Quality of apples and pears after exposure to irradiation as a quarantine treatment

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Abstract: Irradiation at doses between 0.30 and 0.90 kGy reduced apple firmness. Doses of <0.30 kGy had no effect on apple fn-mness. The amount of firmness lost due to irradiation was cultivar dependent. Titratable acidity (TA) of 'Gala' apples was reduced at irradiation levels of 0.60 kGy and above. No loss of TA due to the irradiation dose was evident , for either 'Fuji' or 'Granny Smith' apples. Irradiation at <1 .OO kGy did not influence the external color of apples. There was some change in the internal color of 'Gala' and 'Granny Smith apples due to irradiation exposure. 'Anjou' pear firmness was not influenced by irradiation, but 'Bosc' lost firmness due to irradiation, and the firmness loss was dose dependent. Both 'Anjou' and 'Bosc' ripened normally after irradiation exposure, but 1 to 2 additional days ripen than non-irradiated pears. There was a significant increase in scald for 'Anjou' that was dose dependent. Some reduction in decay was observed in irradiated apple fruit. Disease incidence of 'Fuji' and 'Granny Smith' apples caused by *P. expansum* after 60 days of storage was reduced from about 80% of wounds with lesions to 30% as a result of a dose of 0.60 kGy. Irradiation had no effect on number of lesions caused by either *B. cinerea* or *M. piriformis*. Similarly, no effect was observed on decay of 'Anjou' pear fruit naturally infected with *P. expansum* and *B. cinerea* (7.4% and 7.9% of wounds infected, respectively). However, a reduction in decay was observed in naturally infected 'Bosc' pear fruits treated with 0.90 kGy.

MATERIALS AND METHODS

Radiation treatments were conducted at Battelle-Pacific Northwest Laboratory, Richland, WA using a gamma beam 650 source containing cobalt-60. Distance of the boxed fruit from the source was adjusted to provide a dose rate of 8.32 Gy/min and varying exposure time to for doses of 0; 0.15, 0.30, 0.60 and 0.90 kGy. Apple and pear fruit used as controls were also transported and held under similar temperature and conditions as irradiated fruit.

Apple quality evaluation. Commercially packed 'Fuji' and 'Granny Smith' apples were obtained from Orondo, WA. after 90 d of controlled atmosphere storage (1% to 2% O_2, 1% CO_2 @ 1^0 C). Packed 'Gala' apples were obtained from Wenatchee, WA after 45 of cold storage (1^0 C). Apples were held one to two days at 10^0 C and transported to the irradiator. After treatment, the fruit was transported to Wenatchee, WA and placed in cold storage at 1^0 C. Fruit quality was assessed after 30 or 60 d in cold storage and ripening after 0 or 7 days at 20^0 C.

Pear qulaity evaluation. Three groups of packed, size 100 (220 g) US No. 1 'Anjou' and 'BOSC' pears were obtained in 1995 and 1996. In 1995, fruit had been stored for 45 d in cold storage at 1^0 C, whereas in 1996, fruit were obtained within one week of harvest. Pears were held one to two days at 1^0 C and transported to the irradiation facility.

Fruit quality evaluations were made on each of 20 apples or pears for all combinations of radiation treatment, storage and replication. Ten fruit were evaluated immediately after removal

from storage and the other 10 were ripened for 7 days at 20^0 C before evaluation. Quality factors evaluated were external and internal color, firmness, soluble solids content (SSC), titratable acidity (TA), visual disorders, decay and flavor (pears only).

Apple disease control. To determine if irradiation affected decay incidence, 'Fuji' and 'Granny Smith' fruit from each of the three grower lots were selected about 12 hr before irradiation and fruit surface was disinfested with 150 ppm chlorine for 5 min.. Apples were placed on new fruit trays and then wounded to simulate stem punctures (5 mm diam x 3 mm deep, 2 wounds/fruit). Wounds in each of 3, 6-fruit replicates were inoculated with aqueous spore suspensions (50 µL/wound) of either *Penicillium expansum* Link (2000 conidia/mL), *Botrytis cinerea* Pers.:Fr. (1000 conidia/mL), or *Mucor piriformis* E. Fisch. (500 conidia/ml), as well as sterile water controls.

