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PRACTICAL UTILIZATION OF FOOD IRRADIATION IN DEVELOPING COUNTRIES

1. Resolution GC(XXXVI)/RES/588 of the thirty-sixth General Conference of the IAEA adopted on 25 September 1992 requested the Director General to prepare, in consultation with FAO and WHO, a detailed project proposal for introducing practical utilization of food irradiation in developing countries, for submission to the Board of Governors for a final decision in June 1993 and to report on the matter to the General Conference at its thirty-seventh regular session.

2. Following the endorsement of an Action Plan on this subject by the February 1993 Board of Governors, the Secretariat proceeded to make enquiries via questionnaire among potentially suitable developing countries (i.e. those which have sufficient food production, proper infrastructures for introducing new technologies and regulatory control) in order to determine their interest in introducing commercial-scale food irradiation programmes. Based on the information provided by developing Member States as well as those received from other sources, the Secretariat has attempted to estimate the interest of developing countries in introducing commercial-scale food irradiation technology (Annex 1).

3. Of the four countries selected for introducing commercial-scale food irradiation programmes (i.e. Chile, China, Mexico and Morocco) under the Action Plan adopted by the February Board of Governors, two countries (Mexico and Morocco) have carried out techno-economic feasibility studies with assistance from IAEA. Similar studies are also planned in Chile and China later in 1993. Summary reports on the feasibility of establishing commercial food irradiation in Mexico and Morocco are attached in Annexes 2 and 3. Detailed reports on the studies may be obtained from the Secretariat (Division of Technical Co-operation Programmes or the Joint FAO/IAEA Division). Some preliminary information for a potential TC project in China is included in Annex 4.

4. The Secretariat has also prepared a Project Proposal setting out the purpose of and prerequisites for participating in the Project, type and extent of assistance and information to be provided by IAEA and estimates of costs of such assistance, including costs of an irradiation facility and associated infrastructures, for consideration by the Board. The Project Proposal places emphasis on the economic viability of using food irradiation on a commercial-scale in developing countries.

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5. The Board of Governors, at its June 1993 Session:

(i) Approved the Project Proposal containing the steps to be followed by countries requesting IAEA assistance in the implementation of commercial-scale food irradiation projects, with the understanding that, depending on the status of food irradiation in each case, not all steps may be required for each country.

(ii) Requested the Director General to report the outcome of its deliberations and its decision on this matter to the General Conference at its thirty-seventh regular session; and

(iii) Also requested the Director General to notify the Secretariats of other UN agencies (FAO, WHO and ITC) of its decision to enable them to bring it before their governing bodies with a view to soliciting their support and co-operation in the implementation of this decision.

6. It is envisaged that governments of developing countries having appropriate infrastructures, after close consultation with their interested commercial sectors, will initiate national projects leading to practical utilization of food irradiation, if necessary with technical assistance from IAEA, as described in this document. Unlike R&D type country projects, the national food irradiation projects under discussion will be commercially oriented, with IAEA providing mainly technical know-how, information and limited equipment for safety and control purpose.

7. Pursuant to the request contained in resolution GC(XXXVI)/RES/588, the Director General is bringing to the attention of the Conference, action taken by the Board of Governors on the implementation of the resolution.

PRACTICAL USE OF FOOD IRRADIATION IN DEVELOPING COUNTRIES

I. INTRODUCTION

1. STATUS OF FOOD IRRADIATION TECHNOLOGY

In 1980, the Joint FAO/IAEA/WHO Expert Committee on the Wholesomeness of Irradiated Food (JECFI) concluded that "irradiation of any food commodity up to an overall average dose of 10 kGy causes no toxicological hazard; hence, toxicological testing of foods so treated is no longer required." The JECFI also recognized that irradiation of food up to a dose of 10 kGy introduces no special microbiological or nutritional problems for consumption. In 1983, the Codex Alimentarius Commission (CAC) of the FAO/WHO Food Standards Programme, then represented by some 130 countries, adopted a Codex General Standard for Irradiated Foods (Worldwide Standard) and a Recommended Code of Practice for Operation of Radiation Facilities used for Treatment of Food.

In 1984, the CAC recommended that all its member countries should accept the Codex Standard and Code of Practice and incorporate them in their national regulations. In 1988, the International Conference on the Acceptance, Control of and Trade in Irradiated Foods, jointly organized by FAO, IAEA, WHO and ITC-UNCTAD/GATT and attended by designated experts from 56 governments, endorsed the use of food irradiation as a method for food processing and preservation and laid down strict criteria for acceptance, control and trade in irradiated food.

The recommendations of specialized UN Agencies in the past decade have resulted in the approval of one or more irradiated food items for consumption in 37 countries to date. Currently, 25 of these countries are using some 50 commercial or demonstration irradiators for processing various food items for commercial purposes (Annex 6).

2. FOOD PROBLEMS IN DEVELOPING COUNTRIES

A. <u>Food Losses</u>

FAO estimates that one quarter to one third of the world's food supply is lost after harvesting. With the high birth rates in much of the developing world, some countries are experiencing serious food shortages. Food irradiation is able to contribute to lessening the magnitude of such problems by reducing losses of many fresh and stored food.

B. Food Hygiene

WHO estimates that infectious and parasitic diseases represented 35% of deaths world-wide in 1990, the majority of which occurred in developing countries. Among these, diarrhoeal diseases caused about 25% of deaths in developing countries. It estimated that possibly up to 70% of cases, food is the vehicle for transmission of diarrhoeal diseases.

The use of food irradiation can reduce the incidence of foodborne disease by reducing or eliminating pathogenic microorganisms in food of animal origin such as meat, poultry, fish, other seafood as well as spices.

C. Food Trade

Export of agricultural products provides an important source of foreign exchange for most developing countries. Exported agricultural commodities must meet criteria and quarantine restrictions imposed by importing countries.

Pressure to phase out chemical fumigants on safety and environmental grounds is increasing; irradiation has already been accepted by several advanced and developing countries such as Canada, France, the Netherlands, Mexico, Chile, China, Thailand, United Kingdom and the United States of America as an alternative to fumigation of certain foods.

3. BENEFITS AND LIMITATIONS OF FOOD IRRADIATION

The advantages of food irradiation over existing technologies and its limitations were explained in GOV/INF/664. Food irradiation is not a panacea. It cannot replace good manufacturing practices, it is not applicable to all foods nor can it restore spoiled food to its original condition. However, the benefits of the technology as a method for reducing post-harvest food losses, a substitute for chemical fumigants, a method to ensure the hygienic quality of "solid food" such as poultry, meat, seafood and spices and satisfying public demand for fresh food, outweigh the cost inherent to the process.

