Irradiation as a Phytosanitary Treatment

California Citrus Quality Council

Visalia

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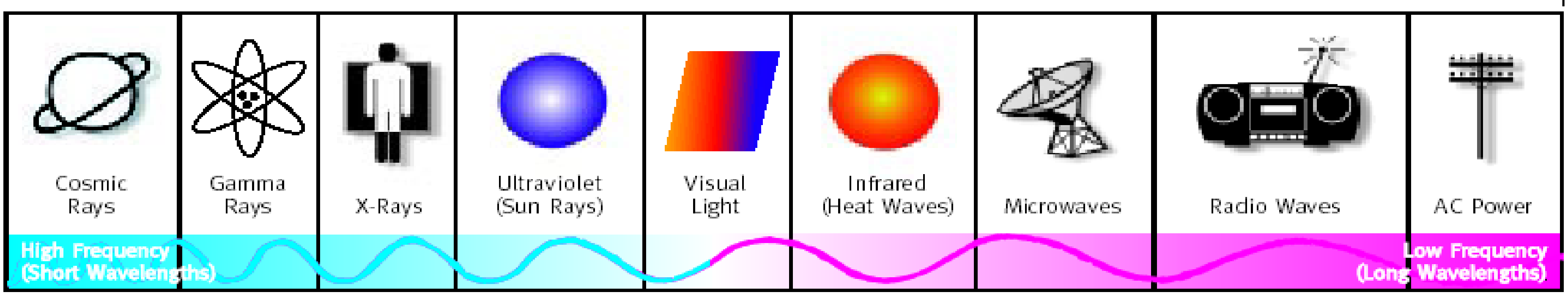
- What is irradiation
- Regulations
- Types of irradiation
- How irradiation works
- Process Control
- Fruit quality and shelf-life

What is irradiation

The process in which the food is exposed to predetermined levels of radiation energy

1 rad = 1 erg/g, 1 Gy = 1 J/kg or 100 rads,

1 kGy = 1000 Gy



Regulations

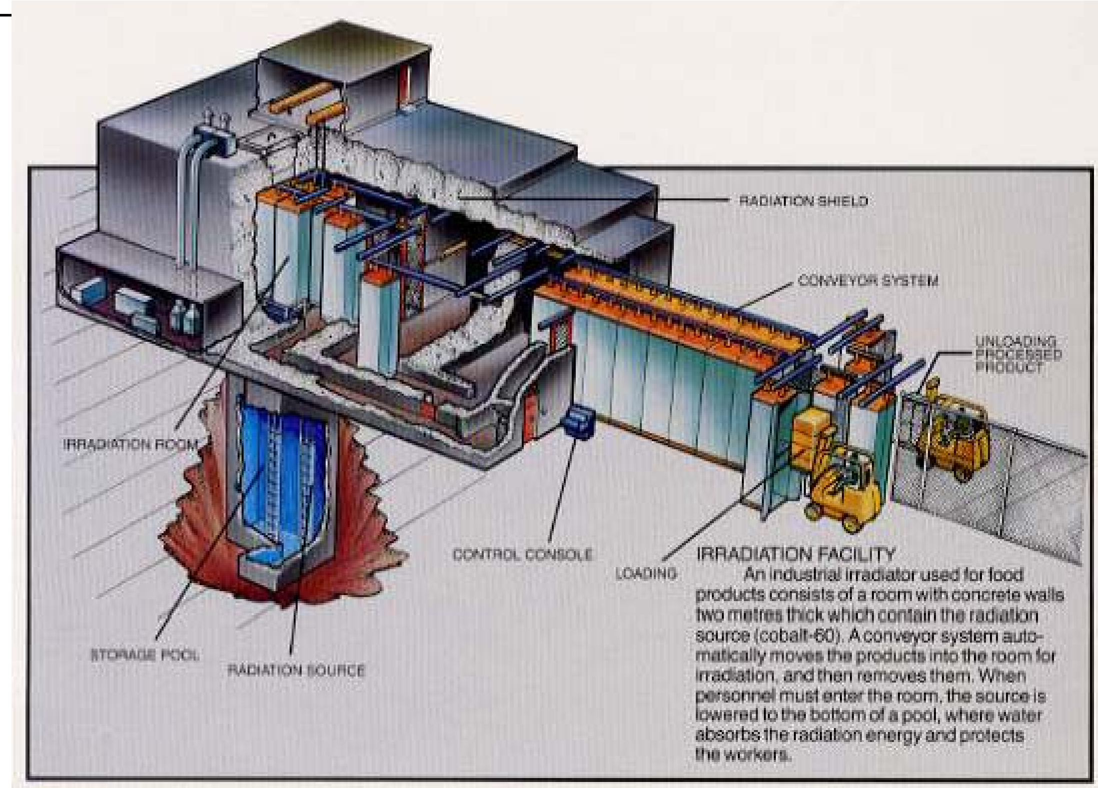
- Defined as food additive
- FDA has main regulatory responsibility, also USDA (FSIS and APHIS)
- Labeled with a radura (no size specification) and the words “Treated with irradiation” or “Treated by irradiation”
- Required for retail, finished products or foods destined for further processing, not required for minor ingredients

