

Latin American regional co-operative programme on food irradiation

*Report of a Co-ordinated Research Programme
jointly organized by the
International Atomic Energy Agency
and the
Food and Agriculture Organization of the United Nations
1986–1990*



INTERNATIONAL ATOMIC ENERGY AGENCY

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FOREWORD

The importance of food irradiation to reduce post-harvest losses, improve hygienic quality of foods and promote trade in food by improving the marketability of fresh produce and other food products has been recognized by the Region of Latin America and the Caribbean. Several of the countries in the Region initiated national programmes on food irradiation and took steps to develop the infrastructures and manpower resources for research into the application of this technology.

With these aims in mind the "Latin American Regional Co-ordinated Research Programme on Food Irradiation" (LAFIP) was established in 1986 with the participation of research scientists from countries in the region to investigate the efficacy of food irradiation as a treatment to (a) reduce post-harvest losses and improve the hygienic quality of food, (b) conduct techno-economic feasibility studies and (c) disseminate knowledge about the scientific, health, legal and commercial aspects of food irradiation. The Co-ordinated Research Programme (CRP) completed its work at the end of 1990.

The present publication contains the final report of the Co-ordinated Research Programme and summaries of individual research reports presented by the participating scientists. The full research reports are published separately as Working Material presented under the Latin American Regional Co-operative Programme on Food Irradiation.

The Scientific Secretaries of this CRP were Drs C.J. Rigney and L.G. Ladomery, Food Preservation Section, Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Vienna.

EDITORIAL NOTE

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Part I

SUMMARY OF THE CO-ORDINATED RESEARCH PROGRAMME

Food is an integral part of international trade and is even more significant for developing countries whose economy is still mainly agricultural. These countries supply an overall 30% of world imports of agro-based products, and even more of tropical commodities and fresh horticultural products. Latin American countries are major suppliers of global food needs and are highly dependent on food exports for foreign exchange earnings.

According to the World Health Organization (WHO), the incidence of food-borne disease today is one of the most widespread health problems in developing and industrialized countries and an important cause of reduced economic productivity. Additionally, contamination of food with pathogens results in rejection of food commodities which represent important sources of foreign exchange earnings.

Post-harvest food losses are quite high considering the level of technological development achieved. According to estimates, between one quarter to one third of world food production is lost to pests or microbiological degradation. Often the losses are the highest in areas where food is needed most, especially developing countries situated in tropical zones. Latin American countries are experiencing difficulties in gaining access to North American markets for fresh tropical produce because of strict phytosanitary regulations. This problem is aggravated by the withdrawal of certain chemical agents used in quarantine control.

In the interest of socio-economic development, it is essential that all efforts be made to reduce food-borne disease and increase food availability. Every effort should be made to facilitate export trade by maintaining quality of food through shelf-life extension, treatment for pests covered by phytosanitary regulations, improved hygienic quality, and prevention of post-harvest losses.

Food irradiation offers an additional means to help achieve these objectives. It is a simple and effective way to process food; one whose potential has not been fully recognized.

Food irradiation requires continued research into its practical application to individual foods, trained personnel to control the process, specialized equipment, and a regulatory system to ensure that safe and good practices are followed. An exchange of information through specialized workshops and co-ordinated research programmes is important as well.

With these problems in mind, the "Latin American Regional Co-ordinated Research Programme on Food Irradiation" (LAFIP) was established in 1986 with the participation of 10 research scientists from 8 countries in Latin America (Argentina, Brazil, Chile, Colombia, Ecuador, Guatemala, Uruguay and Venezuela). The main objectives of the programme were:

- to investigate the efficacy of irradiation as a treatment for reducing post-harvest losses by inhibition of sprouting (eg. onions, garlic, potatoes), by disinfection of shelf-life extension (eg. fruits, cereal grains, legumes), by decontamination of pathogens (eg. red meats, poultry, animal feed), and disinfection (eg. spices, dry food ingredients);
- to conduct economic feasibility studies of radiation treatment of food items of interest, under prevailing conditions in the participating countries;

- to disseminate knowledge about the scientific, health, legal and commercial aspects of food irradiation with a view to promoting the acceptance of irradiated food, and to establishing a common legislative system on food irradiation enabling export between countries in the region.

The Co-ordinated Research Programme completed its work at the end of 1990, following its Final Research Co-ordination Meeting in San José, Costa Rica (26-30 March 1990).

This publication contains the final report of the Co-ordinated Research Programme and the final results of the investigations presented at the conclusion of the programme. The Final FAO/IAEA Research Co-ordination Meeting report is given in Part II of this publication, with conclusions and recommendations for further action. Individual summary reports are given in Part III. The full text of the scientific reports are published separately as working material, in the original language received.

The following is a brief summary of all work carried out under the Co-ordinated Research Programme, including work not included in detail in this publication:

Radiation doses required for shelf-life extension of various foods of importance in export trade and health protection

Several investigators under the programme studied and produced dose requirement data to prolong the shelf-life of such products as mangoes, avocados, strawberries, melons, potatoes, tree tomatoes and passion fruit juice. These experiments have confirmed the technical feasibility of using irradiation to extend shelf-life and to gain economic advantage in marketing these perishable commodities.

Decontamination of meat and vegetable products

Some food products, especially those of animal origin and spices, are contaminated with pathogens despite good manufacturing practices being followed. Doses required to reduce microbial contamination also has the effect of eliminating insect pests (where present) and extending shelf-life. Several studies were performed on commodities of export interest, demonstrating the efficacy of food irradiation for this purpose: chicken (breasts, and thighs), spices (incl. black pepper), condiments (garlic, basil, lemon grass, ginger, Roman chamomile, spearmint, marjoram, thyme).

