collected, and the least susceptible *D. tryoni* stage was determined based on the relative number of pupae formed.

In a follow-up experiment, five replicates each of 100 fruit were infested with *D. tryoni* eggs, irradiated at 0, 75, or 100 Gy once the larvae had developed to the most tolerant stage, and stored as above. Surviving pupae were collected and stored at 26C and the number of emergent adult flies was recorded. The efficacy of the treatment was based on successful adult eclosion.

Following the irradiation of 'Ron's Seedling' cherries and subsequent storage at 10C for 10 days, there were no significant irradiation effects on total soluble solids (10.9 to 12.1 °Brix), firmness (deformation 0.49 to 0.58 mm), external damage (score 6.3 to 7.0), or fruit weight (5.7 to 5.9 g). Peduncle discoloration was linearly correlated with dose ($y = 0.0017x + 2$, $r = 0.96$), based on mean values from five replicates of 60 fruit each. As peduncle discoloration in fruit ir-

radiated at 600 and 1000 Gy, with average scores of 3.40 and 3.58, respectively, did not attain a score >5 , the fruit were classified as commercially acceptable. The addition of potassium permanganate did not reduce the extent of external damage or peduncle abscission.

In the second experiment, there were no significant differences in firmness, the force required to remove the peduncle from the drupe, or external damage when 'American Bing' or 'Lambert' cherries were irradiated at doses up to 300 Gy and then stored at 1C for 20 days (Table 1). There were significant differences in color, with irradiated fruit tending to remain redder than the controls. Cultivar response varied with respect to peduncle discoloration, where irradiation adversely affected 'American Bing' cherries, but not 'Lambert' cherries. The discoloration, however, would not be expected to render the 'Bing' fruit unmarketable.

Other researchers have found significant though small, deterioration in firmness, flavor, and appearance in 'Bing' cherries dosed at 600 to 800 Gy (Johnson et al., 1965); adverse texture effects have also been reported when fruit were irradiated (U.S. Atomic Energy Commission, 1965). In another study, irradiation at 2000 to 4000 Gy in combination with refrigeration enhanced the storage life of 'American Bing' cherries (Salunkhe and Desai, 1983).

Second and third instar larvae of *D. tryoni* were more tolerant than eggs or first instar larvae (Table 2) in terms of the number of pupae formed after fruit were irradiated. No insect survived to adult eclosion when third instar larvae of *D. tryoni* were irradiated at 75 or 100 Gy (Table 3).

The results indicate that a dose of 75 Gy could provide quarantine security against eggs and larvae of *D. tryoni* in cherries by breaking the life cycle of the fruit fly at adult eclosion. This treatment will not affect cherry fruit quality, but efficacy trials must be conducted to confirm quarantine security at the probit 9 level (99.99683% mortality), which

is the level required by the U.S. Animal and Plant Health Inspection Service for the importation of fresh fruit and vegetables into the United States (Baker, 1939). Irradiation even at a dose as low as 75 Gy delayed the normal skin coloration of the red-skinned cherries 'Lambert' and 'American Bing'. Irradiation may, therefore, have some benefit in prolonging the shelf life of some cherry cultivars. Further research is required to test this hypothesis.

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