Food Irradiation - 21CFR § 179

- Fresh Pork — 0.3 - 1.0 kGy
- Fresh/frozen Poultry — 3.0 kGy max
- Enzyme preparations — 10.0 kGy max
- Spices, dehydrates — 30.0 kGy max
- Fresh foods — 1.0 kGy max
  - Control Pests
  - Maturation Inhibition
- NASA space food — 44.0 kGy min
- Fresh/frozen Red Meat — 4.5 or 7.0 kGy max
- Eggs — 1.5 kGy
- Pet Feed — <50.0 kGy
- Ready-to-eat foods — <10 kGy
  - Under review
  - **Iceberg lettuce, spinach* 4 kGy**

*For control of food borne pathogens and extension of shelf-life

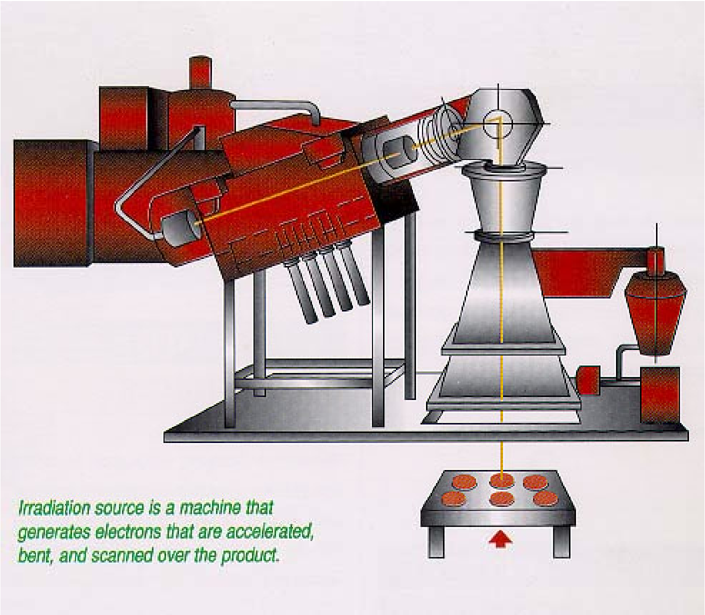
Gamma Irradiation



- Cobalt 60 and Cesium 137
- Demonstrated reliability, efficiency, safety
- Experience with large scale applications
- High penetration depth
- Fairly good uniformity of dose

Electron beam irradiation

- Machine generated primary electrons accelerated to 99% speed of light to produce energies of 5, 7.5, or 10 MeV with beam power of upto 10 kW
- (higher power = higher thoroughput = lower unit cost)
- Limited penetration depth