Assurance of irradiation in disinfestation and quarantine treatment

One of the most important potential technical barriers to export trade is in the field of quarantine control. The Programme has carried out significant work in this field, demonstrating the efficacy of the process for mangoes, papayas, pineapple, asparagus, cherries, grapes, mushrooms, stored beans, cereals (incl. rice), cassava, tubers, spices and tea herbs, against various pests, including Anastrepha sp., Ceratitis capitata, flour moth, etc. This work, together with results of other investigations, enables governments to define the technical parameters required for compliance with quarantine regulations.

Consumer response

One major market trial using irradiated onions was performed. The results indicated acceptance of irradiated onions by the consumer. This result supports other market trials carried out in various countries.

Economic benefit studies

Several studies were performed analyzing the economic advantages of irradiating products such as onions, chicken (legs, breasts), and fresh fruits (eg. mangoes, pineapples).

The collaboration of the researchers and their co-workers in the Co-ordinated Research Programme and the generous hosting of the research co-ordination meetings by the interested authorities in Brazil and Costa Rica are gratefully acknowledged.

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Part II

REPORT OF THE FINAL RESEARCH CO-ORDINATION MEETING

1. INTRODUCTION

The Final Research Co-ordination Meeting of this programme was held in San José, from 26 to 30 March 1990, and hosted by the Atomic Energy Commission of Costa Rica. The meeting was attended by nine scientists from seven countries in the region.

The meeting was opened by Mr. Enrique Góngora Trejos, President of the Atomic Energy Commission of Costa Rica. He welcomed the participating scientists and stressed the need for better consumer education in order to remove the many misconceptions which prevented application of food irradiation technology.

The Scientific Secretary, Dr. Leslie G. Ladomery, IAEA, expressed his Organization's gratitude to the Atomic Energy Commission of Costa Rica for hosting the Third Research Co-ordination Meeting of LAFIP and, in particular, to Dra Ana I. Alvarado Silesky, Co-ordinator of the meeting, for her efforts in organizing the meeting.

The meeting requested Dr. Asher Ludin (Venezuela) and Dr. R. Muñoz (Ecuador) to act as rapporteurs. Dr. Tatiana Rubio (Chile), Dr. Norma Kaupert (Argentina) and Dr. M. Gloria (Brazil) were asked to chair the various sessions during the meeting.

2. GENERAL DISCUSSIONS

2.1. Irradiation as a quarantine treatment

Agricultural exports, including fresh tropical fruits and vegetables are important sources of foreign exchange for many developing countries. A number of important markets for these products are in countries with quarantine regulations. Most of these regulations do not take into account food irradiation treatment to control insect pests. They are generally based on the use of chemical and physical treatments such as freezing and heat treatment. The FAO Plant Quarantine Treatment Manual recommends to governments to accept radiation treatment schedules which prevent emergence of adult insects capable of reproduction or flight for insect eggs, larvae, pupae or adults generally and for Tephritidae (eggs or larvae), Dacus tryoni (eggs or larvae), and Sternoshaetus (cryptorhynchus).

The Inter-American Meeting on Harmonization of Regulations Related to Trade in Irradiated Foods held in Orlando, Florida, USA (1989) considered these questions and recommended to governments that they adopt standard regulations for quarantine treatment of fresh fruits and vegetables and that data should be developed (in addition to existing data) using a standard research protocol to be developed by "an ad hoc working group with USDA participation".

The present meeting was aware of a large number of pests requiring quarantine control in a number of fruits and vegetables exported from a number of countries. Detailed investigations of all these pest/food/country combinations would require considerable investment of resources. The meeting recognized that countries with quarantine regulations would require information on the efficacy of the process and other relevant information. Thus it is necessary to assure the relevance and acceptability of results of research and to reduce the amount of research work required to practically achievable levels. Such research must be carried out in a co-ordinated manner in order to prevent duplication of work and assure the quality of the data.

The meeting noted that significant amount of data were already available demonstrating the effectiveness of irradiation in a variety of foods and against a number of insect pests. There is, however, urgent need for a standard research protocol such as suggested by the Orlando Meeting, so that further research can be carried out in an harmonized and co-ordinated way. The results of research carried out according to a standard protocol would simplify the analysis of the data and would permit experiments to be conducted more easily at the commercial level. Furthermore, such data would more likely be accepted by those countries which have quarantine regulations. This, in turn, would facilitate the adoption of harmonized quarantine regulations and facilitate trade.

The meeting suggested that the research protocol should take into account a number of factors as indicated in the recommendations (see Section 5).

The meeting stressed the urgency of convening a special workshop to develop the research protocol and suggested that experts from countries in the region with significant export trade in fresh fruits and vegetables and with experience in quarantine treatment using radiation processing, as well as from the USA and other importing countries with quarantine regulations, should participate in such a workshop.

2.2. Irradiation to ensure hygienic quality of food

Extensive research data are available for ensuring the hygienic quality of irradiated food, suitable for the transfer of this technology to the industry. In order to do so, however, more research is needed at the pilot-scale or industrial level. On the other hand, further basic research is needed on radiation treatment of food (e.g. meat and its products) to prevent the transmission of parasitic food-borne diseases to humans and livestock, as well as a demonstration of the practical and economic feasibility of this type of application. It was recognized that this area of research may require close co-operation with specialist institutions. The meeting was informed of the recommendations of the Workshop on the Use of Irradiation to Ensure Hygienic Quality of Food held in Buenos Aires, Argentina (1989). It endorsed the views expressed by the Workshop and, in particular, the recommendation that countries in the Region should, with the support of Regional Organizations such as PAHO, establish a reliable register of food-borne disease outbreaks and their prevalence. The hygienic quality of food also relates to virus contamination which is a risk to human health. This problem is well known in the Region and was also considered by the Orlando Meeting as one of the points that should be taken into account.