4. AVAILABLE TECHNICAL INFORMATION[1]

A. Effectiveness of the technology

Through R&D programmes in several Member States and through a series of Co-ordinated Research Programmes carried out by the Joint FAO/IAEA Division in the past three decades, irradiation has been demonstrated to be effective for controlling sprouting of roots and tubers, eliminating insect infestation of fruits, grain and other stored products, extending the shelf-life and ensuring the hygienic quality of fresh food of animal origin, eliminating parasites in meat and fish to be consumed raw, etc. Food irradiation is uniquely able to ensure hygienic quality of frozen food, and of live shellfish to be consumed raw (e.g. oysters and clams) and disinfest seed weevils in mangoes (a quarantine pest).

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[1] See Annex 5, Information on Food Irradiation

B. Safety of Irradiated Food and Facilities

The safe installation and operation of irradiation facilities is amply described in literature published by national and international organizations. Many years of practical experience are available on safety operation of such facilities. The wholesomeness of irradiated food itself has been established through the Codex General Standard for Irradiated Foods as indicated above.

C. Regulatory Aspects and Control of Food Irradiation

Several guidelines, codes and other advisory documents exist, elaborated mainly by the International Consultative Group on Food Irradiation (ICGFI) which, together with the Codex Standard for Irradiated Foods and its associated Code, can form the basis of appropriate regulations to ensure the safe and proper application of the process, and the safety of an irradiation facility. The Joint FAO/IAEA Division is in a position, therefore, to provide countries with technical assistance in drawing up an effective regulatory control system.

D. Consumer Acceptance and Public Information

Information is available on the outcome of direct comparison trials carried out in over 10 countries to assess consumer acceptance of irradiated food (Annex 6). These studies show that consumers choose, purchase and consume irradiated food products presented to them in a real competitive market. As mentioned above, different types of foods are routinely irradiated for commercial purposes in 25 countries.

5. TRAINING

Information is available concerning opportunity for training personnel in the proper application of food irradiation and also in the regulatory control of the process. The Joint FAO/IAEA Division provides training courses under the international Network for Training in Food Irradiation (INTFI), which is operated under ICGFI and with the support of governments and the IAEA Technical Co-operation Programmes. The Joint FAO/IAEA Division can also provide information and guidance on the type of training required in individual cases.

II. STEPS TO BE FOLLOWED IN INITIATING FOOD IRRADIATION ACTIVITIES WITH TC ASSISTANCE

Depending on the need of individual countries, the steps described below may be followed in requesting technical assistance in introducing commercial-scale food irradiation programmes in developing countries. It is understood that the description of possible assistance by IAEA represents the maximum involvement the IAEA through its TC programme could have and that not all countries wishing to initiate food irradiation projects would require assistance for each step.

1. PREREQUISITES FOR INTRODUCING COMMERCIAL-SCALE FOOD IRRADIATION IN DEVELOPING COUNTRIES

Commercial-scale food irradiation can only be introduced successfully in countries which have significant food handling, storage and marketing, know-how of the technology and the infrastructures for the operation and control of a commercial food irradiation facility. Furthermore, significant domestic and/or export trade in the foods concerned, and interest to invest in food irradiation technology. The following are prerequisites for introducing commercial-scale food irradiation.

(1) Existence of the necessary infrastructures for the production, quality control, storage, distribution and marketing of the food product(s) to be irradiated;

(2) A clear economic benefit to trade in irradiated food product(s). A significant potential for the likely market expansion of the market of the treated food is also desirable.

(3) There must be a firm commitment by the food trade or industry and the government of concerned in the establishment of a commercial food irradiation facility;

(4) Existence of appropriate regulations on approval of irradiated food, control and inspection of irradiation facilities and the process.

(5) Trained personnel for the operation of the commercial food irradiation facility must be available before commercial operations commence.

2. POSSIBLE ASSISTANCE BY IAEA

Developing countries with an interest in introducing commercial-scale food irradiation and which can meet the criteria mentioned above may wish to request technical assistance from IAEA. The type of assistance, in addition to providing information (see para 4), is described below:

2.1 **Pre-project Mission**

Developing countries may request that IAEA provide expert services in order to determine the feasibility of proceeding with the introduction of commercial-scale food irradiation. The pre-project mission would define the extent of assistance required in carrying out a definitive techno-economic feasibility study.

2.2 **Economic Feasibility Study**

Prior to introducing food irradiation on a commercial-scale, developing countries should evaluate the economic effects (e.g. cost vs. benefits) of using irradiation for food processing under the conditions prevailing in their countries. An economic feasibility study is required to evaluate the types and volume of food products to be irradiated, type, source, strength, capacity and location of the irradiation facility, manpower requirements and marketing channels of the irradiated food. A typical feasibility study may require expertise and expenditures approximately given below. The estimates are for a maximum involvement by IAEA. The extent of expert services required will depend on the needs of individual countries.

Expert Services

	man months	US$
(a) Salaries		
One Specialist in food irradiation technology	1	10,000
One Economist/food marketing specialist with knowledge of food irradiation	1	9,000
One Irradiation engineer	1	9,000
Total cost of expert services	3	28,000

(b) Mission

The cost of a mission of 2-3 weeks duration by the expert team (3 members) to assist in carrying out a feasibility study (mainly to evaluate data compiled by national authorities and the food industry) in the participating county is estimated to be:

	US $
Daily subsistence, etc.	15,000
Travel costs for 3 team members	9,000
Total cost of mission	24,000
Total cost of a feasibility study (per country)	52,000

2.3 **Irradiation Facility**

Once the economic viability of a commercial scale food irradiation programme has been determined and the decision to proceed has been taken, financial resources have to be assembled from local industry, governments and donor organisations for constructing a suitable irradiation facility. The cost of a semi-automatic irradiator for food processing, equipped with an initial source strength of 100 kCi irradiator production device and other essential equipment is estimated to be approx. US$ 800,000. In addition, the cost of biological shielding of the irradiator is estimated to be US$ 500,000. The cost of product handling and storage areas, laboratories and offices would be additional to that stated above and would vary according to the requirements of each country.

As the scope of such an irradiation facility and its application is commercially-oriented, extra-budgetary resources will have to be made available for supporting such a facility.