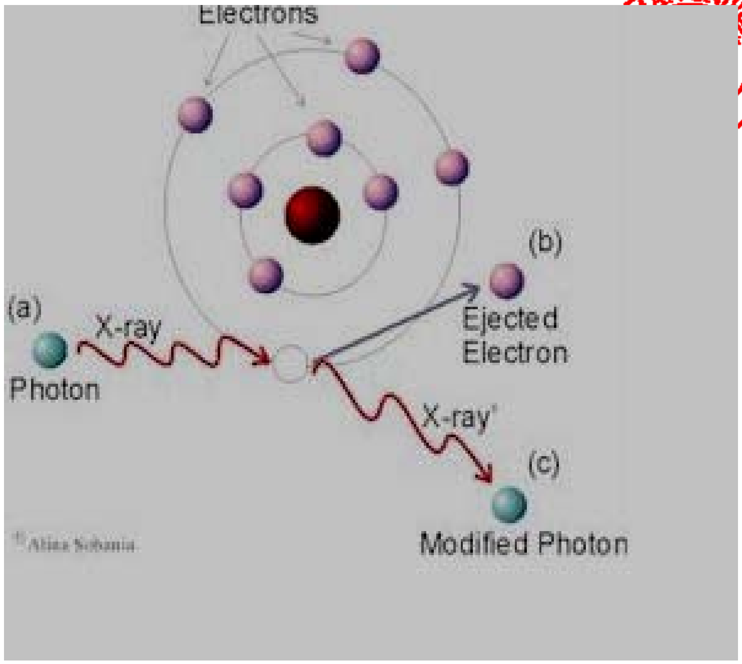
X-ray

- When electrons strike a metal plate, x-rays are generated
- Same as gamma rays
- High penetration depth
- Inefficient conversion of electron beam to x-rays (~8%)

Reasons to irradiate food

- Eliminate pathogens
- Insect and parasite disinfestation
- Extend shelf-life (microbial, enzymatic)
- Inhibit sprouting