2.3. Irradiation for shelf-life extension

Available numerous research data on the viability of this type of application of food irradiation should be transferred to the industry through tests at the pilot-scale or industrial level. Further basic research into new applications is still necessary, including combined treatments with synergistic effect such as hot-water dipping, refrigeration, appropriate packaging, etc.

2.4. Consumer acceptance

A series of well designed market tests should be carried out, which may reveal consumer acceptance of irradiated foods. Such tests should involve the actual sale of irradiated food under real market conditions in collaboration with existing commercial infrastructures. Through such market tests with

various treated products, consumers would be in a better position to appreciate the health and economic benefits of irradiation technology. Market tests also have an educational value in promoting public awareness of irradiated foods and leading to better understanding and acceptance of the process.

2.5. Economic feasibility and trial shipments

In order to promote the transfer of irradiation technology to the industry, economic feasibility studies should be carried out with the participation of the interested producers and food industry, especially where consumer acceptance has been demonstrated and where there is evidence of market access. Trial shipments (regional and extraregional) should also be carried out in order to study the effects of the irradiation process and transport on the keeping quality of the irradiated food. Trial shipments should also be carried out in co-operation with research institutes and the interested food industry.

2.6. Dosimetry

Dosimetry must be performed in such a way as to give clear data on dose distribution, dose rate and absorbed dose. This is especially important in research at the pilot-scale and commercial levels. Co-operation between researchers and nuclear institutions engaged in dose assurance is important.

3. FURTHER WORK IN THE REGION

Following consideration of work carried out under the Co-ordinated Research Programme (LAFIP) and the needs of the region for further research activities and assistance, the meeting concluded that the following topics and food commodities should be investigated:

Further studies on: (a) quarantine treatment, (b) improvement of the hygienic quality of food (pathogens, parasitism, exchange of information on viruses) and (c) shelf-life extension.

Market trials and trial shipments at the commercial level performed intra-regionally (quarantine treatment, improving the hygienic quality of food and extension of shelf-life). Those countries that do not have irradiation facilities at present should also be included.

Studies on the application of combined treatments with irradiation, eg. hot water treatment.

Studies on intermediate-moisture products using irradiation to improve hygienic quality.

Studies on irradiation technology using electron accelerators and X ray machines.

The following food commodities are of special interest to the region: spices, dry and intermediate-moisture foods, poultry, fish, pork, beef, tuber crops (e.g. onions, garlic, potatoes, etc.), fresh fruits and vegetables, mushrooms.

4. CONCLUSIONS

Quarantine:

Most national quarantine regulations do not appear to take into account FAO recommendations based on prevention of emergence of adult insects capable of reproduction or flight. National regulations are not harmonized, causing difficulties for exporting countries.

Research so far carried out has shown the effectiveness of irradiation to satisfy quarantine requirements on the basis of the FAO recommendations.

It is essential to include radiation processing as a quarantine treatment in national regulations, on the basis of clear and agreed criteria on quarantine requirements, as recommended by FAO.

There is a need to simplify and optimize experimental design in order to assure insect pest control, while avoiding unnecessary duplication of research effort in the region.

A standard research protocol is needed to ensure a harmonized approach to research and the acceptability of the data.

Hygiene:

Despite the numerous data already available, more work is needed especially on fresh or raw commodities, for which consumer preference is increasing.

More research is needed on parasite control in food in relation to human and animal health, including consideration of practical feasibility.

Microbiological results have demonstrated benefits of irradiation technology from the economic and public health point of view.

These results are available for upgrading this technology to the industrial scale.

Results of research have demonstrated that irradiation treatment is useful in controlling some diseases caused by food-borne viruses.

Shelf-life extension:

Available research results are sufficient for transfer to industrial application, however pilot and industrial scale tests should still be carried out where necessary.

There are more potential irradiation applications to extend shelf-life of fresh produce and processed food, which could be investigated.

Available results show great potential for combined treatment with irradiation, and these could be further investigated and extended to other products.

Consumer acceptance:

There is a need for more extensive and properly designed market tests to determine consumer acceptance of irradiated food. There is also a need for programmes to improve consumer information about this technology.

There is little co-operation between research institutions and commercial organizations in determining consumer acceptance of irradiated food.

Economic feasibility studies and trial-shipments:

Economic feasibility studies would be improved by the participation of the interested food industry, especially where consumer acceptance has been demonstrated, and where there is evidence of market access.

Trial shipments have involved co-operation between research institutions and the interested industry.

Education:

There is a lack of irradiation technology programmes in the curricula of educational institutes related to food technology.

5. RECOMMENDATIONS

It is recommended that:

Governments adopt the recommendations included in the FAO manual (prevention of emergence of adult insects capable of reproduction or flight).

A special workshop be convened urgently to develop a standard research protocol for quarantine treatment¹.

The research protocol should take into account the following:

- (a) The large number of pest/fruit/country combinations and the need to develop a simplified approach to testing for quarantine control purposes;
- (b) Recognize the prevention of the emergence of adult insects capable of reproduction or flight as indicator of compliance with quarantine regulations;
- (c) Details of the basic methodology to assure acceptable data (e.g. number of items of fruit or vegetable and number of insects to be studied, statistical analysis, etc.);
- (d) Dosimetry to be used;
- (e) Actual quarantine regulations in force;
- (f) Conditions of the experiments taking into account commercial practices regarding the handling storage and shipment of the food (e.g. temperature, packaging, etc.); and
- (g) The use of a reasonable number of insects at all stages to establish the effectiveness of the process without lowering statistical reliability.