2.4 Project Implementation

Governments of developing countries may wish to request the assistance from the Agency through its TC Programmes to assist in implementing a project aimed at introducing commercial scale food irradiation:

The following types of expert services may be requested to assist the local authorities in implementing the project:

(a) Expert Services

Salaries:

	man months	Cost (US$)
One: Food irradiation specialist (Team Leader)	6	50,000
One: Stored product entomologist	6	45,000
One: Irradiation engineer	6	45,000
One: Food marketing/consumer relations specialist	6	45,000
	24	185,000

(NB: the composition of the Team will depend on individual country needs)

Missions

Depending on the needs of the country and the availability of local experts, it is anticipated that 4 expert missions each of 2-3 weeks duration would be mounted to the participating country during the course of the project. The cost per mission (daily subsistence, etc) is estimated to be in the order of US$ 15,000, with an additional US$ 3,000 travel cost per expert. The maximum cost of 4 missions is estimated to be US$ 108,000.

(b) Training

Up to 5 scientists/officials should receive specialized training on different aspects of food irradiation each of 6 months duration for a total of 30 m/m and an estimated US$ 90,000.

(c) Public Information

Seminars of 5 days duration for the benefit of media representatives, representatives of consumer organizations, policy makers and other interested parties should be organized. Up to 3 such seminars may be required during the construction of a commercial irradiation facility, commissioning of the facility and marketing of irradiated food. Estimated cost of each seminar is US$ 30,000, totalling US$ 90,000 for 3 seminars.

III. SUMMARY OF ESTIMATED MAXIMUM BUDGET

The following summarizes estimated cost per country project. This cost may be lower, depending on the extent of technical assistance required and the availability of infrastructures, etc.

	man months	US $
FEASIBILITY STUDY[a]		
Expert services (salaries)	3	28,000
Missions		24,000
Total cost of feasibility study:		52,000
PROJECT IMPLEMENTATION[a]		
Expert services (salaries)	24	185,000
Missions		108,000
Training		90,000
Public Information		90,000
Total cost of project operation excluding irradiation facilities		473,000
Irradiation facilities[b] (Irradiation equipment, source, etc,)		800,000
Buildings[b]		500,000
Total cost (assuming provision of new irradiation facilities throughout):		1,300,000
Total cost of project		1,825,000

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[a] to be funded by TACF
[b] to be funded by extra-budgetary sources or national authorities

IV. STATUS OF IMPLEMENTATION OF ASSISTANCE TO CHILE, CHINA, MEXICO and MOROCCO

1. CHILE. Expertise for conducting feasibility studies for introducing a commercial-scale food irradiation programme is available in the country. The Agency is expected to provide an expert service to verify the data and to recommend further assistance required.

2. CHINA. The Chinese authorities have conducted their own feasibility study for installing a commercial food irradiator in Beijing. The Government has already allocated approx. US$ 1.2 million required for constructing the facility. The Agency is expected to receive a request for TC assistance in terms of radiation source (100,000 curies of Co-60), equipment for quality control of the facility, training and expert services. The potential TC project for China is described in Annex 4.

3. MEXICO. The Agency has assisted the Mexican authorities in evaluating data on economic feasibility of installing the first multi-purpose irradiator for treating food and non-food products in April 1993. The outcome of the evaluation of such an irradiator was positive. Such a facility would require an investment of approx. US$ 4.6 million, could process a minimum of 20,000 tonnes of food and non-food products per annum with the return on investment ranging from 15 to 18% per annum and an internal rate of return from 54 to 65%. Further assistance in implementing such commercial-scale irradiation facilities may be required in the form of expert services, training, public information and some equipment. The outcome of the evaluation is included in Annex 2.

4. MOROCCO. The Agency has assisted the Moroccan authorities in evaluating the feasibility of introducing a commercial-scale food irradiator in the country. It appears that the introduction of such a programme in Morocco is premature due to regulatory constraints, unclear markets for irradiated food for export and not well-developed infrastructures for storage and distribution of food for domestic consumption. Further assistance is required from the Agency in term of training, expert services, equipments and public information. The outcome of the evaluation is included in Annex 3.

DEVELOPING COUNTRIES WHICH HAVE POTENTIAL FOR COMMERCIAL APPLICATION OF FOOD IRRADIATION

COUNTRY	FACILITY AVAILABLE	STATUS OF APPROVAL OF IRRAD. FOOD	TARGET FOOD	REMARKS
Algeria	R&D, Commercial plant under construction	None (drafted regulation)	Potatoes, onions, dates, grains, spices	Conducted techno-economic feasibility
Argentina	R&D and commercial plant	Approved several food items	Potatoes, onions, fresh fruits, poultry, spices, dried vegetables, cocoa powder	Commercial irradiation of spices and Cocoa powder
Bangladesh	R&D and demonstration plant	Approved several irradiated foods	Potatoes, onions, pulses	Conducted economic feasibility study, market testing, consumer acceptance.
Brazil	R&D and commercial plant	Approved several irradiated food	Cereals, beans, potatoes, onions, spices, fresh fruits, vegetables, poultry	Commercial irradiation of spices, dehydrated vegetables
Bulgaria	R&D	Experimental batches	Potatoes, onions, garlic, grain, dry food, fresh fruits	

Chile	R&D and demonstration plant	Approved several food items	Potatoes, onions, fresh fruits, spices, dehydrated vegetables, poultry	Commercial irradiation of spices and dehydrated vegetables
China	R&D and a few commercial plants	Approved several food items	Potatoes, onions, grains, fresh fruits, poultry, meat, spices and seasonings	Commercial irradiation of garlic, spices, seasonings, wine
Columbia	R&D	None	Potatoes, onions, fresh fruits and vegetables	
Costa Rica	R&D	None (drafted regulation)	Potatoes, onions, grains, beans, mangoes, papayas	
Côte d'Ivoire	R&D, commercial plant under construction	None (drafted regulations)	Yams, cocoa beans, onions	Conducted market testing of irradiated yams
Croatia	Pilot plant	Approved several irradiated food	Spices, dried food ingredients	Commercial irradiation of spices, rice and vegetable seasoning
Cuba	Demonstration	Approved several irradiated food	Cocoa bean, potatoes, onions	Commercial irradiation of cocoa beans, potatoes, onions
Ecuador	R&D	None	Potatoes, onions, grains, fresh fruits	