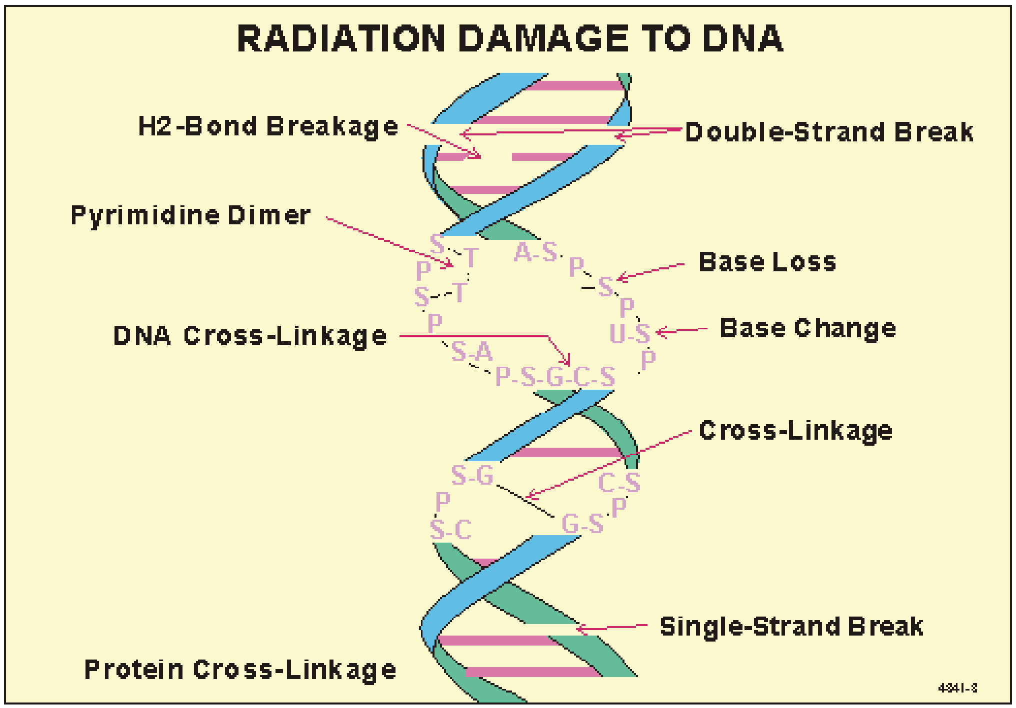
Compton Effect



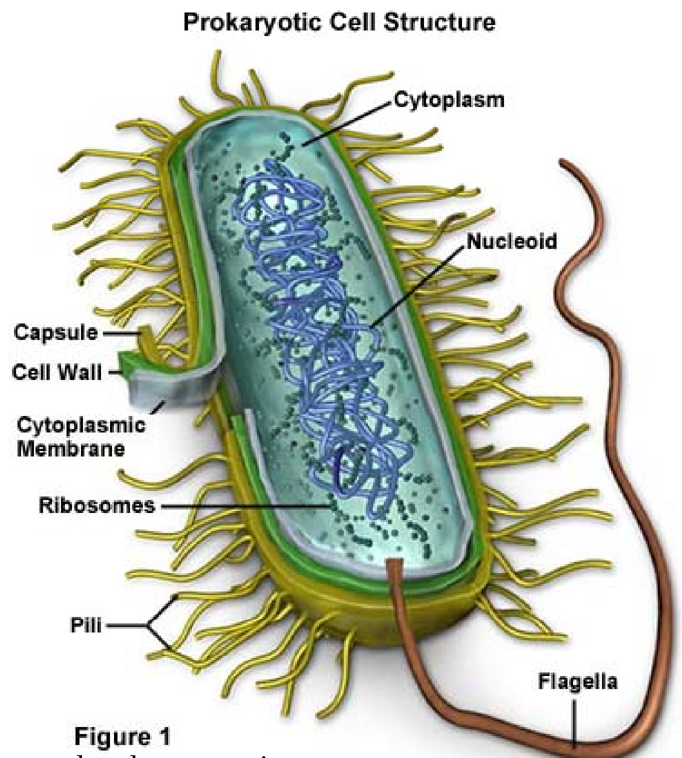
- Absorbed energy leads to ionization and excitation of atoms
- Resultant low energy photon and ejected electrons cause further excitations and ionizations
- Secondary processes: various reactions of primary species which result in ultimate molecular products-free radicals-damage to DNA and cell membranes, fat oxidation, pectin breakdown, etc

Effects of irradiation

- Effect on DNA and RNA
- Effect on structure of cell membrane



www.radiation-scott.org/radsource/4341-3.gif



www.molecularexpressions.com

Phytosanitary action

- For most phytosanitary treatments, death is the desired response
- For irradiation, response options may be:
  - Mortality
  - Sterilization
  - Inactivity or devitalization
  - Inability to emerge or fly
- Mortality is not usually the desired response for irradiation treatments, live but sterile insects may remain

Table 5-2-4 Pest-Specific Minimum absorbed dose (Gy)

Scientific Name	Common Name	Minimum Absorbed Dose (Gy)
Anastrepha ludens	Mexican fruit fly	70
Anastrepha obliqua	West Indian fruit fly	70
Anastrepha serpentina	Sapote fruit fly	100
Anastrepha suspensa	Caribbean fruit fly	70
Aspidiotus destructor	Coconut scale	150
Bactrocera cucurbitae	Melon fruit fly	150
Bactrocera dorsalis	Oriental fruit fly	150
Bactrocera jarvisi	Jarvis fruit fly	100
Bactrocera tryoni	Queensland fruit fly	100
Brevipalpus chilensis	Chilean false red mite	300
Ceratitis capitata	Mediterranean fruit fly	100
Conotrachelus nenuphar	Plum curculio	92
Copitarsia declora		100
Cryptophlebia ombrodelta	Litchi fruit moth	250
Cryptophlebia illepida	Koa seedworm	250
Cylas formicarius elegantulus	Sweet potato weevil	150
Cydia pomonella	Codling moth	200
Euscepes postfasciatus	West Indian sweet potato weevil	150
Grapholita molesta	Oriental fruit moth	200
Omphisa anastomosalis	Sweet potato vine borer	150
Pseudaulacaspis pentagona	White peach scale	150
Rhagoletis pomonella	Apple maggot	60
Sternochetus mangiferae	Mango seed weevil	300
	All other fruit flies of the family Tephritidae which are **not** listed above	150
	Plant pests of the class Insecta **not** listed above, except pupae and adults of the order Lepidoptera	400

http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/treatment_pdf/05_02_t100schedules.pdf

Generic treatments

- Dose requirements depend upon target pest
- Generic fruit fly dose 150 Gy
- Generic dose for all insects 400 Gy

(Except adults and pupae of lepidoptera)