¹ "Irradiation as a Quarantine Treatment of Fresh Fruits and Vegetables", Rep. of Task Force, Jan. 1991, ICGFI Document No. 13 (1991).

Each country in the region should prepare a list of commodities and related pests (indicating their scientific and common names), of interest to its trade.

Countries in the region should establish a reliable register of food-borne disease outbreaks and their prevalence, with the support of regional health organizations.

Governments should encourage the use of food irradiation technology to improve public health.

National authorities should, in considering food-borne viruses as a health problem, promote research in food irradiation as a potentially useful technology.

Market tests and consumer acceptance studies should be performed in collaboration with public and private organizations.

Economic feasibility studies and trial shipments should be done in co-operation with national and international trade organizations and the interested public entities. Such studies should be co-ordinated within the region.

All efforts should be made to assure proper dosimetry and calibration against reference standards available in the region.

Irradiation technology should be included in the curricula related to food technology of educational institutions.

Countries of the region should introduce regulations permitting the sale of irradiated foods and promote intra-regional trade in such foods. In order to achieve this, the control of the facilities and the process should be strengthened. Such action would lead to development of the technology and export markets.

As many countries in the region as possible should be involved in work on food irradiation. Countries without irradiation facilities should also participate in market trials, training and similar activities.

Training courses in food irradiation technology should be regarded as essential and should include: dosimetry, control of gamma facilities and processes, and also the use of electron accelerators and X ray machines.

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Part III

INDIVIDUAL SUMMARY REPORTS

Title: RADICIDATION OF FRESH DEBONED CHICKEN MEAT

CSI (Country): N. Kaupert (Argentina)

Contract No: 4454/R1/CF

Starting Date: 1 August 1986

RESULTS:

This work was performed on chicken thighs and breasts in order to ensure hygienic quality and to improve shelf-life extension. All the analysed samples were packaged in plastic trays wrapped with a semipermeable plastic film. 400 trays containing chicken samples were analyzed during the whole experiment. The samples arrived at the Ezeiza Atomic Centre under refrigerated conditions. Immediately after arrival, the chicken meat was irradiated in the Co-60 multipurpose semi-industrial facility. The irradiation treatment was carried out at the temperature of melting ice. The applied dose was 2.5 kGy (average). The dose rate was 100 Gy/min. After irradiation the samples were stored at refrigeration temperature ($2^{\circ}\text{C} \pm 1^{\circ}\text{C}$). The D10 value of Salmonella typhimurium LT2 (in this food) was determined at 0.66 kGy.

Microbiological, chemical and sensory tests were performed periodically on control and irradiated samples, until they were organoleptically discarded.

After preliminary research, 2.5 kGy was defined as the most suitable dose treatment.

The initial T.A.B. load was in the order of 10^4 cfu/g. Immediately after treatment it was reduced by two orders of magnitude. After irradiation and during the storage period, pathogenic bacteria could not be detected. When sample T.A.B. loads exceeded 1×10^6 cfu/g, they were considered at the threshold purchase limit.

Water binding capacity as water content, rancidity as peroxide index, were analyzed. They showed that irradiation promotes less muscle water binding capacity and higher rancidity level, as compared with the untreated samples. Nevertheless, these data did not cause a deleterious effect on sensory quality of 2.5 kGy irradiated samples stored at ($2^{\circ}\text{C} \pm 1^{\circ}\text{C}$).

At the same time, samples irradiated with higher doses (up to 4.5 kGy) were also sensory-evaluated.

A dose of 2.5 kGy extends the shelf-life of the samples about 2 or 3 times longer than that of the unirradiated ones.

Considering the usual microbial load present in this foodstuff, and taking into account the experimental data, the industrial application should be done in a facility providing a minimal dose of 1.5 kGy, a medium dose of 2.5 kGy and a maximal dose of 3.3 kGy (5 log *Salmonella* cycles).

Assuming that the biggest chicken slaughter factory, located in Argentina, would apply this working methodology, a study of the irradiation cost incidence was performed for an annual irradiation requirement of 20×10^3 t. The facility throughput was 300 kGy m^3/days ; the source activity = 260×10^3 Ci of Co-60 and 0.41 the facility efficiency ratio. Estimated facility cost = US \$832 000; annual operation cost = US \$268 000; irradiation cost/kg = US \$0.013. The process percentage cost incidence kg^{-1} will be 0.6% more than the unirradiated food sale price. The refrigeration cost incidence for the extended shelf-life period was not included in this study.

CONCLUSIONS:

A dose of 2.5 kGy promotes shelf-life extension about two to three times longer than the unirradiated samples, with good hygienic and sanitary qualities.

OTHER COMPLEMENTARY ACTIVITIES:

During the last part of 1988 and the whole of 1989 the food irradiation activities of the CNEA staff were directed to various aspects involved in this technology.

(a) In this field, CNEA's efforts were aimed at satisfying the demands of local industry.

<u>Material</u>	<u>Treat Objective</u>	<u>Packaging Material</u>	<u>Dose (kGy) Treatment</u>	<u>Dose Rate Gy/min</u>
Egg (powder)	Radicidation	Polyethylene + Kraft paper	2	9.1
Dry seasonings (onion-garlic powder)	Radicidation	Polyethylene	30	1.5
Spices	Radicidation	Polyethylene	30	1.5
Bovine blood serum (powder)	Radicidation and Radurization	Polyethylene Kraft + paper	5	10.55
Mushrooms	Radurization	Plastic trays cover with PVC film	3	71.22
White aspragus (raw state)	Radurization	Plastic trays covered with PVC film	2	71.78

(b) Other activities were related to the legal aspects of food irradiation. On April 1989, Annex 1 and Appendix A were included in the National Food Code (Code of Practice and Dosimetry chapter respectively).