Pear disease control. Commercially packed 'Anjou' pear fruit were obtained from a packinghouse in the Wenatchee, WA area. Three replicate boxes each of tight-packed (tissue paper wrapped), size 100 fruits and foam tray-packed, size 70 fruits were irradiated at 0, 0. 15, 0.30, 0.60, and 0.90 kGy. Commercially packed 'Bosc' fruit were obtained from two packinghouses. Tight-packed fruit (size 120) were obtained from the Wenatchee area and pulp tray-packed fruit (size 100) from the Yakima area. Tray-packed fruits had been treated with thiabendazole at harvest, stored in field bins and were packed two days before treatment.

CONCLUSIONS

Low dose irradiation (<0.90 kGy) can be used as a quarantine treatment in apples and pears. Fruit response to irradiation was cultivar dependent. Some quality response was evident, but not to the extent of reducing quality grade, except for 'Anjou' pears with increased scald due to irradiation. Loss of firmness (4% to 12%) and acid content (7% to 12%) was the major response of apples to irradiation, with no change in external and only slight change in internal color for 'Gala' and Granny Smith'. The loss in firmness for apples, due to irradiation exposure, was not of great concern. Pears also lost firmness due to exposure to irradiation, but both 'd'Anjou' and 'Bosc' pears ripened normally. Ripening of irradiated 'Bosc' pears was slowed, requiring approximately one additional day to reach the same firmness levels as non-irradiated fruit. No loss of TA content was evident for pears subjected to irradiation. Scald on 'Anjou' pears was enhanced after exposure to irradiation, but only at the highest (0.90 kGy) level of irradiation. At irradiation levels sufficient to meet quarantine requirements, only very slight quality loss was evident for apples and no quality loss was evident for pears.

Decay caused by *P. expansum* was reduced at absorbed dosages of 0.60 kGy and 0.90 kGy in apples and 'Bosc' pear fruit, respectively. A strong trend showing reduction of decay in 'Fuji' fruit caused by *M. piriformis* also was observed. Apple cultivars were differentially susceptible to decay by *B. cinerea,* but not *P. expansum* or *M. piriformis* at the inoculum densities used. While some increase in shelf life due to control of decay may be obtained at these irradiation dosages, higher absorbed doses likely will be required to achieve commercially acceptable levels of decay control. Irradiation at doses from 0.30 to 0.90 kGys has the potential as a quarantine treatement on apples and pears with little or no quality loss.

Table 1. Firmness and titratable acidity of 'Fuji', Gala' and Granny Smith' apples as influenced by irradiation treatment, storage time and ripening.

Treatments	Firmness (N) 'Fuji	'Gala'	'Granny Smith	Titratable Acidity (% malic) 'Fuji'	'Gala'	'Granny Smith
Radiation Dose (kGy)						
0.00	60.4a[z]	57.3a	63.7a	0.29ab	0.32a	0.57b
0.15	60.1a	57.2a	63.6a	0.30a	0.3 lab	0.60a
0.30	59.9a	56.0ab	61.5b	0.29ab	0.30ab	0.59b
0.60	59.3ab	55.0b	58.7c	0.26c	0.28b	0.57b
0.90	58.0b	54.4b	55.8d	0.27bc	0.28b	0.57b
Storage (days @ 1^0 C)						
30	60.0a	58.0a	60.5a	0.30a	0.35a	0.60a
60	59.0b	55.8b	58.6b	0.27b	0.29b	0.54b
Ripening (days @ 20^0 C)						
0	62.6a	58.9a	62.6a	0.30a	0.31a	0.60a
7	58.7b	53.1b	58.7b	0.29b	0.28b	0.56b

'Means within treatments in a column not followed by a common letter are significantly different by Tukey's HSDT ($P \geq 0.05$).

Table 2. External and internal Hunter color of 'Fuji', 'Gala' and 'Granny Smith' apples as influenced by u-radiation treatment, storage time and ripe.