FDA regulations for fruits and vegetables limit dose to 1000 Gy

Verification of treatment

- Research studies provide effective dose
- Treatment protocol is validated
- Records for treatment are maintained and verified
- Pest proof packages and monitoring by APHIS officials

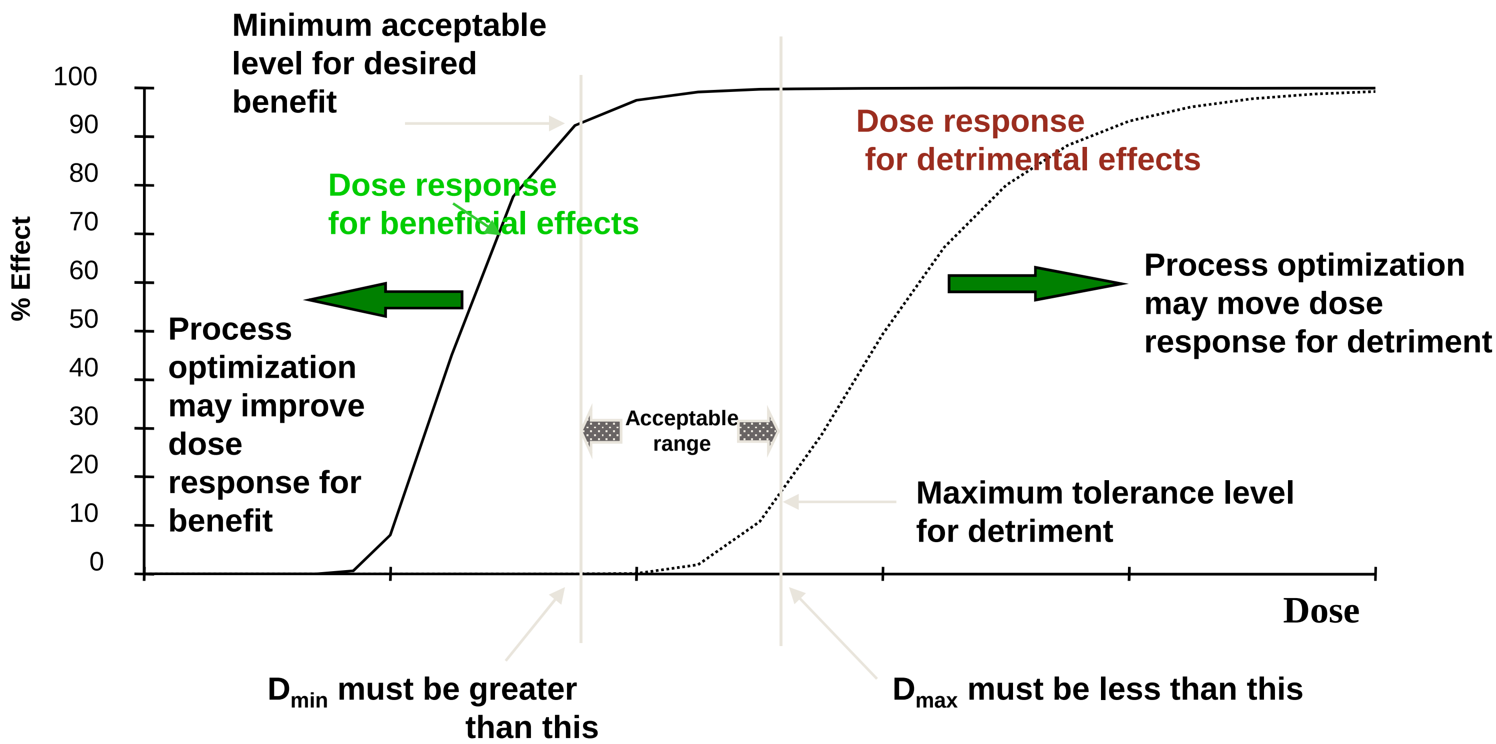
Commercial scale processing

- GrayStar, Hawaii: star fruit, papaya
- FTSI, Florida: guava, boniato
- Thailand: mangosteen, lychee, rambutan
- Australia: mango, lychee, papaya, paw paw
- India: mango, onion
- Vietnam: Dragon fruit
- Philippines: mango
- Pakistan: mango
- Mexico: guava, mango

