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Standard Guide for Irradiation of Fresh Fruits as a Phytosanitary Treatment[1]

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INTRODUCTION

The purpose of this guide is to present information on the use of ionizing energy (radiation) in treating certain fresh fruits to control insects and other arthropod pests, in order to meet phytosanitary requirements.[2]

This guide is intended to serve as a recommendation to be followed when using irradiation technology where approved by an appropriate regulatory authority. It is not to be construed as a requirement for the use of irradiation nor as a required code of practice. While the use of irradiation involves certain essential requirements to attain the objective of the treatment, some parameters can be varied in optimizing the process.

This guide has been prepared from a Code of Good Irradiation Practice published by the International Consultative Group on Food Irradiation (ICGFI), under the auspices of the Food and Agriculture Organization (FAO), the World Health Organization (WHO), and the International Atomic Energy Agency (IAEA).[3]

1. Scope

1.1 This guide provides procedures for the radiation processing of fresh fruits as a phytosanitary treatment. Because many insect pests are found on more than one type of fruit, this guide is directed primarily toward the treatment needed to control certain insect pests commonly associated with various fresh fruits.

1.2 The absorbed dose range covered by this guide is between 75 gray (Gy) and 1.0 kilogray (kGy). The practical minimum or maximum dose of a treatment may be higher or lower than this range, depending on the type of pest to be controlled and the radiation tolerance of a particular type of fruit. If the minimum effective dose necessary to achieve the desired phytosanitary effect is greater than the radiation tolerance of the fruit, then irradiation is not an appropriate treatment (see 5.2).

2. Referenced Documents

2.1 *ASTM Standards:*

E 170 Terminology Relating to Radiation Measurements and Dosimetry[4]

E 1204 Practice for Dosimetry in Gamma Irradiation Facilities for Food Processing[4]

E 1261 Guide for the Selection and Calibration of Dosimetry Systems for Radiation Processing[4]

E 1431 Practice for Dosimetry in Electron and Bremsstrahlung Irradiation Facilities for Food Processing[4]

E 1539 Guide for Use of Radiation-Sensitive Indicators[4]

F 1640 Guide for Packaging Materials for Food to be Irradiated[5]

2.2 *Codex Alimentarius Commission Recommended International Codes and Standards:*[6]

STAN 1-1985 General Standard for the Labelling of Prepackaged Foods

STAN 106-1983 General Standard for Irradiated Food

2.3 *ISO Standards:*[7]

ISO 873 Peaches—Guide to Cold Storage

ISO 931 Green Bananas—Guide to Storage and Transport

ISO 1134 Pears—Guide to Cold Storage

ISO 1212 Apples—Guide to Cold Storage

ISO 1838 Fresh Pineapples—Guide to Storage and Transport

ISO 2168 Table Grapes—Guide to Cold Storage

[1] This guide is under the jurisdiction of ASTM Committee F-2 on Flexible Barrier Materials and is the direct responsibility of Subcommittee F02.40 on Food Processing and Packaging.

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[2] The term pests is used in this guide to mean insects and other arthropod pests.

[3] International Consultative Group on Food Irradiation, *Code of Good Irradiation Practice for Insect Disinfestation of Fresh Fruits (As a Quarantine Treatment)*, ICGFI Document No. 7, Issued by the Secretariat of ICGFI, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Vienna, Austria, 1991.

[4] *Annual Book of ASTM Standards*, Vol 12.02

[5] *Annual Book of ASTM Standards*, Vol 15.09.

[6] Available from Joint FAO/WHO Food Standards Programme Joint Office, FAO, Via delle Terme di Caracalla 00100 Rome, Italy.

[7] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

ISO 2826 Apricots—Guide to Cold Storage
ISO 3631 Citrus Fruits—Guide to Cold Storage
ISO 3659 Fruits and Vegetables—Ripening After Cold Storage
ISO 6660 Mangoes—Guide to Storage
ISO 6661 Fresh Fruits and Vegetables—Arrangement of Parallelpipedic Packages in Land Transport Vehicles
ISO 6664 Bilberries and Blueberries—Guide To Cold Storage
ISO 6665 Strawberries—Guide to Cold Storage
ISO 6949 Fruits and Vegetables—Principles and Techniques of the Controlled Atmosphere Method of Storage
ISO 7558 Guide to the Prepacking of Fruits and Vegetables

3. Terminology

3.1 *Definitions*—Other terms used in this guide may be defined in Terminology E 170.