	External Color						Internal Color					
	"L"			hue			" "			hue		
Treatment	'Fuji'	'Gala'	'Granny Smith	'Fuji'	'Gala'	'Granny Smith'	'Fuji'	'Gala'	'Granny Smith	'Fuji'	'Gala'	'Granny Smith'
Radiation Dose (kGy)												
0.0	55.0a[z]	54.0a	64.8a	50.8a	36.9a	108.1b	71.3a	70.8ab	75.1 a	93.1	89.5 a	100.8 a
0.15	55.6a	52.7a	64.3a	53.6a	35.0a	108.4a	71.5a	71.3 a	75.8 a	93.3	89.5 a	100.2ab
0.30	56.1a	53.7a	64.3a	53.1a	35.6a	108.3ab	71.5a	70.7 b	75.4 a	93.2	89.5 a	99.8abc
0.60	54.6a	53.1a	64.5a	50.9a	34.9a	108.2 ab	71.4a	70.7 b	75.7 a	92.4	88.9ab	99.1 bc
0.90	55.8a	53.0a	54.7a	54.4a	35.2a	108.0 b	71.4a	70.6 b	75.2 a	92.8	88.5 b	98.5 c
Storage (days)												
30	55.4b	53.3a	64.8a	50.5b	36.1a	108.7 a	72.1b	78.2 a	74.1 b	89.4a	91.5 a	101.1 a
60	56.5a	53.7a	65.2a	53.9a	35.4a	108.0 b	74.7a	67.0 b	76.8 a	89.9a	87.8 b	99.2 b
Ripe (days)												
0	56.3 a	53.1a	65.2 a	52.7a	34.9 b	108.3 a	70.5 b	70.0 b	76.3 a	96.5a	89.6 a	100.0 a
7	54.6 b	53.5a	63.9 b	52.3a	36.1 a	108.1a	72.5 a	71.6 a	74.7 b	89.4b	88.8 b	99.2 b

[z]Means within treatments in a column not followed by a common letter are significantly different by Tukey's HSDT ($P \geq 0.05$).

Table 3. Effect of irradiation on incidence of decay in apple fruit (cv. 'Granny Smith' and 'Fuji') that were wounded and inoculated with *Penicillium expansum*[x]

Radiation Dose (kGy)	Disease incidence (%)[y]	
0.00	80.3	a[z]
0.15	80.6	a
0.30	59.2	ab
0.60	33.1	b
0.90	29.4	b

[x] Wounds were each inoculated with 50 µl of an aqueous spore suspension (2000 conidia/ml).
[Y] Means of 3 replicates of 5 fruit with 2 wounds/fruit
[z] Means in a column not followed by a common are significantly different by Tukey's HSDT (P≥0.05).

Table 4. Effect of irradiation on incidence of decay in apple fruit (cv. 'Granny Smith' and 'Fuji') that were wounded and inoculated with *Botrytis cinerea*[w] or *Mucor piriformis*

		Disease incidence (%)[x]	
Cultivar	Radiation Dose (kGy)	*B. cinerea*	*M. piriformis*
'Granny Smith'	0.0	87.2 ns[y]	35.0 ns
	0.15	96.7	41.7
	0.30	93.3	16.7
	0.60	84.5	24.4
	0.90	88.9	24.4
	Mean	90.1 a[z]	28.4 ns
'Fuji'	0.0	50.0 ns	50.0ns
	0.15	70.0	26.7
	0.30	56.7	30.0
	0.60	50.0	13.3
	0.90	76.7	6.7
	Mean	60.7 b	25.3 ns

[w] Each wounds was inoculated with an aqueous spore suspensions (50 µl) of either *B. cinerea* (1000 conidia/ml)or *M. piriformis* (500 conidia/ml).
[x] Means of 3 replicates of 5 fruit with 2 wounds/fruit.
[y] ns = no significant difference among treatments
[z] Means in a column within cultivars not followed by a common letter are significantly different by Tukey's HSDT (P≥0.05).