RADIATION PROCESSING: A PROMISING NUCLEAR TECHNOLOGY TO ADDRESS POST-HARVEST LOSSES OF AGRI-PRODUCE AND THUS ENSURING NATIONAL FOOD SECURITY

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I. Radiation processing of food: An overview:

For the sustainability of life, availability of food is very important. In this context, food security and safety play very important roles. There are various techniques and approaches for preserving food as well as to make the food safe for human consumption. With the advancement in knowledge, humans are preserving food and adopting various measures for the same.

One such methodology to preserve food is through the exposure of food commodities to radiation coming from the approved radioisotopes or machine sources. Just like the way our baggage is screened through an X-ray based scanner, similarly the food to be treated with invisible radiation is passed through a conveyor set-up in an irradiation chamber for the treatment.

Thus 'Food irradiation' refers to a physical non-thermal process in which food and allied commodities are exposed to ionizing radiation in a highly controlled set-up. The irradiated foods specific Joint Expert Committee comprising of regulatory agencies including the World Health Organization (WHO), International Atomic Energy Agency (IAEA) & Food and Agriculture Organization (FAO) has concurred approval to the ionizing radiation such as gamma radiation emanating from the radioisotopes Cobalt-60 (Co-60) and Cesium-137 (Cs-137), electron beam (≤10 MeV) or X-ray (≤7.5MeV) from machine sources (i.e., accelerators) for food processing applications[1-3]. Accordingly, the facilities are termed: Radioactive source based Gamma Radiation Processing Facility (GRAPF) and Accelerator based, Industrial Accelerator Radiation Processing Facility (IARPF).Globally, for food irradiation applications, Co-60 is reckoned as one of the prominent sources of gamma radiation. India's first food irradiation facility (Food Package Irradiator) was set-up at Food Irradiation and Processing Laboratory (FIPLy), BARC, Mumbai in 1967 (Fig. 1)

Table 1. Radiation sources approved for food irradiation applications

RADIOISOTOPE		MACHINE	
Cobalt-60 (Co^{60})	Cesium-137 (Cs^{137})	Electron beam (EB)	X-rays
Photons of energy 1.17 & 1.33 MeV	Photons of energy 0.66 MeV	Electron beam of energy 10 MeV (max)	Photons of energy 7.5 MeV (max)

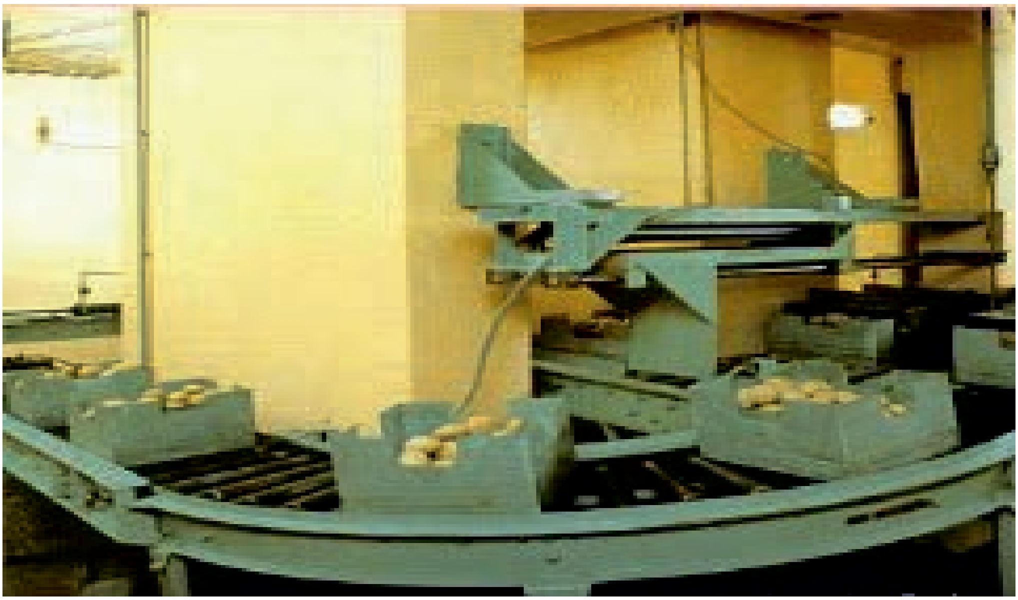

Figure 1. India's first food irradiation facility (Food Package Irradiator) set-up at FIPLy, BARC, Mumbai in 1967