Egypt	R&D and commercial plant	None (drafted regulation)	Beans, potatoes, onions, spices, dates, fish & fishery products	
Ghana	R&D and demonstration plant under construction	None (drafted regulation)	Yams, cocoa beans, onions, fish & fishery products	
Hungary	R&D and commercial plant	Approved several irradiated foods	Spices, onions, dehydrated food ingredients	Commercial irradiation of spices
India	R&D, demonstration and planned commercial plant	Approved several food items	Onions, fresh fruits, seafood, spices and seasonings	
Indonesia	A pilot and a commercial plant	Approved several irradiated food	Spices, rice, seafood, frog legs, dry food, fresh fruits, potatoes, onions	Commercial irradiation of spices
Iran	R&D and demonstration plant	Approved irradiated spices	Spices, dried fruits, onions, grains	Commercial irradiation of spices
Korea, Republic of	A demonstration and a commercial plant	Approved several irradiated food	Spices, dry vegetable seasoning, dry food, potatoes, onions	Commercial irradiation of spices, vegetable seasonings and dry food
Libya	Pilot plant	None	Onions, dates	
Malaysia	R&D and demonstration plant	None (drafted regulation)	Citrus, cocoa beans, grains, poultry, spices	

Mexico	Semi-commercial plant	Approved several food items	Fresh fruits, poultry, spices and dehydrated vegetables	Commercial irradiation of spices and dehydrated vegetables
Morocco	None	None (drafted regulation)	Fresh fruits, potatoes, onions, seafood, dried fruits, spices and dried vegetables, dried pulses and beans	
Nigeria	R&D	None	Yams, cocoa beans, pulses & beans, cereals, meat & products	
Pakistan	R&D and commercial	Approved potatoes, onions, garlic, spices	Potatoes, garlic, dried fruits, spices and dried food ingredients	Conducted test marketing
Philippines	R&D	Appproved potatoes, onions, garlic	Onions, garlic, tropical fruits, fish & fishery products	Conducted test marketing
Peru	R&D	None	Potatoes, onions, fresh fruits & vegetables	
Poland	R&D, Demonstration plant	Approved several irradiated food	Potatoes, onions, spices, poultry	Conducted test marketing
Portugal	Demonstration plant	None	Potatoes, onions, spices, poultry	
Saudi Arabia	Commercial plant	None	Dates, grains, poultry, meat & products	

Syria	R&D and demonstration plant under construction	Approved several irradiated foods	Dried fruits, potatoes, onions, pulses, fresh fruits, cut flowers	
Thailand	R&D and demonstration plant	Approved several irradiated foods	Onions, fish & products, fermented pork sausage (nahm), pulses, cereals	Commercial irradiation of nahm
Tunisia	None	None	Potatoes, onions, dates, fish and fishery products	Strong interest in food irradiation
Turkey	R&D and demonstration plant under construction	None	Potatoes, onions, pulses, dried fruits, garlic, fresh fruits, meat & products	
Uruguay	None	Approved irradiated potatoes	Agricultural products (fruits and vegetables) mainly for export	Plans to build a multipurpose irradiator within 3 years
Venezuela	R&D	None	Potatoes, onions, fresh fruits & vegetables	
Viet Nam	R&D and demonstration plant	Approved several irradiated foods	Grains, onions, fish & fishery products	
Zambia	Pilot plant	None	Potatoes, onions, cereals, fresh fruits	
Zaire	R&D	None	Cereals, fish & products, food ingredients	

COMMERCIAL APPLICATION OF FOOD IRRADIATION IN MEXICO

Executive Summary

An expert mission* travelled to Mexico from 14 to 30 April 1993 on behalf of FAO/IAEA to evaluate all aspects of building one or more commercial irradiation facilities in Mexico to process food for both the domestic and export markets. The overall conclusion is that food irradiation offers many important health and economic benefits to the Mexican populace, and that Mexico's domestic market could easily support a profitable multi-purpose irradiator now. The mission also concluded that if food irradiation were to be utilized to its full potential, there would be enough volume of produce to support many commercial scale irradiation facilities for Mexico's domestic market and additional facilities for processing export commodities.

In arriving at its conclusions, the mission examined Mexico's production, domestic consumption, and export of food; reviewed Mexico's and United States' food irradiation and trade regulations; considered the benefits of this technology to Mexican consumers, commercial enterprises, and to Mexico in general; and undertook a financial analysis for a proposed commercial facility located in the central region of Mexico. Based on their analysis, the authors formulated recommendations that they believe, if implemented, would help put this technology to work.

An important consideration in the formulation of the mission's conclusions was the imminent banning of methyl bromide a widely used fumigant for food and agricultural products. Unless something is done to expedite and develop alternative methods, this ban will affect Mexican agriculture negatively in much the same way as the banning of ethylene dibromide did in the mid-1980s. These fumigants have been used to treat food after harvest to retard ripening, reduce spoilage, slow down sprouting, and/or kill insects. The banning of methyl bromide by the year 2000, because it affects the Earth's ozone layer, will almost certainly increase the food industry's interest in the alternative and in many ways more effective technology or unique for some products: i.e. irradiation.

Public opposition to any technology using the word 'radiation' appears to be lessening, at least in the United States, and clearly labelled irradiated food is now being sold successfully wherever it is available, mainly because of its obvious quality advantages. Mexican consumers are expected to accept irradiated food even more willingly because they generally rely heavily on the government to protect their safety. At the present time, small commercial amounts of dried foods and spices are being routinely irradiated at ININ outside Mexico City using a relatively small demonstration facility designed to sterilize medical products. This facility has

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been running at capacity for three years and cannot meet the existing demands for its services. The present analysis of food production in the country of Mexico and the transportation routes and the benefits that would accrue, have led the mission to conclude that a commercial multipurpose irradiator built in the central region, within 200-450 km of Mexico City, would be profitable. To reduce the financial risk and increase the initial profits, the mission recommends that the facility be available to irradiate non-food items such as medical disposables as well as agricultural produce for the domestic market. It is believed that additional facilities at other locations dedicated to specific food products would soon be required, but the reliance on exports where irradiation is the quarantine treatment, should wait until the importing country accepts this technology for this purpose.

Using irradiation as a quarantine treatment has only been approved by the United States for papayas from Hawaii. Recent estimates by the USDA are that it will take up to two years or more following the completion of research demonstrating the effectiveness of the treatment, for the US government to accept radiation as an acceptable treatment for assuring that mangoes are not carrying fertile fruit flies. Exporters and the Mexican government strongly support irradiation because the existing approved quarantine treatment (hot water dip) damages the fruit and results in a significant loss of product. Mexican officials may be expected to pressure the United States government to speed up the approval process for mangoes and possibly for other fruits as a replacement of alternative methods that are damaging to the fruit or to the environment.