Title: STUDIES ON PRE-COMMERCIAL SCALE IRRADIATION OF ONIONS AND GARLIC TO CONTROL SPROUTING

CSI (Country): O.A. Curzio (Argentina)

Contract No.: 4453/R2/RB

Starting Date: 1 August 1986

RESULTS:

This final report shows the results obtained in studies conducted with onions and garlic bulbs produced in the region of the South National University (Argentina), and includes:

1. Consumer acceptance of irradiated onion was assessed in a marketing trial. The responses were evaluated through four marketing trials during 1985, 1986 and 1988 in Bahía Blanca and Buenos Aires, which became the first experiences of this sort in the country. The results of these trials showed that irradiated onions are widely accepted by the consumers.

After consuming the irradiated bulbs the consumers rated them very highly. With regard to intent to purchase irradiated foodstuffs, most of them (60%) were undecided and said they needed more information about irradiated foodstuffs in general and about the benefits for each foodstuff in particular and their physical characteristics after treatment.

This shows that there is an internal market in Argentina in favour of the introduction this technology and it is clear that the consumer public should be educated by means of campaigns using the mass media.

2. The benefits of irradiation of onion and garlic bulbs in terms of both the regional gross economic benefit and the farmer's benefit was evaluated as a first step. The work showed that economic benefits are significant at both levels as a second step, the benefits of introducing this technology in the region in terms of the economic impact on the net income of the onions sector, was estimated. The optimum volume of onions to be irradiated is 56% of the total production. The treatment of this volume generates an increase of 22.5% in net income of the regional onions sector, which is an important economic benefit for this sector from the point of view of internal market.

3. The performance of irradiated Argentinian onions and garlic bulbs after shipping by boat under practical conditions is of great interest in view of the probable opening of international markets for irradiated foodstuffs and Argentina's capacity to export these products.

With this in mind, lots consisting of irradiated onions and garlic bulbs were shipped to the Netherlands. The control of the commercial quality of the samples were made at the IFFIT. The irradiation treatment improves the keeping quality of the bulbs and reduces the loss of weight. The irradiated garlic and onion bulbs showed a significant improvement from a point of view of general appearance and the shelf-life was extended for several weeks when the irradiated bulbs were stored under commercial conditions.

4. The building of an irradiation facility at the UNS will make it possible to have a non-profit undertaking that will facilitate the growth of the techno-scientific capacity of the region and to lend irradiation services at demonstration and commercial levels. The execution of the project includes the design, building and operation of an experimental multipurpose irradiation facility with Co-60 source.

Bahía Blanca, is the most important city in the south of Argentina and its direct area of influence represents an important production of food commodities. The city is served by the major seaport in the country,

important from the point of view of exports, principally regarding the export of cereals in bulk. An important railway and road system leads into the city, making the port system a natural exit for the regional products.

In order to reach the objectives of the experimental multipurpose irradiation facility, it was necessary to collect primary information. Our strategy was to evaluate the attitude of consumers regarding the purchase of irradiated products via market tests and asked the opinion of industrialists and producers in the region, as regards the adoption of this technology.

On the basis of the information obtained in this survey, it can be assumed that most of the food of economic interest produced in the region, is suitable for developing the proper technology for irradiation processing and the assessment of the economic benefit.

Title: GAMMA IRRADIATION FOR DISINFESTATION OF MEDITERRANEAN
FRUIT FLY IN BRAZILIAN TROPICAL FRUITS

CSI (Country): M. Gloria (Brazil)
Contract No.: 4455/R1/RB
Starting Date: 1 August 1986

RESULTS:

A project has been carried out to study the potential of gamma irradiation as a quarantine treatment for fruit flies infesting tropical fruits in Brazil. Initially, we investigated the effectiveness of gamma irradiation for disinfecting Brazilian Tropical Fruits that contain eggs and last instar larvae of the Mediterranean fruit fly. A number of mango varieties and one of papaya were studied.

Fruits were infested in laboratory cages containing approximately 1000 mature fruit flies. The fruits were exposed to the ovipositing flies for 48-72 hours, after which they were placed individually in plastic boxes covered with cotton screening. The infested fruits at different instars of larval development were irradiated in a Co-60 source of 600 000 Ci. Fricke dosimeters were used in each lot of boxes.

The preliminary results with eggs and larvae of the first instar showed that no adult emerged at a dose of 150 Gy or higher. Larvae of the Mediterranean fruit fly, C. capitata of the first instar were more sensitive to radiation than last instar larvae.

Data were obtained through irradiation of Ceratitidis eggs and 3rd instar larvae placed on moistened blotting paper inside petri dishes. Irradiation effects on their development were also analysed.

Title: IRRADIATION OF AGRICULTURAL PRODUCTS TO REDUCE
POST-HARVEST LOSSES IN BRAZIL

CSI (Country): R. Domarco (Brazil)

Contract No: 4455/R1/RB

Starting Date: 1 August 1986

RESULTS:

This research included the shelf-life extension of mangoes with combined treatments and the preservation of concentrated orange juice.

1. Shelf-life extension of mangoes with combined treatments:

The variety Haden, the main exportation variety of Brazil, was used. After previous selection, the samples were separated into three lots which received three different treatments: (i) hot water dip at 55°C for 5 minutes followed by cooling in running tap water and irradiation; (ii) hot water plus fungicide dip (Benlate 0.2%) at 55°C for 5 minutes followed by cooling in running tap water and irradiation; (iii) irradiation. The applied doses were: 0.7, 0.8, 0.9 and 1.0 kGy. The dose rate was in the order of 1.1 kGy/h. After the irradiation the mangoes were stored at 11°C for 39 days plus 7 days more at 22°C. Chemical (pH, total acidity, total soluble solids, ratio), physical and sensorial properties were studied. The results indicated that, at 39 days of storage period, the mangoes were considered to have optimal maturity for trade, with better results on mangoes subjected to thermal treatment and irradiation with doses between 0.7 and 1.0 kGy.