Salient features of food irradiation process:

- During the entire course of radiation exposure, subject food commodity being irradiated never comes in direct physical contact with the radiation source. In-fact, it is exposed to the required radiant energy in a controlled mechanism.
- Radiation processing is a cold physical process which does not leave any residue in the food.
- The effective residence time of the commodity subjected to irradiation depends upon the dose rate or the source strength of the facility in coherence with the dose to be delivered.

- When a food commodity is exposed to radiant energy (i.e., ionizing radiation in the form of gamma rays or e-beam from approved sources), a proportion of this energy gets absorbed by the commodity which is termed as radiation absorbed dose. This is quantified in terms of SI unit Gy (acronym for Gray) where 1Gy is equivalent to absorption of 1J energy per kg.
- During radiation processing, the offered radiation dose depends upon the type of food and the desired technological objective (i.e., the application to be achieved).
- Depending upon the amount of dose required, the applications are categorised as low (< 1kGy), medium (1-10 kGy) and high dose (> 10 kGy) applications.
- These dose limits are carefully decided and quality control measures ensure that the dose limits do not exceed permitted range. In simpler terms, the applied radiation dose should be well within the range spanning from minimum radiation dose (D_{min} to suffice the desired objective) to maximum radiation dose (D_{max} which does not impact the wholesomeness). Routine dosimetry (i.e., dose measurement) ensures proper radiation dose delivery to the subject food or allied product exposed to radiant energy.
- It is worth mentioning that the process of radiation exposure is practised in properly shielded irradiation facility with in-built safety features (design safety, operational safety, administrative & regulatory controls) which ensure 'Fail-Safe' feature to the facility.

Interaction of ionizing radiation with food:

There exist three possible ways by which gamma or the X-ray photons can interact with food viz. photoelectric effect, Compton scattering and pair production.. Also the type of interaction depends upon the energy of the incident photon. For instance, absorption through photoelectric interaction occurs predominantly with photons having energy level below 100 keVwhereas pair production happens primarily with photons having energy level more than 10 MeV. Thus in food irradiation it is the Compton effect which serves as the dominating interaction because of the energy range of the ionizing radiation from the approved sources[4].

Statutory approvals and policy documents

Through comprehensive research and development in the last many decades, there has been wide-spread adoption of the food irradiation programme on the global canvas. Currently, food irradiation is being practiced in more than 60 countries for wide range of food commodities for attainment of broad-spectrum technological objectives[5]. This technology has been endorsed by the Food Safety and Standards Authority of India (FSSAI) and subsequently Gazette notified by the Government of India in the year 2016. Besides, this technology has been approved by various other national and international statutory bodies including United States-Food and Drug Administration, United States Department of Agriculture-Animal and Plant Health Inspection Services, Food Standards Australia New Zealand, World Trade Organization, Institute of Food Technologists and many more.

Salient advancements pertaining to guidelines on Food Irradiation are as following:

- The international consultative group on food irradiation has published 14 fact sheets providing comprehensive coverage to various aspects of food irradiation[6].
- As policy advancement in the context of food irradiation, the Codex Alimentarius Commission (CAC) constituted by the United Nations FAO & WHO framed important guidelines in the year 2003. These included the 'Codex General Standard for Irradiated Foods and the Recommended International Code of Practice for Radiation Processing of Food'[7,8].
- IAEA in association with FAO and IPCC developed documents 'Requirements for the Use of Irradiation as a Phytosanitary Measure and the Phytosanitary Treatments for Regulated Pests'. Guidelines outlined in these reports serve the basis not only for trade agreements but also aimed at trade promotion across the globe thus facilitating the accessibility of food from one country to the other. Trade of several varieties of irradiated fruit and vegetables at the international level is taking place in the Americas and the Asia and the Pacific regions.
- IAEA has developed a database titled 'International Database on Commodity Tolerance' (IDCT), wherein comprehensive listing of the various food commodities is provided along-with commodity quality after phytosanitary irradiation treatment.
- The International Organization for Standardization (ISO) has also published documents (ISO 14470:2011) comprehensively specifying various aspects (development, validation and routine control) of food irradiation through the approved sources[10].
- In a recent development, the assessment of the European Union legal framework on food irradiation affirms the efficacy of food irradiation. It also emphasizes if integrated in the existing food supply and QC chain, consumer health risks imposed by the food borne pathogens can be significantly controlled.
- Food irradiation in India is governed by the Atomic Energy (Radiation Processing of Food and Allied Products) Rules, 2012. The Atomic Energy Regulatory Board (AERB) provides guidelines pertaining to the flow chart of regulatory requirements, plant commissioning/re-commissioning dosimetry for food etc.

II. Post-harvest food losses and its possible mitigation by radiation processing

Globally, significant extent of qualitative and quantitative post-harvest losses are incurred in agri-produce sector. As per an estimate by the Food and Agriculture Organization (FAO), the loss or wastage of food in India can be as high as 40% (FAO, 2019).Therefore, technological interventions which are aimed at mitigation of food losses may serve as possible solutions. In this context, radiation processing offers a superior alternative.

Multiple value-added benefits of food irradiation include reduced post-harvest losses of bulbs (onions) and tubers (potato) through sprouting inhibition, insect pest dis-infestation of food grains, microbial hygienization of medicinally important herbs and spices, microbial safety assurance in special purpose foods, phytosanitary treatment of agri-produce to overcome quarantine barrier for promoting international trade as well as shelf-life extension of processed food products[11-17]. Many nations have regulated radiation processing as an effective phytosanitary measure that restricts the spread of pests of quarantine concern[18].

Thus, radiation processing is an effective eco-friendly approach of societal relevance as it strengthens 'Food Security', 'Food Safety' and 'Trade Promotion'.

Some prominent applications of radiation processing of food are as following:

Sprouting inhibition in bulbs and tubers:

Potato:

Potato represents an important agri-commodity globally and its long term preservation is generally practised in cold storages through the application of chemical sprout suppressants (including chlorpropham i.e., isopropyl N-3-chlorophenyl carbamate, CIPC). However, this leads to cold induced sweetening (CIS) in the potato tubers eventually affecting its processing quality and negatively impacting its marketability at the industrial level[20]. However, low dose radiation processing of potato allows its extended preservation at elevated temperature (14°C) thus offering dual advantages including sprouting inhibition as well as maintenance of processing quality attributes (Fig. 2 A). CIPC is being gradually restricted and recently (from January, 2020) European Union has banned its usage. Shift towards an eco-friendly and physical approach for the chemical sprout inhibitor free preservation of potato is one of the challenges for the potato industry in India. In this context, radiation technology provides an effective solution. In Japan, extended preservation of potato is done through the deployment of radiation technology only.

Non-irradiated | **Irradiated**

(Extensive sprouting and textural loss) | ***(No sprouting and retained quality)***

Figure 2A. Sprouting in non-irradiated potato and sprouting inhibition by irradiation

Underlying molecular mechanism: *Sprouting inhibition by gamma radiation processing in potato is attributed to the modulation at the gene expression level. The transcriptome profiling has provided convincing molecular insights ascertaining the retention of dormancy in irradiated potato tubers through enhanced biosynthesis of abscisic acid and breakdown of growth hormones including auxin. Besides, down-regulation of genes functionality associated with cell cycle progression, cell division, replication as well as transcription were found to contribute to the observed sprouting inhibition by irradiation (unpublished data).*

Onions:

The annual onion production in India is around 26.91 million MT with an estimated monthly consumption at 13 lakh tones[19]. Besides, approx. 30-40% of the onion crop undergoes qualitative and quantitative storage.Weight loss, microbial spoilage, rotting and sprouting are the key post-harvest losses that significantly affect the storage of onions over extended period subsequently impacting availability of quality onions during lean period and high price fluctuations. As per the recent data by the Ministry of Consumer Affairs, Government of India, every year onion crop to the tune of Rs. 11,000 Cr is lost due to improper storage[19].