3.1.1 *absorbed dose*, *n*—the quantity of energy from ionizing radiation absorbed per unit mass of a specified material (for example, food). The special name for the unit of absorbed dose is the gray (Gy). One Gy is equal to one joule of absorbed energy per kilogram of food. Formerly, the unit of absorbed dose was the rad (1 rad = 0.01 Gy).

3.1.1.1 *Discussion*—A standard definition of absorbed dose appears in Terminology E 170.

3.1.2 *dose distribution*, *n*—the variation in absorbed dose within a process load exposed to ionizing radiation.

3.1.3 *phytosanitary*, *n*—pertaining to the killing, removal, or rendering infertile of regulated plant pests on shipped commodities.

3.1.3.1 *Discussion*—The term "phytosanitary treatment" includes, but is not limited to, treatment to satisfy quarantine requirements.

3.1.4 *process load*, *n*—a volume of material with a specified loading configuration irradiated as a single entity.

3.1.5 *transport system*, *n*—the conveyor or other mechanical means used to move the process load through the irradiator.

4. Significance and Use

4.1 The purpose of radiation treatment, as referred to in this guide, is to accomplish appropriate and effective control of agricultural pests that infest fresh fruits.

4.2 The objective of irradiation as a phytosanitary treatment is usually to prevent development or emergence of the adult stage, in fruits where adult pests are not present (for example, fruit flies) or to sterilize the adult pest, where the adult stage is present (for example, weevils).

5. Selection of Fruits for Irradiation

5.1 Most fresh fruits are not adversely affected at the doses indicated in 7.5.2. In particular, the following fruits have been found to be tolerant of those doses: apple, cantaloupe, carambola, cherry, citrus, currant, date, fig, grape, guava, honeydew melon, kiwi, lychee, mango, muskmelon, nectarine, papaya, peach, prune, raspberry, strawberry, and tomato.

5.2 Other fruits may be damaged or exhibit unacceptable changes in shelf-life, color, taste, or other properties at the doses indicated. If fruits other than those listed above are considered for irradiation as a phytosanitary treatment, it is necessary to evaluate the effects of irradiation on the fruit at the required dose level. Differences among varieties, origins, growing and harvest conditions of a fruit, and elapsed time between harvest and processing should be considered.

5.3 Only fruits of good marketable quality should be accepted for irradiation. Irradiation may preserve quality, but it will not improve it.

6. Pre-Irradiation Product Handling and Treatment

6.1 Fruits to be irradiated should be of good overall quality and reflect the results of good agronomic practices.

6.2 Normal storage procedures should be used prior to radiation treatment. Pre-irradiation storage should include appropriate temperature and atmospheric conditions. Information on storage conditions is provided in ISO Standards (see 2.3).

6.3 There are no special requirements for treatment or handling of fruits before irradiation except to provide means to prevent post-irradiation re-infestation. A safeguard system that provides adequate security (for example, product packaging or storage in a separate, insect-free room) should be provided. Irradiation combined with other forms of treatment may improve efficacy, increase the range of pests controlled, or further improve product shelf-life.

6.4 *Product Separation*—It may not be possible to distinguish irradiated from unirradiated product by inspection. It is therefore important that appropriate means integral with facility design, such as physical barriers or clearly defined staging areas, be used to maintain unirradiated product separate from irradiated product.

7. Irradiation

7.1 *Scheduled Process*—Irradiation of food should conform to a scheduled process. A scheduled process for food irradiation is a written procedure that is used to ensure that the absorbed dose range and irradiation conditions selected by the radiation processor are adequate under commercial processing conditions to achieve the intended effect on a specific product in a specific facility. The scheduled process should be established and validated by qualified persons having expert knowledge in irradiation requirements specific for the food and the processor's irradiation facility.

7.2 *Radiation Sources*—The sources of ionizing radiation that may be used in irradiating fruits are limited to the following (see CAC Standard 106-1983):

7.2.1 Gamma rays from the radionuclides ^{60}Co or ^{137}Cs,

7.2.2 X-rays generated from machine sources operated at or below an energy level of 5 MeV, and

7.2.3 Electrons generated from machine sources operated at or below an energy level of 10 MeV.

NOTE 1—The depth of penetration of electrons in a material is dependent upon the energy of the electrons and the density of the material.