2. Preservation of concentrated orange juice by gamma radiation:

The aim of this work was to evaluate the preservation of concentrated orange juice, through the synergistic action of heat and irradiation under different temperatures and periods of storage. All the analyzed samples were canned in 200 ml recipients. One lot of 200 samples was heated at 50°C for 30 minutes and irradiated and another lot of 200 samples were irradiated at room temperature (25°C). The applied doses were 2.5, 5.0 and 7.5 kGy, at a dose rate of 5.37 kGy/h.

After the irradiation the samples were stored at 0°C, 5°C and room temperature (22-25°C). Chemical and sensory analyses were done after 1.30, 60, 90, and 180 days of storage. The irradiation doses caused small variation in the total soluble solids, acidity, pH and ascorbic acid. The degradation of ascorbic acid was influenced by temperature and length of storage. Colour changes were detected on the juice stored at room temperature. The characteristics of quality received a score of 5 on a 9 point scale.

3. Other research carried out in CENA:

- Disinfestation and decontamination studies of cereals and grains.
- Desinfestation of mangoes and papayas against fruit flies.
- Effect of different dose rates on the preservation of potatoes.

Title: EFFECT OF LOW DOSES (< 1 kGy) ON THE COMMERCIAL QUALITY OF FRESH FRUITS AND VEGETABLES FOR EXPORT

CSI (country): T. Rubio (Chile)

Contract No: 4456 R1/RB

Starting Date: 1 August 1986

RESULTS:

The research on the effect of low doses on the commercial quality of fruits was continued under the renewal of contract No. 4456/RB. The final objective of these studies is to analyze the feasibility of the use of ionizing radiation as a quarantine treatment for Chilean fruits to be exported. This time two products were studied: pears and raspberries (including a pilot scale study and a preliminary research with Frankliniella cestrum).

Pears (Pyrus communis): The summer Barlett variety was used. The pears were irradiated 72 hours post-harvest and, doses of 0.5 and 1.0 kGy were applied. The product was stored for 84 days at 0°C and 90% r.h.

The controls carried out were: pH, acidity, soluble solids, resistance to pressure, weight loss, spots, internal browning, colour, moulds (rotting), general appearance and sensorial evaluation.

The samples irradiated with 1.0 kGy obtained the best scores in the market quality parameters, such as: resistance to pressure, weight loss, spots, internal browning, rotting and general appearance. This dose would also produce a delay of ripening of the pears.

No significant differences in acceptability (sensorial evaluation) were observed between the different samples at the end of the storage period.

From the market quality point of view, a dose of 1.0 kGy could be used on pears of the summer Barlett variety, as a substitute for fumigants such as methyl bromide.

Raspberries (Rubus idaeus L.): Experimental and pilot scale studies. These studies were carried out with the Heritage variety. The harvest, handling and storage conditions were the same that the Chilean companies use for exporting.

The doses applied for the experimental scale studies were 1.0 kGy. The fruit was treated 48 hours post-harvest and evaluated during 15 days, at 0°C and 90% r.h.

The controls carried out were: pH, acidity, soluble solids, resistance to pressure, weight loss, humidity, exudation, desiccation, moulds, colour and sensorial evaluation.

The results of the experimental scale study demonstrated that a dose of 0.5 kGy does not affect the market quality of raspberries (15 days) and, the use of higher doses would depend of the extension of the commercial period.

In the pilot scale study a maximum dose of 1.0 kGy was used. The raspberries - 300 trays of 2.4 kg each - came from different production areas and exporting companies. The evaluation of the fruit was carried out by seven enterprises and research institutes, for a 6 day period (0°C, 80-90% r.h.).

The fruit used (control and irradiated) in the pilot scale study had a good market quality evaluation during the week of the experiment.

At the same time, preliminary studies with Frankliniella cestrum (adults) were began. The mortality, longevity and fertility of this insect was studied.

Entomological studies determined that 1.0 kGy caused 100% mortality of Frankliniella cestrum between 8-12 days post-irradiation. Because of the high perishability of this fruit, the use of ionizing radiation as a quarantine treatment must be based on the inability of the insects to produce viable offsprings and not on their mortality.

A reduction of the offspring with the low storage temperature was observed.

Title: DISINFESTATION BY IRRADIATION OF FRUITS FOR EXPORT.
A TECHNO-ECONOMIC FEASIBILITY STUDY

CSI (Country): S. Zuleta (Colombia)
Contract No: 4457/R1/RB
Starting Date: 1 August 1986

RESULTS:

The study on the disinfestation of Colombian export fruits by irradiation was carried out in the context of a big national plan directed to diversify agricultural production and exports. The final objective is to establish the most important technical parameters of the use of ionizing radiation as a quarantine treatment.

Studies with mango (Mangifera indica), pineapple (Ananas comosus), tree tomato (Cyphomandra betacea) and avocado (Persea gratissima) was performed in order to obtain data for disinfestation and on physicochemical and organoleptic aspects. The controls carried out were: acidity, soluble solids, pH, weight loss, internal and external evaluation of colour and general appearance.

The best dose for the mango, Tommy Atkins variety, was: 0.6-0.7 kGy for the following purposes: disinfestation (Anastrepha sp.), delay in ripening and to control Anthracose. Combined irradiation with thermal treatment (5 min in hot water at 55 °C) immediately after harvest, gives the best results; the mangoes can be stored for 48 days with good appearance and uniform maturity under refrigerated conditions (8-10 °C and 90% r.h.). Doses between 0.7 and 0.9 kGy are optimal to delay the ripening of pineapple; but additional studies are necessary to investigate the effects of temperature changes for the Anthracose contamination. Tree tomato showed good appearance 83 days after combined treatment (0.3-0.4 kGy and hot water dip, 4-5 min, 55 °C). Low doses of 30-50 Gy are enough to delay ripening of avocado, but the effects of storage temperature 8-10°C and the combined treatment need complementary studies.