The regulatory climate for food irradiation in Mexico is very favourable, and laws and regulations are either already in place or are now being enacted. Senior government officials are keen to see this technology implemented, and view the process as a tool to improve the quality of food in Mexico and a means to increase the quantity of food both for domestic consumption and for export. Mexico also has a nucleus of highly trained individuals who can easily train operators of facilities and regulatory personnel.

Three groups in Mexico are actively pursuing the possibility of building commercial food irradiation facilities. Two of these groups met with the mission experts who reviewed the preliminary plans. While both groups had made significant progress towards determining the feasibility of their potential investments, comprehensive financial feasibility studies had not been developed. As a result, the mission experts decided to conduct their own analysis.

The financial analysis undertaken by the mission experts was for a multi-purpose irradiator, preferably near San Luis Potosi, in the central region of Mexico, that would process both food and non-food products for the domestic market. Such a facility would require a capital investment of approx. US$ 4.6 million with an operating cost of US$ 435,000 during the first year. The irradiator could process a minimum of 20,000 tonnes of food and non-food items per year. The results of the analysis show that the facility would be a profitable investment with an average rate of return on investment over the first ten years of operation of 18% and an internal rate of return of 65%. A risk analysis was also completed of the impact on the facility's financial performance of a decrease in revenues of 20%, an increase in capital costs of 15%, and an interest rate increase of 4 percentage points. In each of the risk scenarios, the facility remained profitable with the return on investment in the most unfavourable case falling to only 15% with an internal rate of return of 54%.

Based on its work in Mexico and the analysis it performed, the mission came to the following major conclusions:

1. The irradiation process will provide major benefits to Mexico by increasing the quality and quantity of food and therefore the quality of life, by reducing food spoilage, and by increasing the quantity and value of exported food products.

2. The regulatory framework within Mexico is very favourable toward the food irradiation process.

3. The present demand in Mexico for irradiated food is too uncertain to support building a commercial-scale facility dedicated only to food irradiation.

4. The early introduction of irradiated food in Mexico can be successfully and profitably achieved by building a commercial multi-purpose facility in central Mexico designed to process both food and non-food products.

5. If food irradiation were utilized to its full potential by the Mexican food industry, there would be sufficient volume of produce to support dozens of commercial-scale irradiation plants just for the Mexican domestic market alone.

6. The widely used fumigant methyl bromide is expected to be banned in the United States and in many other countries on or before January 1, 2000. Unless a major effort is undertaken now to get alternative treatments such as irradiation in place, Mexican agriculture could be severely affected.

7. Unless something is done to expedite the process, United States clearance for the use of irradiation as a quarantine treatment of mangoes is at least 2 years away. The clearance for other fruits and vegetables of interest to Mexico is even further off because research and/or demonstration tests must first be performed and analyzed before any petitions can be submitted.

8. Any facility that relies heavily on irradiating Mexican produce as a quarantine treatment for the United States will not be profitable until after the specific quarantine treatment is approved and until the demand for the irradiated produce in the United States is sufficient to support commercial volumes.

9. If or when food irradiation is cleared as a quarantine treatment by the U.S. and by other countries, export volumes of produce would support many commercial-scale irradiation plants in Mexico.

10. Mexico has a nucleus of nuclear physics, personnel who presently provide a variety of

courses in nuclear safety, radiation physics, dosimetry, etc. With appropriate funding and with cooperation between ININ and the National University of Mexico, a programme or course could easily be assembled to train operators and regulatory personnel on a schedule that would meet the needs of a steadily expanding food irradiation industry.

The mission is making fourteen recommendations to the Mexican government and FAO/IAEA to speed up implementation of the irradiation process for the treatment of Mexican food products.

INTRODUCING COMMERCIAL SCALE FOOD IRRADIATION IN MOROCCO

EXECUTIVE SUMMARY

An expert mission composed of Yves HENON (Managing Director of GAMMASTER PROVENCE Company - Marseille) and Bill HARGRAVES (Senior Consultant at VINDICATOR Company - Plant City - Florida) visited Morocco between 18 April and 4 May 1993 to evaluate the economic feasibility of introducing a commercial scale food irradiation facility in the country. The preparation by the counterpart for the mission was insufficient for the experts to work at their full potential. However, a significant number of public organisations and private companies could be met. From the information collected and data provided to the mission the following conclusions were drawn :

a. At present there appears to be no economic justification to introduce a commercial scale irradiation facility for food and non-food products in Morocco because:

- Major importing countries of citrus, the largest export commodity, have not yet approved irradiation as a quarantine treatment of this fruit. The same applies to fishery products, the second largest export commodities.

- Potential markets for irradiated products to be exported from Morocco have not yet been clearly identified.

- Infrastructures for storage and distribution of food for domestic consumption, an essential prerequisite for commercial scale irradiation of food, are not well developed.

- Domestic consumers are not yet aware of the benefits of irradiated foods.

b. The potential for a commercial scale irradiation facility in the mid term (3 to 5 years) is more promising provided the above conditions are met. There appears to be an interest in the use of irradiation for hospital diets and military feeding which could lead the way to commercial application of this technology.

c. Horticulture is export oriented and well organized. It is of critical importance for Morocco, but there is a need to be less dependent on the EC markets. In such a case irradiation could be used:

- to extend shell life of highly perishable products (eg. strawberries, tomatoes, mushrooms) so that they can reach further markets;

- As an alternative quarantine treatment to low temperature (below 2°C) to be exported to the USA and Japan. Irradiation would allow routine refrigeration (eg. 5-8°C) during transit which will be less detrimental to the fragile commodities such as clementines.

d. The use of irradiation to extend the shelf-life of fresh fish fillets should also be considered. Fishery products are an important part of exports from Morocco. They go mostly to Japan, but the added value is low since the products are mostly canned, frozen or salted.

e. The potential applications should be studied in the planned research facility but we consider that it is essential to involve from the beginning :

- the private sector,

- the research institutes that already have competence in this field, especially the Institut Agronomique et Veterinaire Hassan II in Rabat.

f. USDA procedures require up to three years to evaluate data on irradiation as a quarantine treatment for citrus. This approval will be the single most important factor for the feasibility of the irradiation facility.

g. The harbour of Agadir appears to be an optimum location for the first commercial irradiation facility for a wide number of domestic and export products, especially citrus and fish. Citrus alone could make up a baseload 8 months of the year and fish 10 months of the year. The harbour enjoys a very favorable environment in terms of equipment and expertise. The choice of Agadir would also be in accordance with the policy of the government to create activities outside the crowded Casablanca area.