7.3 *Radiation Process Parameters*:

7.3.1 *Absorbed Dose*—Food irradiation specifications from the owner of the product should include minimum and maximum absorbed dose limits: a minimum necessary to ensure the intended effect, and a maximum to prevent product degradation. One or both of these limits may be prescribed by regulation for a given application. See, for example, FDA regulations.[8] It is necessary to configure the irradiation process to ensure that the absorbed dose achieved is within these limits throughout each process load. Once this capability is established, it is necessary to monitor and record absorbed dose values for each production run as described in 11.2.2.

7.3.1.1 Routine dosimetry is part of a verification process for establishing that the irradiation process is under control.

7.3.1.2 Select and calibrate a dosimetry system appropriate to the radiation source being used, the environmental conditions, and the range of absorbed doses required (see Practice E 1261).

7.3.1.3 Verify that the product receives the required absorbed dose by using proper dosimetric measurement procedures, along with appropriate statistical controls, and documentation. Place dosimeters in or on the process load at locations of maximum and minimum absorbed dose. If those locations are not accessible, place dosimeters at reference locations that have a known and quantifiable relationship to the maximum and minimum absorbed dose locations (see Practices E 1204 and E 1431).

NOTE 2—Radiation sensitive indicators (RSIs), such as labels, papers, or inks, that undergo a color change or become colored when exposed to irradiation in the pertinent dose range are commercially available. The purpose of RSIs is to determine visually whether or not a product has been irradiated, rather than to measure the absorbed dose received by the product. RSIs are not dosimeters and must not be used as a substitute for proper dosimetry (see Guide E 1539).

7.3.2 *Process Load Design*—The size and shape of the process load are determined partly by certain design parameters of the irradiation facility. Critical parameters include the characteristics of the transport system and of the radiation source as they relate to the dose distribution within the process load. The size and shape of the fruit and the minimum and maximum dose limits may also affect the loading configuration of the process load.

7.4 *Doses to Control Various Pests*:

7.4.1 Appendix X1 and Appendix X2 show the principal pests of fruits of national and international economic and quarantine importance.

7.4.2 The sensitivity of a pest to radiation varies with the life stage of the pest at the time of irradiation (see Note 3). In adult fruit fly males, the sensitivity is generally greater in stages involving active cell division. This activity is greatest in the egg stage and diminishes in later stages. In adult males, the gonads have greater sensitivity than the rest of the body due to active reproductive cell division. Irradiation with specific sub-lethal doses causes sterility at this stage. The effect of irradiation at one stage may carry over to, and be more apparent in, a later stage.

NOTE 3—Infestation of a fruit with fruit flies occurs when the adult female lays eggs in the fruit. Later, these eggs hatch and larvae emerge. These larvae feed and develop in the fruit and in this manner damage it. The larvae leave the fruit upon maturation and undergo pupation. In packaged fruits, pupation may occur in the container. In un-packaged fruit, pupation may occur in the surrounding environment. Seed weevils can infest fruits at an early stage and result in damage to the seed and the fruit upon emergence as adults. One should concentrate on developing a treatment against the most radiation-tolerant stage which can be reasonably expected to be in, on, or with the fruit. The most tolerant stage is usually the one closest to the adult if the adult itself is not present in the fruit.

7.5 *Guidelines for Assessing Irradiation Efficacy*:

7.5.1 The key criterion for acceptance of a phytosanitary treatment is verification that the absorbed dose is sufficient to achieve the required level of phytosanitary security. The minimum absorbed dose specified to produce an acceptable level of phytosanitary security is usually established by government regulations. Efficacy should be established based on scientific studies using statistically significant numbers of the pest.

NOTE 4—In the United States for example, quarantine treatments for tephritid fruit flies have required 99.9968 % efficacy (also known as probit 9) at the 95 % confidence level. This means approximately 94 000 insects must be treated without any emerging adults.

7.5.2 The absorbed dose found effective to meet phytosanitary criteria for treatment of fresh agricultural commodities for most arthropod pests is generally 300 Gy. Substantial research and experience with the treatment of certain pests has demonstrated that lower doses may be equally effective on those pests.