Finally, a first approximation of an economic feasibility study for an irradiation plant in Colombia was performed. It shows that the source size will be 400 000 Ci of Co-60, and the total cost of the plant near to US \$2 000 000.

Title: A REVIEW OF THE FEASIBILITY OF IRRADIATION TECHNOLOGY TO INCREASE THE POTENTIAL OF FOOD EXPORTS IN LATIN AMERICAN COUNTRIES: A CASE STUDY IN ECUADOR

CSI (Country): R.A. Muñoz-Burgos (Ecuador)
Contract No: 4458/R1/RB
Starting Date: 1 August 1986

RESULTS:

The Joint FAO/IAEA Division has sponsored a Latin American Food Irradiation Programme (LAFIP), in which Ecuador has been participating for five years.

During this period the research project has covered the preservation of fresh fruits, mainly those which are common in the most Latin American countries and which have a good potential for the export as exotic fresh fruits.

Strawberries (Fragaria chiloensis), draped with cellophane film, irradiated with 2.5 kGy. of gamma rays, and stored at 5°C, extended their shelf-life up to 18 days.

"Babaco" fruits (Carica pentagona, Heilborn) heated at 45°C for 10 minutes, then draped in polyethylene film, and irradiated with 500 Gy, extended the shelf-life up to 24 days, when stored at 15°C and 70% relative humidity.

Avocados (Persea americana, Mill.), draped in saran films and irradiated with 75 Gy, were conserved in good condition at 15°C and 70% r.h. for 15 days.

Fresh juice of tree tomato (Ciphomandra betacea, Cav.) packed in nylon-polyethylene bags, treated at 60°C for 10 minutes, irradiated with 3 kGy, and with 300 ppm of sulphur dioxide added, were maintained in good condition during 120 days, when stored at 20°C, and 70% of r.h.

Fresh juice of passion fruit (Passiflora edulis), Packed, in plastic material heated at 60°C per 10 minutes and then irradiated with 4 kGy maintained unchanged the sensorial properties, when stored at 20°C and 70% relative humidity, during 90 days.

Rice attacked by Mediterranean flour moth (Anagasta kuehniella, Zeller) can be desinfested by 1 kGy of ionizing radiation, since this dose is sufficient to stop the development of all stages of the insect's metamorphosis.

The irradiated rice did not show any difference when compared to the unirradiated control.

Various foodstuffs, when treated with a combined process of gamma irradiation after saturation with ammonia vapours, 5% of lime solution and 5% of sodium hypochlorite, reduced contamination by Aspergillus flavus, and consequently, the concentration of aflatoxins was reduced drastically.

Spices and tea herbs, which are very important agricultural export products, were decontaminated by gamma irradiation to comply with international microbiological regulations. Thus, basil (Ocimum basilicum), lemon grass (Cymbopogon citratus), ginger (Zingiber officinale), Roman chamomile (Matricaria chamomilla), spearmint (Menta piperita), wild majoram (Origanum vulgare), garlic (Allium sativum), and thyme (Thymus vulgaris) were radurized with doses between 2.0 - 4.5 kGy. The applied doses did not affect either the aromatic properties, or the chemical composition.

Mushrooms of micorhizal symbiosis, an abundant and cheap protein food, when irradiated with 2 kGy reduced the microbiological contamination from 10^7 to 10^2 cfu/g.

Preliminary studies with fruit flies, Drosophila guayllabambae, and D. melanogaster, infesting "chirimoya" fruits (Annona cherimolia, Mill.) demonstrate that low doses of gamma irradiation stop the biological cycle at the larval stage, confirming the usefulness of this technology as a quarantine treatment.

Title: APPLICATION OF IRRADIATION TO EXTEND THE SHELF-LIFE OF SHRIMPS

CSI (Country): V.J. Martin (Uruguay)

Contract No: 4460/R2/RB

Starting Date: 1 August 1986

RESULTS:

The investigation on the effect that Co-60 gamma irradiation has on vacuum packed stored refrigerated shrimps (*Penaeus paulensis*) as a preservation method was undertaken. The trials carried out in this project were made in 1987 and 1989. In the 1987 experiment, freshly caught shrimps were immediately block-frozen and stored $-18^{\circ}\text{C} \pm 2$ up to the study; three groups of shrimp samples were prepared: 12 treated with 0.5 kGy, 12 irradiated with 1.5 kGy, and 12 left as control. In 1989 the experiment was done with shrimps caught in the industrial way. Experimental contamination with Enterobacteriaceae, Staphylococci and Salmonella sp. was done and an additional dose treatment of 3.0 kGy included.

The quality evaluation of shrimps was done: (1) by a testing panel using an organoleptic evaluation card; (2) by the chemical Conway microdiffusion method to determine total basic nitrogen (TBN) and trimethylamine (TMA); (3) by a microbiological evaluation by aerobic plate count incubated at 32°C by the APHMA Method. The Salmonella contamination was evaluated through a qualitative method (AOAC Method). The samples were irradiated at the Nuclear Research Centre (CIN) of the University of Uruguay in a gammacell 4000 unit, at a dose rate of 55 Gy/min. The sample bags were introduced into polyurethane boxes with dry ice for the irradiation treatment. The quality evaluation was performed the first day after irradiation, and repeated each seven days later in samples stored at 0°C . During sensory evaluation neither off-flavour nor odour was found, but after a week an ammonical smell was noticed in all samples. Irradiated shrimps became a little bit faded but they recovered colour after boiling. High sensory scores were obtained for irradiated shrimps after 14 days in 1987 and 7 days in 1989. The shrimps irradiated at 3.0 kGy always got lower scores than the control samples. Total bacterial count (ABC) diminished in irradiated shrimps and the reduction was proportional to the irradiation dose. For the samples contaminated with Salmonella sp. (1989), the qualitative test was positive in all case, from control to 3.0 kGy.

