POSTHARVEST TECHNOLOGY
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Produce Irradiation

Recommendations for Maintaining Produce Postharvest Quality, Safety & Marketability

Christine Bruhn, James R. Gorny, Adel A. Kader and Elizabeth J. Mitcham
Department of Plant Sciences, University of California, Davis, CA 95616

Background
Food irradiation including produce irradiation has been actively researched since the late 1950's and there are thousands of published research articles detailing the effects of irradiation as a means of enhancing the quality, safety and marketability of many fresh fruits and vegetables.

How does produce irradiation work?
Irradiation exposes produce to ionizing radiation from cobalt, e-beams or X rays creating ions or free radicals that react with cellular constituents to cause injury to plant cells, insects or microorganisms on or in produce. The energy breaks DNA strands in insect or microorganism cells thereby preventing the insect or microorganism from growing or reproducing.

Unit Converter
The amount of energy absorbed by a food product is expressed in units called grays or kilo grays.
1000 grays = 1 kilogray (kGy) = 100 kilorads = 1000 joules per kilogram

Potential Uses
Produce irradiation can be used for many purposes including, but not limited to:

Enhance Produce Quality

- Sprouting Inhibition: tuber, bulb and root vegetables (0.05 – 0.15 kGy)
- Delayed Growth: mushrooms and asparagus (0.05 – 0.15 kGy)
- Delayed Ripening: banana, mango, papaya (0.25 – 0.50 kGy)
- Delayed postharvest disease development by plant pathogens (>1.75 kGy)

Insect Disinfestation (0.15 – 0.75 kGy depending on the insect species, insect stage of development and location on the produce item)

- Fruit Fly Pests (0.15-0.25 kGy)
- Surface Pests (0.40 kGy)

Enhance Food Safety

- Bacterial Human Pathogens (0.2-0.8 kGy for a one log reduction depending on bacteria and food source)
- Viruses Human Pathogens (1-3 kGy for a one log reduction)
- Fungi (1-3 kGy for a one log reduction)

Negative Quality Effects of Irradiation on Produce

Plants, including fresh fruit and vegetables, are alive and thus will only tolerate finite amounts of irradiation without having adverse consequences on produce quality and shelf-life due to stress. As a consequence of irradiation exposure, produce items exhibit increased rates of respiration and ethylene production. After irradiation exposure, produce may soften more quickly than non-irradiated produce. In most cases, irradiation dosages needed to get a 5 log (100,000 fold) reduction of human pathogens are typically between 2-30 kGy. These levels are not viable for use on most produce items due to unintended adverse consequences of irradiation on produce quality. However, lower dosages (1-2 kGy) may be used as a hurdle (one of many means of reducing risk) by providing a 1-2 log (10 -100 fold) reduction of human pathogens on produce items.

- Tissue Softening: >0.6 kGy results in fruit and vegetable tissue softening due to solubilization of pectins, cellulose, hemicelluloses and starch.
- Electrolyte Leakage: due to cell membrane damage, may cause product to appear excessively moist.
- Produce Respiration & Ethylene Production: irradiation subsequently increases the rate of produce respiration and ethylene production due to an irradiation stress response. However, irradiation has been shown to extend the shelf-life of some produce items by reducing sensitivity to the plant ripening hormone ethylene.
- Chilling Injury Symptom Development: irradiation may increase sensitivity to chilling injury symptom development.
- Dosages above 1kGy may induce the following quality defects in fresh fruits and vegetables:
    - Artichoke: stem pitting
    - Avocado: internal browning
    - Banana: skin damage
    - Corn (sweet): kernel denting
    - Cucumber, Summer Squash & Peppers: skin yellowing
    - Grapes: skin discoloration and stem darkening
    - Oranges & Grapefruit: surface blemishes, oil gland swelling, peel pitting
    - Lemons & Limes: internal cavities
    - Iceburg Lettuce & Endive: reddish-brown, sunken spotting on leaf mid ribs

Factors Affecting Produce Irradiation Efficacy and Detrimental Effects

Irradiation of fruits and vegetables in a nitrogen atmosphere can reduce the amount of free radicals produced and thus reduce injury to produce. However, this may also reduce the efficacy of the irradiation treatment in killing insects or microorganisms.

Available Technologies

Approved sources for produce irradiation are:

- Gamma rays (produced by radioisotopes such as Cobalt-60 or Cesium-137)
- Machine generated X-rays (maximum energy 5 MeV)
- Machine generated electrons (maximum energy 10 MeV)

Nutritional Quality of Irradiated Produce

- Irradiation below 1kGy does not significantly reduce the nutritional quality of produce since only negligible losses of most vitamins may occur.
- Fruits and vegetables are a major source of Vitamin C (ascorbic acid) in the human diet and it is one of the vitamins most susceptible to irradiation-induced losses depending upon commodity, cultivar, irradiation dose/duration and storage temperature and duration.
- Water soluble vitamins in order of sensitivity to irradiation degradation: thiamin > ascorbic acid > pyridoxine > riboflavin > folic acid > cobalamin > nicotinic acid.
- Fat soluble vitamins in order of sensitivity to irradiation degradation: vitamin E > carotene > vitamin A > vitamin K > vitamin D.