- Meat, spices, herbs, frog legs

Information provided by Ron Eustice, Minnesota Beef Council

Process Optimization

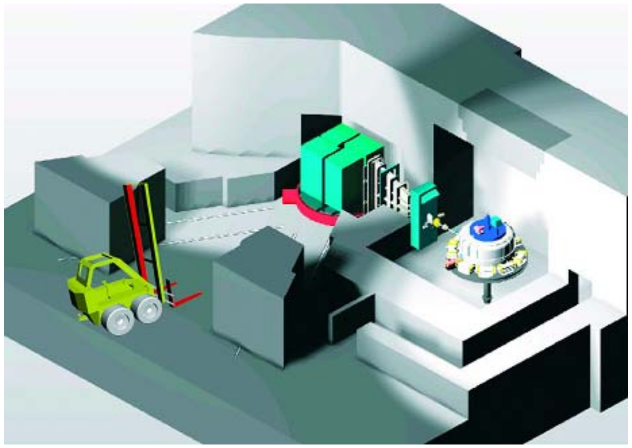


The illustrated D_{min} and D_{max} represent the 'allowed' range of dose. The 'actual' range delivered by the irradiator must fall within the 'allowed' range.

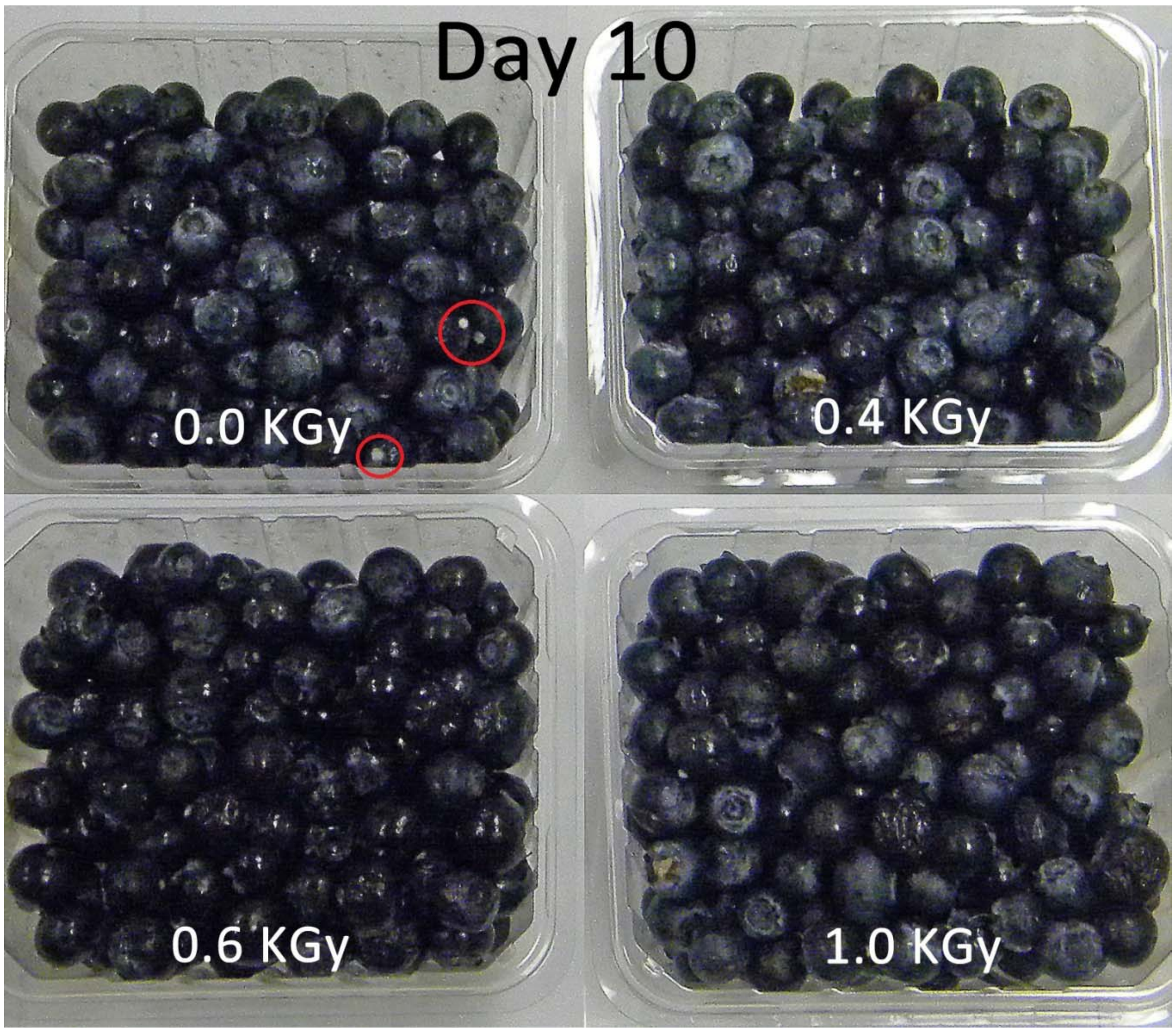
Figure courtesy Joseph Borsa, MDS Nordion