The chemical test showed that irradiation extended food quality but erratic figures for TBN and TMA were found and there was no correlation with the organoleptic test. In 1987 no differences in sensorial quality was found for 0.5 kGy and 1.5 kGy. In 1989 the dose of 1.5 kGy always got the high scores and the 3.0 kGy got lower scores than the control.

The irradiation doses used have a positive effect on extending shelf-life of refrigerated vacuum packed shrimps.

Title: UTILIZATION OF LOW DOSE IRRADIATION FOR SENESCENCE RETARDATION AND DISINFESTATION OF CROPS IMPORTANT TO THE DEVELOPMENT OF TROPICAL COUNTRIES

CSI (Country): A. Ludin (Venezuela)

Contract No.: 4867 R1 CF

Starting Date: 1 November 1987

RESULTS:

The following is a summary of the research carried out in the project financed by the US-Israel Co-operative Development Research Programme.

1. The effect of combined heat-radiation treatment on post-harvest storage of melons

Melons (cv Galia) dipped in water at 52°C for 5 minutes had the decay reduced to 15% as compared 75% in control. Irradiation with 0.5 kGy as an additional treatment further reduced the decay to 5%.

Irradiation at this level without the hot dip was also effective. However a hot dip at 60°C without irradiation resulted in damage to the peel of the melon.

2. Low dose irradiation for delaying ripening of avocados

The avocado was irradiated at 0.078-0.094 kGy, then waxed and stored for 2 weeks at 5°C and 14°C, and then at 22°C. The softening of the irradiated fruit was retarded by several days in comparison to the control. No significant difference in taste was detected by the evaluation panel.

3. Tolerance of tropical fruits and vegetables to low dose irradiation

The study of tropical fruits and vegetables tolerance to varying doses of irradiation, required to disinfest them, was initiated by analysing the lipids of yams (Manihot esculentum C.). A relationship was found between the changes in lipid composition and visible deterioration. These changes were related to certain structural and functional alterations in the membrane of the senescent organs, which permitted an interaction between the substrates and the enzymes that caused the changes in colour.

4. Effect of the combined treatments on post-harvest maturation of mangoes.

Studies were carried out in Israel and Venezuela, to evaluate the ability of gamma irradiation alone or in combination with heating, to extend their useful postharvest life. Mangoes of the Haden cultivar were subjected to treatments ranging from irradiation of 0.25 to 1 kGy with and without heat treatment ranging from 52 to 60°C for periods of 1 to 5 minutes. A combination of irradiation that did not exceed 0.50 kGy and hot water temperature that did not exceed 57°C for 1 minute, were found to be beneficial for prolonging the shelf-life of the mango.

5. Effect of ionizing radiation and synergistic treatments on the spoilage microorganisms of tropical fruits and vegetables

The studies involved: (1) Isolation and identification of spoilage microorganisms on mango (cv Haden), papaya (cv Solo), and melons (cv Galia and Honey Dew); (2) a study of the phytopathogenicity of moulds; (3) test for resistance to ionizing irradiation of some mould phytopathogens; (4) a study of the synergistic effect (irradiation and heat) on the development in vitro of an isolated Colletotrichum sp. phytopathogen.

Title: IRRADIATION OF MANGOES OF THE VARIETY 'TOMMY ATKINS' FOR SHELF--LIFE EXTENSION AND PEST CONTROL

CSI (Country): C. Villagrán (Guatemala)

Contract No.: 4459 R2 RB

Starting Date: 1 August 1986

RESULTS:

During the last years, the export of perishable agricultural produce has assumed great importance in Guatemala, especially to the USA and Europe, where potential markets are rather great and with attractive margins of profit. Very often this export is greatly limited because of the perishability of the products and also, because of lack of adequate and efficient methods of preservation for the necessary time needed for marketing.

Mango is a product with great export possibilities, which is restricted by quarantine regulations and the perishability of the product. It is for this reason that the project was set up for the variety Tommy Atkins intended for export of fruit harvested on a plantation in the Valle de la Fragua, Zacapa. The lots were irradiated at doses of 0.50, 0.75 and 1 kGy and compared with the chemically treated and untreated product, stored at ambient temperature (18-22°C) and refrigerated (8-12°C). After 5 days the parameters loss of weight, hardness and visual characteristics, such as appearance and external colour, were evaluated, as well as infestation by pests and microorganisms.

Analysis of the results obtained indicated that a dose of 0.75 kGy was the most effective one both during storage at ambient temperature and under refrigeration. At ambient storage conditions, the untreated and chemically treated lots behaved identically, i.e. they were preserved in optimum condition for 7 days, the lot treated at 0.75 kGy was preserved in optimum condition for 13 days, thus gaining 6 additional days in optimum condition.

Under refrigeration, the untreated lot was preserved for 15 days, the chemically treated lot for 22 days and the lot treated at 0.75 kGy for 29 days, gaining 14 additional days as compared with the untreated lot and 7 days as compared with the chemically treated lot.

This study suggests that a dose of 0.75 kGy, in combination with refrigeration at 8-12°C, will preserve the fruit in optimum condition for consumption and marketing for a period of 29 days, a period of time sufficient to achieve effective marketing for export.