Consumer Safety

Produce may be irradiated with NO adverse health affects on humans who consume these foods. The food product is never in danger of becoming radioactive or containing radioactive compounds. When FDA approves use of irradiation, the agency evaluates the effect of the treatment on safety and nutritional value. Any chemicals formed must be documented to be within safety limits. Any change in nutritional value must not impact the health of the American diet. Irradiation of some foods may cause the production of compounds deleterious to human health such as furans. These foods have not yet been approved by FDA, pending an evaluation of the impact of the chemicals on human health. An overwhelming body of scientific evidence indicates that FDA approved irradiated fresh fruits and vegetables are safe for human consumption.

Consumer Attitudes

Consumer reaction to irradiated produce has never been overwhelmingly positive nor overwhelmingly negative, most consumers are ambivalent. A few consumers will never accept irradiated produce, others are ready to buy irradiated products and wonder why the choice is not widely available. Information from trusted sources about safety and benefits increases consumer interest in buying irradiated products for food safety or quality benefits. A 1996 survey reported that 60% of those surveyed indicated that they would buy irradiated foods with a longer shelf life, and almost 70% would buy foods irradiated to destroy harmful bacteria.

Regulatory Issues

In the United States, the U.S. Food and Drug Administration (FDA) is responsible for regulating the use of irradiation in the treatment of food and food packaging. This authority derives from the 1958 Food Additives Amendment to the Federal Food, Drug, and Cosmetic Act (FD&C Act) where Congress explicitly defined a source of radiation as a food additive (Section 201(s) of the FD&C Act). The 1958 Food Additives Amendment also provides that a food is adulterated (that is, it cannot be marketed legally) if it has been irradiated, unless the irradiation is carried out in conformity with a regulation prescribing safe conditions of use (Section 403(a)(7) of the FD&C Act). Thus, FDA regulates the lawful use of irradiation through the food additive petition process, the completion of which results in the promulgation of a regulation published in the Federal Register prescribing the approved use.

Irradiation as a Food Additive

Under section 201(s) of the Federal Food, Drug, and Cosmetic Act (the act) (21 U.S.C. 321(s)), a source of radiation used to treat food is defined as a food additive. The additive is not added to food literally, but is rather a source of radiation used to process or treat food such that, analogous to other food processing technologies, its use can affect the characteristics of the food.

Importantly, the statute does not prescribe the safety tests to be performed but leaves that determination to the discretion and scientific expertise of FDA.

Produce Specific Irradiation Rules and Regulations

- The FDA issued a final rule effective April 18, 1986 which permits the irradiation of fresh foods including fruits and vegetables at doses up to 1 kGy for the inhibition of growth and maturation and for insect disinfestation.
- On August 22, 2008 FDA amended the food additive regulations to provide for the safe use of ionizing radiation for control of food-borne pathogens, and extension of shelf-life in fresh iceberg lettuce and fresh spinach at a dose up to 4.0 kiloGray (kGy).

Packaging Materials

Materials used to package produce before irradiation must be accepted for use by the FDA. Acceptable materials are listed in 21 CFR 179.45. This means that any co-extruded or laminate multi-component films including film components used for packaging produce that will be subject to irradiation must be approved specifically before use by the FDA.

Labeling

- Retail: irradiated produce sold in retail packages must be labeled with the radura symbol and contain the statement "Treated with radiation (or irradiation)"
- Food Service: for irradiated produce not sold in retail packages, the radura symbol and the statement must appear on either the individual item, the bulk container or a sign at the point of purchase.
- Bulk Produce for Re-packing or Processing: The labeling and invoices of bills of lading for products shipped for further processing, labeling or packaging must bear the statement "Treated with radiation – do not irradiate again".

Current Commercial Irradiation of Produce

- Irradiation of tropical produce to meet USDA APHIS insect quarantine treatment requirements
    - Hawaiian tropical fruits being before shipment from Hawaii to the mainland USA.
    - Indian mangoes exported to the USA.
    - Tropical fruits exported to the USA from the Philippines, Thailand and Vietnam.
- Sprout inhibition of potatoes sold in the EU
- Irradiation of tropic fruits from other countries is under review

Dosimetry Issues

The available energy output from an irradiation source decreases inversely and exponentially in relation to the distance from an irradiation source. For example, a piece of fruit two feet from an irradiation source will only receive one-fourth as much energy as piece of fruit one foot away from the irradiation source. This variation in available energy creates a challenge to the commercial use of produce irradiation, as it makes it difficult to uniformly apply a specific dosage of irradiation to produce items especially for example whole pallets of produce because the dosage is NOT uniform from the outside to the inside of the pallet. The outside of an irradiated pallet of produce will receive more irradiation than the geometric center of the pallet when irradiated by an external source. Through careful placement and evaluation, a high level of uniformity can be achieved using electron beam, X ray or cobalt facility.

This issue can be addressed in an electron beam facility by singulating small units (i.e. individual pieces of produce or single bags/cartons of produce) on a conveyor belt before exposing the produce to the irradiation source. However, one may need multiple units to treat multiple production lines of product increasing the capital expenses associated with produce irradiation.

References

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