Process Control

- Dose measured using dosimeters
- Dose uniformity ratio (DUR) = Dmax/Dmin
- Dmin cannot fall below minimum level needed to achieve a particular goal
- Dmax should not exceed a certain maximum due to effects on quality and to stay under maximum dose allowed by regulations
- Need to consider optimal dose delivery and processing efficiency



Irradiation limits mold growth on blueberries



DUR = 1.64 with attenuation

Quality factors that may be affected by irradiation

- Spoilage organisms
- Appearance
  - Skin damage
  - Interior
- Electrolyte leakage
- Texture
  - Pectic substances
- Color
  - chlorophyll
  - anthocyanins
  - carotenoids
- Flavor and aroma
  - Organic acids
- Wound response
  - Respiration rate
  - Ethylene
  - Phenol biosynthesis
- Scald (apples and pears)
- Lipid oxidation
- Nutritional factors

www.toucano.com/irradiation.html

Effect on quality attributes

- Most fruits can be irradiated between 150-600 Gy with no adverse effects on quality
- Different varieties of the same fruit can exhibit varied responses to irradiation
- Stage of ripeness or maturity
  - Climacteric vs. preclimacteric
- Modified or controlled atmosphere packaging
- Other combination treatments: heat, hot water dips, chlorination

Studies on citrus products

- Most studies conducted at very high dose levels >1000 Gy
- Reduction of mold
- Decay was reduced but some peel pitting was possible
- Transient increase in respiration rate
- Varietal effects

Effect on nutritional value

- Folic acid
- Thiamin
- Vitamin C
- Vitamin A (carotenoids)
- Vitamin E

	Day 1		*Day 14*	
	0 kGy	**1 kGy**	**0 kGy**	**1 kGy**
Broccoli	926	902	855	855
Cilantro	528	538	115	157
Red leaf lettuce	74	39	34	15.7
Spinach	265	199	198	69

Vitamin C content (µg/g fresh weight)
Fan and Sokorai. J. Food Science. 2008.

Benefits

Guavas from Mexico

- Cold process
- Leaves no residue
- Can be combined with other treatments
- Approved quarantine treatment
- Enhances safety
- Increases shelf-life

Cents per pound cost of post-harvest treatments of fresh commodities (2009 prices).

	Commodity	Irradiation (large scale)	Irradiation (small scale)	Meth. brom.	Meth. brom. qual. discount	Cold treatment	Modified atmosphere
Forsythe and Evangelou (1994)	Grapes	2.42	–	0.93			
	Nectarines/peaches	2.42	5.2	0.93			
	Okra	5.95	5.95	0.93			
	Plums	2.6	5.95	0.93			
Calvin et al. (2008)	US apples			3	5		
Federal Register (2003)	Sweet potatoes	17.21		8 to 46			
Aegerter and Folwell (2000)	Apple	3.71		1.96		1.49	1.96
	Sweet cherry	1.96		0.55			
	Nectarine, peach and Plum	1.96		0.24			

P. Ferrier, Food Policy, 2010