POTENTIAL TC PROJECT ON INDUSTRIAL SCALE FOOD IRRADIATION DEMONSTRATION PLANT FOR CHINA

Year	Experts		Equipment	Fellowships		Training	Subcontract		Grand Total $
	m/m	CC $	CC $	m/m	CC $	CC $	CC $	NCC $	
1993	-	-	-		15 000	-	-	-	15 000
1994	1	10 000	150 000		15 000	-	-	-	175 000
1995	1	11 000	85 000		-	-	-	-	96 000

Objectives

To irradiate, for disinfestation purposes, 9 000 tonnes of rice per year to respond to market demand of Beijing City and use this experience to demonstrate the advantages of this technology and in order to expand its use in China.

Background

The Institute for Application of Atomic Energy of the Chinese Academy of Agricultural Sciences coordinates research programmes on application of nuclear sciences in agriculture in 21 provincial agriculture organizations. It has been a leading research centre for food irradiation in China, has a 4 000 Ci Cobalt-60 irradiator, laboratories and experienced staff. With the rising of living standard there are increased requirements for high quality food which in turn provides a good opportunity for commercialization of food irradiation technology. Progress in this direction has been hampered by the small number and size of such irradiators in China. After a public acceptance survey, identification of a sure market (Beijing) and contract with local producers of rice the Institute prepared a plan for a project for a commercial scale rice irradiation disinfestation. This project consists of construction of a 300 000 Ci food irradiator near the Institute for treating approximately 9 000 tonnes of rice per year. The project is financially supported by the local Government, CNNC and the Academy of Agricultural Sciences. The design of the irradiator has been finalized by the Beijing Institute for Nuclear Engineering - BINE. It corresponds to an upgraded version of BINE-WTJZ irradiator with loading capacity of 500 kg and PC based controlled operation. Rice will be supplied by the Beijing's Jinlian Cereal Products Company which will be responsible for the distribution of the irradiated product.

National Input

For this project the Government and Institute will construct the irradiator which is estimated to cost 6 Mi yuans (about US$ 1.2 Mi), will provide the personnel for operation and will be responsible for the operational costs, including distribution of the product. Active participation of the Jinlian Cereal Products Company and funds for the construction as above have been secured. Construction will start in May 1993 and should be completed in 14 months.

Agency Input

Requested Agency assistance consists of training (dosage monitoring and quality control; analysis of irradiated food; management and marketing of irradiated food), expert services (hygienic standards and microbiology; international trade of such products) and equipment (100 000 Ci Cobalt source and quality control equipment);

End User and Long-Term Impact

The irradiated rice will go directly to the end users, in this case the population of Beijing. Estimated loss in quality due to infestation is about 15-20%. Few months extension of shelf-life resulting in sale of large volumes of high quality rice will make the project viable. A preliminary feasibility study indicated very positive results in this direction. The participation of the Jinlian Cereal Product Company, to keep transportation-storage-irradiation-marketing smooth, is an assurance of sustainable development.

INFORMATION OF FOOD IRRADIATION

The following information on food irradiation is available from the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, from the VIC Library, the AGRIS or INIS database systems, from other IAEA Divisions, FAO or WHO. The information is in the form of references to published papers, publications (eg. manuals, reports, proceedings, codes, guidelines, expert evaluations, etc.), data bases (some computerized) and information on file with the Food Preservation Section of the Joint FAO/IAEA Division.

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1. Effectiveness of Food Irradiation Technology

1.1 Individual published research papers on specific applications of food irradiation processing, available from the VIC library (Reference Desk) and the AGRIS and INIS data systems (IAEA Division of Scientific and Technical Information).

1.2 Radiation Control of Salmonella in Food and Feed Products
Technical Report Series No. 22, IAEA, Vienna (1963) STI/DOC/10/22.

1.3 Food Irradiation, Proceedings of a Symposium, IAEA, Vienna (1966) STI/PUB/127.

1.4 Microbiological Problems in Food Preservation by Irradiation, Panel Proceedings Series, IAEA, Vienna (1967) STI/PUB/168.

1.5 Preservation of Fruit and Vegetables by Radiation, Panel Proceedings Series, IAEA, Vienna (1968) STI/PUB/149.

1.6 Elimination of Harmful Organisms from Food and Feed by Irradiation, Panel Proceedings Series, IAEA, Vienna (1968) STI/PUB/200.

1.7 Enzymological Aspects of Food Irradiation, Panel Proceedings Series, IAEA (1968) STI/PUB/216.

1.8 Nuclear Techniques for Increased Food Production, Basic Study No. 22, FAO, Rome (1969).

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1.10 Radurization of Scampi, Shrimp and Cod, Technical Reports Series, No.124, IAEA Vienna (1971) STI/DOC/10/124.

1.11 Disinfestation of Fruit by Irradiation, Panel Proceedings Series, IAEA (1971) STI/PUB/299.

1.12 Radiation Preservation of Food, Proceedings of a Symposium, IAEA, Vienna (1973) STI/PUB/317.

1.13 Improvement of Food Quality by Irradiation, Panel Proceedings Series, IAEA (1974) STI/PUB/370.

1.14 Food Preservation by Irradiation, Vol I, Proceedings of a Symposium, IAEA, Vienna (1978) STI/PUB/470.

1.15 Food Preservation by Irradiation, Vol II, Proceedings of a Symposium, IAEA (1978) STI/PUB/470.

1.16 Combination Process in Food Irradiation, Proceedings of a Symposium, IAEA (1981) STI/PUB/568.

1.17 Use of Irradiation as a Quarantine Treatment of Agricultural Commodities, Final Report of a FAO/IAEA Consultants Group, Honolulu, Hawaii, Nov. 1983.

1.18 Food Irradiation Processing, Proceedings of a Symposium, IAEA (1985) STI/PUB/695.

1.19 Task Force Meeting on the Use of Irradiation to Ensure Hygienic Quality of Food, Report of a Task Force Vienna (1986), WHO/EHE/FOS/87.2, WHO 1987.

1.20 Radiation Preservation of Fish and Fishery Products, Technical Report Series, IAEA (1989) STI/DOC/10/303.

1.21 Irradiation as a Quarantine Treatment of fresh Fruits and Vegetables - Report of a Task Force, ICGFI Document No 13. (1991)

1.22 Use of Irradiation as a Quarantine Treatment of Food and Agricultural Commodities, Panel Proceedings Series, IAEA, Vienna (1992) STI/PUB/873.

1.23 Decontamination of Animal Feeds by Irradiation, Proceeding of an Advisory Group Meeting, IAEA, Vienna (1970) STI/PUB/508.