Weight loss	Microbial spoilage & rotting	Sprouting	Radiation processed and cold stored

Figure 2B. Post-harvest spoilage issues in Onion and preservation by integrated approach

Therefore, to address the concern pertaining to the onion storage, technological intervention is indispensable. In this context, an integrated approach involving radiation technology and customized cold storage maintains the quality of onions for 7.5 months from the harvesting date (Fig. 2 B). Thus by this integrated approach 'Rabi' onions can be effectively stored with minimal weight loss and quality retention thus ensuring its availability and may also assist in price stabilization.

Underlying molecular mechanism:

The molecular mechanism underlying sprouting inhibition in onions by radiation processing (D_{min} 60 Gy), as deciphered through transcriptome analysis indicated down-regulation of genes associated with cell division, cell cycle, cellular growth as well as embryo development in radiation treated onion bulbs compared to non-irradiated onion. Besides, genes related to cell wall modulation, DNA replication and repair were also down-regulated in the radiation treated onion. As sprouting involves metabolic changes such as DNA replication, cell division, cell wall expansion, embryo development and growth, modulation in the gene expression level thus accounts for the observed inhibition of sprouting in radiation treated onion compared to the control set (unpublished data)

B. Control of insect infestation in food grains:

Food grains including cereals and pulses are highly vulnerable to insect infestation primarily with insects belonging to the class *Coleoptera* and *Lepidoptera* which significantly impacts their qualitative and quantitative values. Irradiation at low dose (D_{min}: 0.65 kGy) is effective in killing all the metamorphic stages of the insect pests. Besides, it also leads to sterility in the adult pests mitigating their reproductive capacity. Extensive R&D work at BARC has demonstrated the efficacy of radiation processing in controlling insect infestation in various food grains including cereals and pulses thereby extending their shelf-life up to 12 months (Fig. 3).

Biological effect of ionizing radiation on insect pests and their eggs: The deoxyribonucleic acids (DNA) represent the most susceptible critical target inside the cell of the insect pests and their eggs owing to their larger size and being the carrier of genetic information. The direct and indirect effect of radiation is responsible for oxidative DNA damage. The damage to the DNA culminates into inhibition of cell functioning leading to cell death[21]. However, the wholesomeness and nutritional adequacy of the food and allied products remains unaltered upon irradiation.

Non-irradiated
(After 12 months of storage)

Irradiated
(After 12 months of storage)

Figure 3. Insect pest infestation in non-irradiated wheat grains during storage and its mitigation by radiation processing

c. Microbial hygienization of spices, herbs and seasonings:

India is the largest producer and exporter of spices in the world and different kinds of spices are cultivated in the country. Quite often, the spices and herbs get contaminated during open sun-drying and secondary processing with insect eggs and microbes. Microbial contamination with pathogenic and food spoiling microbes significantly affects the shelf-life of spices. Besides, mycotoxin producing spoilage microbes are also immensely challenging. Therefore, fumigation is generally practiced however the fumigants are being gradually restricted due to health and environmental concerns. In this context, radiation processing being a cold physical process offers a very effective superior alternative. Gamma radiation (D_{min} 6kGy) is known to hygienize spices and herbs without impacting quality attributes (Fig. 4).