NOTE 5—Accepted minimum doses vary with different national authorities. Users should always contact such authorities to determine the required minimum effective dose for the type of pest and type of fruit to be treated before using irradiation as a phytosanitary treatment.

8. Post-Irradiation Handling and Storage

8.1 Handle and store irradiated fruits in the same manner as non-irradiated fruits. A safeguard system that provides security against reinfestation of the products should be used (see 6.2 and 6.3).

9. Packaging

9.1 Fresh fruits are not usually packaged, but should be appropriately segregated or otherwise safeguarded before and after irradiation to ensure phytosanitary integrity (see 6.3). Guide F 1640 provides complete guidance on packaging materials for food to be irradiated.

10. Labeling

10.1 Because some consumers may wish to choose between irradiated and non-irradiated foods, many governments have adopted labeling requirements (see Section 5.2, Codex STAN 1-1985). Labeling identifies the food as irradiated, and may also serve to inform the purchaser of the purpose and benefits of the treatment. An increasing number of countries are adopting the internationally recognized "Radura" symbol as a means of labeling (see Fig. 1). In some countries, for example the U.S., the symbol must be accompanied by a statement, such as "treated with radiation" or "treated by irradiation."

11. Documentation

11.1 Ensure that each lot of product to be processed carries an identification number or other code that will distinguish it

[8] U.S. Food and Drug Administration, Code of Federal Regulations, Title 21, Section 179.25(d), Washington, DC.

FIG. 1 Radura Logo

from other lots of product in the facility. Use this identification on all lot documents.

11.2 Establish a record of the operation of the irradiation facility.

11.2.1 Record and document the date the lot arrives at the facility, the date it is irradiated, the starting and ending times of the irradiation, the date the lot leaves the facility, the name of the operator, and any special conditions that could affect the irradiation process or the irradiated product.

11.2.2 Record and document all dosimetry data associated with product absorbed-dose mapping, and routine processing.[9,10] See Practices E 1204 and E 1431.

11.2.3 Record and document any deviation from the scheduled process that could help assess the validity of the process.

11.3 Audit all documentation prior to product release to ensure that records are accurate and complete. The person making the audit should sign the documentation. Make all deficiencies the subject of a separate file available for examination by a regulatory authority.

11.4 Retain all records about each lot irradiated at the facility for the period of time specified by relevant authorities and have them available for inspection as needed.

11.5 Ensure that documentation accompanying the shipment of irradiated product includes the name of the product owner, the name and address of the irradiation facility, description of the product irradiated including the lot number or other identifier (see 11.1), the irradiation date, and any other information required by the product owner, irradiator, or government authority.

12. Keywords

12.1 arthropod pest; food; fruit; insect; insect control; irradiation; labeling; packaging; phytosanitary treatment; processing; quarantine

[9] McLaughlin, W. L., Boyd, A. W., Chadwick, K. H., McDonald, J. C., and Miller, A., *Dosimetry for Radiation Processing*, Taylor and Francis, London, New York, Philadelphia, 1989.

[10] Chadwick, K., Ehlermann, D. A. E., and McLaughlin, W. L., *Manual of Food Irradiation Dosimetry*, Technical Report Series No. 178, International Atomic Energy Agency, Vienna, 1977.

APPENDIXES

(Nonmandatory Information)

X1. FRUIT FLY SPECIES OF QUARANTINE IMPORTANCE (See Table X1.1)

TABLE X1.1 Fruit Fly Species[A]