2. Safety of Irradiated Food

2.1 Wholesomeness of Irradiated Food, WHO Technical Report Series 604, WHO Geneva (1977).

2.2 Wholesomeness of Irradiated Food, WHO Technical Reports Series 659,WHO Geneva (1981).

2.3 Wholesomeness of the Process of Food Irradiation, Technical Document No 256, IAEA, Vienna (1981) IAEA-TECDOC-256.

2.4 Report of WHO Consultation to Review the Safety and Nutritional Adequacy of Irradiated Food, Geneva, 1992 (provisional edition: WHO/HPP/FOS.92.2) (Final version in print by WHO in Geneva).

2.5 Bibliography of Irradiated Foods, published annually by the Federal Institute for Nutrition, Karlsruhe, Germany.

2.6 International Food Irradiation Project (IFIP), Computerized Data Base, Federal Institute for Nutrition, Karlsruhe, Germany, 1992.

2.7 Computerized Database on Food Irradiation, US National Agricultural Library (data base being set up).

3. **Regional Co-operation on Food Irradiation Technology**

3.1 Application of Food Irradiation in Developing Countries, Technical Report Series No. 54, IAEA, Vienna (1966) STI/DOC/10/54.

3.2 Aspects of the Introduction of Food Irradiation in Developing Countries, Panel Proceedings Series, IAEA, Vienna (1973) STI/PUB/362.

3.3 Food Irradiation for Developing Countries in Asia and the Pacific, Report of a FAO/IAEA Seminar, Tokyo (1981), IAEA-TECDOC-271, Vienna (1982).

3.4 La Irradiacion de Alimentos en Latinoamerica, Actas de Seminario, Lima 1983, IAEA-TECDOC-331, Vienna (1985).

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3.6 Asian Regional Co-operative Project on Food Irradiation: Research and Development, Report of a Co-ordinated Research Programme, IAEA-TECDOC-545, Vienna (1990)

3.7 Food Irradiation for Developing Countries in Africa. Proceedings of a FAO/IAEA International Seminar, Dakar, 1988, IAEA-TECDOC-576, Vienna (1990).

3.8 Latin American Regional Co-operative Programme on Food Irradiation - Report of a FAO/IAEA Co-ordinated Research Programme, IAEA-TECDOC-651, Vienna (1992).

4. **Commercialization of Food Irradiation Processing**

4.1 Factors Influencing the Economical Application of Food Irradiation, Panel Proceedings Series, IAEA, Vienna (1973) STI/PUB/331.

4.2 Requirements for the Irradiation of Food on a Commercial Scale, Panel Proceedings Series, IAEA, Vienna (1975) STI/PUB/394.

4.3 Marketing and Consumer Acceptance of Irradiated Foods, Report of a FAO/IAEA Meeting of Consultants, Vienna (1982), IAEA-TECDOC-290.

4.4 Trade Promotion of Irradiated Food. Report of an ICGFI Task Force Meeting, Vienna (1985), IAEA-TECDOC-391.

5. **Legislative and Legal Aspects**

5.1 The Technical Basis for Legislation on Irradiated Food, FAO Atomic Energy Series No.6, FAO, Rome (1965).

5.2 Report of a Consultation Group on the Legal Aspects of Food Irradiation, IAEA,Vienna (1973) STI/DOC/59 (1973).

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5.7 Harmonization of Regulations on Food Irradiation in the Americas, Proceedings of an Inter-American Meeting, Orlando, USA (1989), IAEA-TECDOC-642.

5.8 Guidelines for Preparing Regulations for the Control of Food Irradiation Facilities, ICGFI Document No.1. Vienna (1991)

5.9 Codex General Standard for Irradiated Foods and Recommended International Code of Practice for the Operation and Control of Facilities used for the Treatment of Food, CAC/VOL. XV-Ed. 1, FAO, Rome (1984).

5.10 Codex General Standard for the Labelling of Prepackaged Food (CODEX STAN 106-1985 as amended in 1991).

6. **Control of Facility and Good Irradiation Practice**

6.1 Microbiological Specifications and Testing Methods for Irradiate Food, IAEA, Vienna (1970) STI/DOC/10/104.

6.2 Training Manual on Food Irradiation Technology and Techniques, IAEA, Vienna (1970) STI/DOC/114.

6.3 Training Manual on Food Irradiation Technology and Techniques, Ed.2, IAEA, Vienna (1982) STI/DOC/10/114/2.

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6.5 International Inventory of Authorized Food Irradiation Facilities, ICGFI Document No.2. Vienna (1993).

6.6 Code of Good Irradiation Practice for Insect Disinfestation of Cereal Grains, ICGFI Document No.3. Vienna (1993).

6.7 Code of Good Irradiation Practice for Prepackaged Meat and Poultry Products (to control pathogens and/or extend shelf-life), ICGFI Document No.4. Vienna (1991).

6.8 Code of Good Irradiation Practice for the Control of Pathogens and other Microflora in Spices, Herbs and other Vegetable Seasonings, ICGFI Document No.5. Vienna (1991).

6.9 Code of Good Irradiation Practice for Shelf-life Extention of Bananas, Mangoes and Papayas, ICGFI Document No. 6. Vienna (1991).

6.10 Code of Good Irradiation Practice for Insect Disinfestation of Fresh Fruits (as a quarantine treatment), ICGFI Document No 7, Vienna (1991).

6.11 Code of Good Irradiation Practice for Sprout Inhibition of Bulb and Tuber Crops, ICGFI Document No. 8. Vienna (1991).

6.12 Code of Good Irradiation Practice for Insect Disinfestation of Dried Fish and Salted and Dried Fish, ICGFI Document No. 9. Vienna (1991).

6.13 Code of Good Irradiation Practice for the Control of Microflora in Fish, Frog Legs and Shrimps, ICGFI Document No. 10. Vienna (1991).

6.14 Guidelines for the Authorization of Irradiation by Groups or Classes of Food (Annex 7, 9th ICGFI Report, 1992, in preparation).

6.15 Acceptance of Irradiated Food in Trade - a compilation of principles and international recommendations for regulatory control measures (in preparation).

6.16 Manual of Food Irradiation Dosimetry, IAEA Techn. Rep. Ser. No. 178, Vienna (1977).

6.17 Radiation Safety of Gamma and Electron Irradiation Facilities, IAEA Safety Series, STI/PUB/896, IAEA, Vienna (1992).

6.18 ASTM Standard E 1204, Practice for Application of Dosimetry in the Operation of Gamma Irradiation Facility for Food Processing, Annual Book of ASTM Standards, Vol. 12.02 (1992).