Non-irradiated turmeric

Irradiated turmeric

Non-irradiated black pepper

Irradiated black pepper

Figure 4. Microbial hygienization of different spices by radiation processing

d. Radiation hygienization and safety assurance of fish, meat and associated products

Fish undergoes rapid microbial spoilage leading to significant qualitative and quantitative losses. Radiation processing being a cold physical process helps in the quality retention of fish and fishery products. It is known to extend the shelf-life (2-3 times) of fresh fish in ice through the prevention of spoilage losses. Irradiation (4-6 kGy) of sea-foods is reported to eliminate various food borne pathogens including *Salmonella*, *Vibrio*, *Campylobacter*, *Listeria monocytogenes* etc. Besides, radiation processing (0.25-1.0 kGy) is also effective in controlling pest infestation in dried and packaged fishery products. Besides, in the meat sector radiation processing leads to shelf-life enhancement in non-frozen state, improved microbial safety of ready-to eat-products and enables the complete microbial safety assurance in radiation sterilized meat products.

e. Phytosanitary treatment for trade promotion:

Mango (*Mangifera indica* L.), the king of fruits belongs to the family *Anacardiaceae* is reckoned as the country's most important commercially grown fruit crop. India holds distinction of the highest global mango production, amounting to about 18.5 million tons (contributing 45% to the world mango production). Besides, India has the richest collection of delicious mango cultivars, with diverse flavor and aroma. Indian mangoes are highly valued for their unique flavor all across the world and United States is considered as one of the prominent destinations of Indian mangoes. In January 2006, USDA-APHIS published rule in the Federal Register (71 FR 66881-66888, Docket No. APHIS-2006-0121) approving a minimum generic dose (D_{min} 400 Gy) of irradiation for the agri-produce including fruits & vegetables which are imported. It is worth mentioning that the stone weevil (*Sternochetus mangiferae*) infested fruits do not exhibit symptoms on fruit surface. Fruits should be randomly selected & cut opened to reveal the larvae, pupae and adults within the kernel. After the ban of 18 years, eventually in the year 2007 United States Department of Agriculture (USDA) permitted import of Indian mangoes subject to irradiation to overcome the quarantine barrier of trade. The KRUSHAK irradiation facility, Lasalgaon, Nashik, Maharashtra became the first food irradiation facility in Asia to be approved by the USDA-APHIS for exporting irradiated mangoes from India to USA. India exported approx. 2500 MT of irradiated mangoes to USA. International trade of irradiated Indian mango also started to Australia, Malaysia and South Africa.

III. Safety and wholesomeness of irradiated foods:

Energy of permitted ionizing radiation from the approved radioisotopes or machine sources is incapable of inducing any radioactivity in the elements constituting any food matrix. Therefore, radiation processing does not make the food radioactive and there is no mutagenicity induction in the treated foods as reported in earlier studies[4, 22-25].

Additionally, it has also been affirmed by the Joint FAO/IAEA/WHO Study Group on High-Dose Irradiation that food commodity subjected to any irradiation dose which is suitable to accomplish the aimed objective does not pose any kind of risk to the consumer as the food retains its wholesomeness[26,27].

IV. Labeling of Irradiated Foods:

Radiation processing is a value-addition to the food. Therefore, to inform the consumers, radiation processed foods are labeled with an internationally followed 'Radura' symbol which is derived from the term radurization[28]. Radura comprises of the words 'rad' meaning 'radiation' and 'durus' meaning 'long lasting'. Symbolically, it comprises of a central dot with two leaves signifying a plant which is enclosed in a circle representing a closed package and ionizing radiation emanating from the source & passing through package (dashed lines) to the subject food commodity (Fig. 5).

Figure 5. RADURA label for irradiated foods

V. Commercial aspects of radiation processing of food:

a. Global food irradiation market:

Food irradiation is being seen as a highly value adding and profitable business venture. The market value as per the market research report was assessed to be ~US$199.4 billion in 2021 and expected to grow with a CAGR of 5.0% from 2022-2030 as per the projection by the Coherent Market Insights[29]. This primarily attributed to the increased consumer willingness in purchasing irradiated foods coupled with approval of phytosanitary status to irradiation by the U.S. Food and Drug Administration (FDA). Similarly, the food irradiation market is also rapidly expanding in Asia.

b. Setting of an irradiation facility and regulatory approvals:

The steps involved in the commissioning of an irradiation facility are outlined as Figure 6. The land requirement to establish an irradiation facility is approx. 1.5 to 2 acres. Besides, the irradiation facility needs to be complemented with an ancillary infrastructure such as a cold storage (in case of perishable products) and dry storage (in case of food grains). As Co-60, being a radioisotope has a natural decay process, therefore maximum utilization of this facility is required for higher commercial gains. As the facility is capital intensive, for the involvement of Ministry of Micro, Small & Medium Enterprises (MSMEs), new start-ups & FPOs, financial support by the Government in the form of subsidy are required to encourage its adoption. The payback period of capital investment of an irradiation facility is 4-5 years and total 9 to 15 personnel are required to operate the facility in three shifts. Food irradiation facilities are operated by trained operators under the surveillance of a Radiation Safety Officer (RSO). The food irradiation facilities in India can be operated only after obtaining a valid license from the Atomic Energy Regulatory Board as well as the Department of Atomic Energy.

c. Commercial viability:

To reduce the transportation cost and make the process more economical, it is advisable to commission the food irradiation facility either at the harvest point or at the selling site. For full-fledged utilization of this facility, different stakeholders including Food storage sites, Mega food parks/agro-cluster, Multi-product processing facilities, farmers produce organizations are required to be encouraged to get involved in processing and marketing chain for domestic uses as well as export to ensure backward and forward integration.

VI. Restraining factors in the wide-spread dissemination of radiation technology:

With respect to the huge quantum of agri-production in the country, the expected number of the irradiation facilities is significantly low. This primarily contributes to the insignificant visibility of irradiated products in the public domain. The throughput of the existing irradiation facilities is satisfactory enough to cater the needs of the spice industry for microbial hygienization as well as irradiation of mango for phytosanitary applications etc. However, with respect to the quantum of food grains being handled in the different warehousing facilities in the country, it is the need of the hour to augment the throughput of the irradiation facility and approaches should be adopted for integration of irradiation facility with existing food grains processing chain. Logistic limitations primarily related to cold chain, storage (with adjustable humidity, temperature and ventilation) & transportation facilities further aggravate this situation. The capital cost incurred in the commissioning of an irradiation facility as well as the annual Operations & Maintenance of irradiation facility is also one of the bottlenecks. Misconceived notion related to safety aspect of irradiated foods is another concern of relevance. However, it has been observed and reported in various surveys that if provided factual information and the plethora of associated socio-economic benefits, consumers are extremely willing to purchase the irradiated foods. This same concept holds true for other stakeholders including the industry.

VII. Future aspects and new perspectives:

In the current context, it becomes imperative to envision low cost multitasking irradiation facilities for broad spectrum applications and capable of handling huge quantum of food. This will further strengthen the sustainability of the irradiation facility. Improvisation in the design of the irradiation facility in order to increase the throughput to meet the industrial requirements specifically with reference to high-quantum agri-produce including onions, potato, food grains etc is also an important technological task. For the wide-spread commercial adaptation, policy intervention and back-up by the associated agencies is a pre-requisite. Besides, awareness build-up is also equally important among various stakeholders including general consumers, academia, traders, industry etc. For enhancing consumer willingness in procuring irradiated foods, it is quite important to prominently showcase the benefits of the radiation technology. Significant involvement of stakeholders who are strong proponents of radiation technology should be taken into consideration. Food security is one of the sustainable development goals (SDGs) in the United Nations charter. Besides, amidst phasing out chemical fumigants worldwide, eco-friendly technologies seem to be immensely indispensable. Furthermore, there is an increased willingness of consumers towards foods free from chemical preservatives. In this context, radiation processing seems to be a highly effective indispensable modality. It is also very likely that if irradiation is coupled with other available processing or preservation approaches, this may further facilitate inclusion of more and more food commodities, could be energy saving, user friendly ultimately resulting in increased final product quality[30].