Scientific Name	Common Name	Primary Economic Hosts[B]	Geographic Distribution
Anastrepha fraterculus	South American fruit fly	apple, guava, citrus, peach	Mexico to South America
Anastrepha grandis		cucurbits	South America, Panama
Anastrepha ludens	Mexican fruit fly	citrus, mango, peach	Mexico, Central America
Anastrepha obliqua	West Indian fruit fly	mango, guava, *Spondias*	Caribbean, Mexico to South America
Anastrepha serpentina		citrus, mango, guava	Mexico to South America
Anastrepha striata	Guava fruit fly (New World)	guava	Mexico to South America
Anastrepha suspensa	Caribbean fruit fly	guava, loquat, citrus	Greater Antilles, Florida
Bactrocera carambolae	Carambola fruit fly	many fruits, especially carambola	Malayan Peninsula, Indonesia, Surinam
Bactrocera cucumis		cucurbits, tomato, papaw	Australia
Bactrocera cucurbitae	Melon fly	cucurbits	Africa, Southeast Asia, Pacific Islands
Bactrocera dorsalis	Oriental fruit fly	many fruits	Asia
Bactrocera oleae	Olive fly	olive	Europe, Africa, West Asia
Bactrocera papayae		many fruits, especially mango & papaya	Malayan Peninsula, Indonesia
Bactrocera passiflorae	Fiji fruit fly	many fruits, especially citrus	Fiji
Bactrocera philippinensis		many fruits, especially mango & papaya	Philippines
Bactrocera psidii	Guava fruit fly	guava, mango	Pacific Islands
Bactrocera tryoni	Queensland fruit fly	many fruits	Australia
Bactrocera tsuneonis	Japanese orange fly	citrus	Japan, China
Ceratitis capitata	Mediterranean fruit fly	most fruits	Africa, Asia, America, Europe
Ceratitis punctata		cacao, mango, guava	Africa
Ceratitis rosa	Natal fruit fly	many fruits	Africa
Ceratitis rubivora	Blackberry fruit fly	berries	Africa
Dacus cucumarius		cucurbits	Africa
Myiopardalis pardalina	Baluchistan melon fly	melons	Southwest Asia
Rhagoletis cerasi	European cherry fruit fly	cherry, honey-suckle, soft fruits	Europe
Rhagoletis cingulata	Eastern (U.S.) cherry fruit fly	cherry	North America
Rhagoletis fausta	Black cherry fruit fly	cherry	North America
Rhagoletis indifferens	Western (U.S.) cherry fruit fly	cherry	North America
Rhagoletis pomonella	Apple maggot	apple	North America

[A] The original list was developed by the International Consultative Group on Food Irradiation, Task Group Meeting on Irradiation as a Quarantine Treatment, Chiang Mai, Thailand, February 1986, IAEA, Vienna Austria. Additions and changes have been made to this table to follow current nomenclature.

[B] Inclusion of a commodity in this table does not necessarily imply that pests present on this commodity can be controlled by irradiation.

X2. SOME OTHER PESTS OF QUARANTINE IMPORTANCE (See Table X2.1)

TABLE X2.1 Other Pests[A]

Scientific Name	Common Name	Primary Economic Hosts[B]	Geographic Distribution
		Lepidoptera	
Cryptophlebia leucotreta	False codling moth	cotton, maize, many fruits, especially citrus	Southern Africa
Cryptophlebia ombrodelta	Macadamia nut borer	macadamia, lychee	Australia
Cydia molesta	Oriental fruit moth	deciduous fruits	Temperate regions
Cydia pomonella	Codling moth	deciduous fruits	Temperate regions
Epiphyas postvittana	Light brown apple moth	deciduous fruits	Australia, Hawaii, New Zealand, United Kingdom
Lobesia botrana	Vine moth	grapes	Europe
Prays citri	Citrus flower moth	citrus	Europe, Asia
		Coleoptera	
Cryptorhynchus mangiferae	Mango seed weevil	mango	Asia, Africa, Australia, West Indies
Heilipus lauri	Avocado seed weevil	avocado	Mexico, Central America
		Hemiptera-Homoptera	
Aleurocanthus woglumi	Citrus black fly	many fruits, citrus, ornamentals	Tropics and subtropics
Hemiberlesia lataniae	Latania scale	various fruits, avocado in particular	North and South America, Asia, Europe, Africa
Leptoglossus chilensis		various deciduous fruits	Chile
Quadraspidiotus perniciosus	San Jose scale	many fruits, apple in particular	Americas, Asia, Europe, Africa
Pseudococcus spp.	Mealy bugs	citrus, ornamentals	Various
		Diptera	
Liriomyza trifolii	serpentine leaf miner	many plants, especially composits	Americas, Europe, Africa
		Thysanoptera	
Caliothrips fasciatis	Bean thrips	beans	North America, Europe
		Acaridae	
Brevipalpus chilensis		grapes	Chile
Tetranychus mcdanieli	McDaniel mite	deciduous fruits	North America

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