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6.20 Training Manual on Operation of Food Irradiation Facilities, ICGFI Document No. 14, Vienna (1992).

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7.2 Analytical Detection Methods for Irradiated Foods, IAEA, Vienna (1991), IAEA-TECDOC-587.

7.3 Report of the Second Research Co-ordination Meeting of the FAO/IAEA Co-ordinated Research Programme on the Analytical Detection of Methods for Irradiation Treatment of Food, Budapest, 1992.

7.4 Potential New Methods of Detection of Irradiated Food, Commission of the European Communities, BCR Information, Report EUR 13331 en, 1991.

7.5 Recent Advances on Detection of Irradiated Food, Commission of the European Communities, BCR Information, Report EUR 14315 en, 1992.

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8.1 Food Irradiation - A technique for Preserving and Improving the Safety of Food, WHO, Geneva (1988).

8.2 Safety Factors Influencing the Acceptance of Food Irradiation Technology, Report of an ICGFI Task Force, Cadarache, 1988, IAEA-TECDOC-490.

8.3 Acceptance, Control of and Trade in Irradiated Food, Proceedings of an FAO/IAEA/WHO/ITC-UNCTAD/GATT Conference, Geneva, 1988, IAEA, Vienna (1989) STI/PUB/788.

8.4 International Acceptance of Irradiated Food; Legal Aspects, Legal Series No.11, IAEA, Vienna (1979) STI/PUB/530.

8.5 Guidelines for Acceptance of Food Irradiation, Report of an ICGFI Task Force, Ottawa, 1986, IAEA-TECDOC-432, Vienna (1987).

8.6 Facts About Food Irradiation, ICGFI Fact Series Nos. 1 to 14.

8.7 Up-to-date Results of consumer acceptance trials carried out in various countries (available from the Joint FAO/IAEA Division, IAEA, Vienna).

9. Information for Authorization of Applications of Food Irradiation

9.1 Irradiation of Spices, Herbs and other Vegetable Seasonings - a compilation of technical data for its authorization and control, IAEA-TECDOC-639, Vienna (1992).

9.2 Irradiation of Poultry Meat and its Products - a compilation of technical data for its authorization and control, IAEA-TECDOC-699, Vienna (1993).

9.3 Irradiation of Strawberries - a compilation of technical data for its authorization and control, IAEA-TECDOC-...(in preparation).

9.4 Irradiation of Bulbs and Tubers - a compilation of technical data for its authorization and control, IAEA-TECDOC-...(in preparation).

10. **Techno-economic Feasibility Studies**

10.1 Reports on techno-economic Studies performed in various countries under Technical Co-operation Projects.

10.2 Handbook for Conducting Feasibility Studies, ICGFI, Vienna, 1986.

Countries with Irradiation Facilities Available for Food Processing (April 1993)

Underlined facilities are under construction or planned
Underlined countries are irradiating food for commercial use

Country	*Location (starting date for food irradiation)*	*Products*
Algeria	Mascara (1992)	Potatoes
Argentina	Buenos Aires (1986)	Spices, spinach, cocoa powder
Bangladesh	Chittagong (1993)	Potatoes, onions, dried fish, pulses, frozen seafoods, frog legs
Belgium	Fleurus (1981)	Spices, dehydrated vegetables, deep frozen foods
Brazil	Sào Paulo (1985) Sào Paulo (1992)	Spices, dehydrated vegetables
Canada	Laval (1989)	Spices
Chile	Santiago (1983)	Spices, dehydrated vegetables, onions, potatoes, poultry meat
China	Chengdu (1978)	Spices and vegetable seasonings, Chinese sausage, garlic.
	Shanghai (1986)	Apple, potatoes, onions, garlic, doehydrated vegetables
	Zhengzhou (1986)	Garlic, seasonings, sauces
	Nanjing (1987)	Tomatoes
	Jinan (1987) Lanzhou (1988) Beijing (1988) Tienjin (1988) Daqing (1988) Jianou (1991)	Not specified Not specified Not specified Not specified Not specified Not specified
Côte d'Ivoire	Abidjan	Yams, cocoa, beans
Cuba	Havana (1987)	Potatoes, onions, beans
Denmark	Riso (1986)	Spices
Finland	Ilomantsi (1986)	Spices

Country	Location (starting date for food irradiation)	Products
France	Lyon (1982) Paris (1986) Nice (1986) Vannes (1987) Marseille (1989) Pouzauges (1991) Osmanville Sablé-Sur-Sarthe (1992)	Spices Spices, vegetable seasonings Spices Poultry (frozen deboned chicken) Spices, vegetable seasonings, dried fruit, frozen frog legs, shrimp Not specified Not specified Camembert
Hungary	Budapest (1982)	Spices, onions, wine cork, enzyme
India	Bombay Nasik	Spices Onions
Indonesia	Pasr Jumat (1988) Cibitung (1992)	Spices
Iran	Tehran (1991)	Spices
Israel	Yavne (1986)	Spices, condiments, dry ingredients
Japan	Hokkaido (1973)	Potatoes
Korea, Rep.	Seoul (1986)	Garlic powder spices and condiments
Mexico	Mexico City (1988)	Spices and dry food ingredients
Netherlands	Ede (1981)	Spices, frozen products, poultry, dehydrated vegetables, rice, egg powder, packaging material
Norway	Kjeller (1982)	Spices
Philippines	Quezon City (1989)	Not specified
Poland	Warsaw (1984) Wlochy (1991) Poznan (1992) Przysucha Lodz (1984)	Not specified Not specified Not specified Not specified Not specified
South Africa	Pretoria (1968) Pretoria (1971) Pretoria (1980) Tzaneen (1981) Kempton Park (1981) Mulnerton (1986)	Potatoes, onions Fruits Spices, meat, fish, chicken, fruits, spices Onions, potatoes, processed products Fruits, spices, potatoes Fruits, spices
Thailand	Bangkok (1971) Patumthani (1989)	Onions Fermented pork sausages, enzymes, spices
Ukraine	Odessa (1983)	Not specified

Country	*Location (starting date for food irradiation)*	*Products*
United Kingdom	Swindon (1991)	Spices
USA	Rockaway, NJ (1984) Whippany, NJ (1984) Irvine, CA (1984) Gainsville, FL (1992) Ames, IA (1992) Mulberry, FL (1992)	Spices Spices Spices Not specified Not specified Fruits, vegetables
Viet Nam	Hanoi (1991)	Onions, potatoes, seafood, spices, rice
Yugoslavia	Belgrade (1986)	Spices
Croatia	Zagreb (1985)	Spices, rice, food ingredients