Table 2 A. Generic Class based Food Irradiation Approval

Class	Food	Purpose	Dose Limit (kilo Gray)	
			Minimum	Maximum
Class 1	Bulbs, stem and root tubers, and rhizomes	Inhibiting sprouting	0.02	0.2
Class 2	Fresh fruits and vegetables (other than class 1)	Delay ripening	0.2	1
		Insect disinfestation	0.2	1
		Shelf life extension	1	2.5
		Quarantine application	0.1	1
Class 3	Cereals and their milled products, pulses and their milled products, nuts, oil seeds, dried fruits and their products	Insect disinfestation	0.25	1
		Reduction of microbial load	1.5	5
Class 4	Fish, aquaculture, sea food and their products (fresh or frozen), and crustaceans	Elimination of pathogenic microorganisms	1	7
		Shelf-life extension	1	3
		Control of human parasites	0.3	2
Class 5	Meat and meat products including poultry (fresh and frozen) and eggs	Elimination of pathogenic microorganisms	1	7
		Shelf-life extension	1	3
		Control of human parasites	0.3	2
Class 6	Dry vegetables, seasonings, spices, condiments, dry herbs and their products, tea. Coffee, cocoa and plant products	Microbial decontamination	6	14
		Insect disinfestation	0.3	1
Class 7	Dry foods of animal origin and their products	Insect disinfestation	0.3	1
		Control of moulds	1	3
		Elimination of pathogenic microorganisms	2	7
Class 8	Ethnic foods, military rations, space foods, ready-to eat, ready-to cook/ minimally processed foods	Quarantine application	0.25	1
		Reduction of microorganisms	2	10
		Sterilization	5	25

Table 2 B. Generic Class based Food Irradiation Approval (Schedule II)

SCHEDULE – II

[Sec. Clause (b) of rule 6]

Dose Limits for Radiation Processing of Allied Products

Sr. No.	Allied Product	Purpose	Dose Limits (Kilo Gray)	
			Minimum	Maximum
1.	Animal food and feed	Insect disinfestations	0.25	1.0
		Microbial decontamination	5.0	10.0
2.	Ayurvedic herbs and their products, and medicines	Insect disinfestations	0.25	1.0
		Microbial decontamination	5.0	10.0
		Sterilization	10	25
3.	Packaging materials for food/allied products	Microbial decontamination	5.0	10.0
		Sterilization	10.0	25
4.	Food additives	Insect disinfestations	0.25	1.0
		Microbial decontamination	5.0	10.0
		Sterilization	10	25
5.	Health foods, dietary supplements and nutraceuticals	Insect disinfestations	0.25	1.0
		Microbial decontamination	5.0	10.0
		Sterilization	10	25
6.	Body care and cleansing products	Microbial decontamination	5.0	10.0
		Sterilization	10	25
7.	Cut flowers	Quarantine application	0.25	1.0
		Shelf-life extension	0.25	1.0

Figure 6. Steps involved in the commissioning of a food irradiation facility

STEP 1

SITE SELECTION OF THE FACILITY FOR AERB APPROVAL

STEP 2

MEETING WITH MANUFACTURERS/CONSULTANTS OF THE FACILITY (LICENSEE OF THE TECHNOLOGY)

STEP 3

REGISTRATION OF SECURITY PLAN WITH DISTRICT LAW & ENFORCEMENT AUTHORITY AND ENDORSEMENT

STEP 4

SIGNING OF MOU WITH BRIT (BOARD OF RADIATION & ISOTOPE TECHNOLOGY, DAE)

STEP 5

CIVIL CONSTRUCTION AND MECHANICAL SYSTEMS INSTALLATION ON APPROVAL OF AERB

STEP 6

STAFF EMPLOYMENT (RSO, OPERATOR, QCO AND MAINTENANCE PERSONNEL)

STEP 7

SOURCE LOADING BY BRIT AND COMMISSIONING DOSIMETRY ON APPROVAL OF AERB

STEP 8

LICENCE FROM AERB FOR ROUTINE COMMERCIAL OPERATION

STEP 9

LICENCE FROM DAE AND FDA FOR RADIATION PROCESSING OF FOOD & PHARMA PRODUCTS AND PLANT OPERATION

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