# FOOD IRRADIATION AND ITS FUTURE PROSPECTS

By K.F.MacQueen

**Radiation for food preservation is a way of alleviating problems of food deficiencies in a large part of the world. A review of progress achieved and future prospects was made at the eleventh session of the General Conference in a scientific lecture by Kenneth F. MacQueen, Head of the Food Irradiation Section, Atomic Energy of Canada Ltd.**

A pioneer in the subject, Mr. MacQueen prepared the petition which led to official acceptance of irradiated potatoes for human consumption in Canada in 1960. He said:

## MAGNITUDE OF THE WORLD FOOD PROBLEM

Before discussing the progress and potential benefits of food irradiation, let us first consider the magnitude of the world food problem. The startling fact is that over 50 percent of the world's population suffers from either hunger, malnutrition or both.

The low level of protein in the diets of the developing countries contributes to an incidence of deficiency diseases which are rare in the developed countries. The view of the medical profession is that better food is the only cure for deficiency diseases.

Adding to the present problem of food deficiency which affects over half the world, is the rapid rate of population growth. With the present population at 3.4 billion, United Nations experts estimate that the world's population will be 6 to 7 billion by the year 2000 and about four-fifths of this projected increase will occur in the less developed countries where food shortages already exist.

A further aspect of the problem is the unbalanced distribution of agricultural production and income in the world. While the less developed areas of the world have 70 percent of the world's population, they contribute only 40 percent of the world's agricultural production and earn a meagre 20 percent of the world's income.

The increase in food requirements to the year 2000 are estimated by FAO for the undernourished areas of the world and are given in Table I. For the world as a whole, food supplies would have to triple by the turn of the

century. For each additional 100 million mouths in the Far East, FAO estimates it will require annually 16 million tons of cereals, 3 million tons of pulses, 7 million tons of fruit and vegetables, 3 million tons of meat, eggs and fish and 3 million tons of milk.

ESTIMATED FOOD REQUIREMENTS 2000 A.D.
(Indexes Based on Approximately 1958 = 100)

| Area | Index of Consumption Per Person | Population Index | Index of Total Food Requirements |
|---|---|---|---|
| Asia and Far East | 167 | 243 | **406** |
| Africa | 128 | 202 | **259** |
| Near East | 117 | 262 | **307** |
| Latin America* | 105 | 322 | **338** |

* Excluding River Plate countries

The majority of new food supplies must be generated within the food deficient areas since the quantity of food required to feed the additional population of the undernourished world by 1980 is about equal to the present production of North America and Western Europe combined.

## POSSIBLE SOLUTIONS

What are the possibilities for increasing food supplies in these undernourished regions of the world? It is generally agreed that a policy of supplying a large amount of food aid cannot solve the world food problem on a long term basis. The best approach is to assist these food deficient regions to overcome their problems.

Possible methods of increasing food supplies include the following:

1. **Extending Areas Under Cultivation**
   Prospects are very limited since most of the arable land is already in use, particularly in Asia. In the long term — after the year 2000 — the availability of low cost nuclear power does offer the possibility of irrigating arid lands.

2. Increasing the Crop Yields by the Application of Modern Agricultural Technology
Prospects are much brighter. Experience in Mexico for example, has shown that wheat yields can be doubled by new technology.

3. Increasing Protein Supply by Increasing the Production of Fisheries and Livestock and by the Development of Higher Protein Cereals or New Protein-Rich Foods
Fish presently contribute about 10% of man's total intake of animal protein. Since three-quarters of the earth's surface is covered with water, the potential of fish as a food source is providing relief for protein-short regions may be substantial.

Animals tend to be inefficient in converting feed to food. For example, in North America most of the plant material is fed to livestock to provide a human diet in which one-third of the calories is composed of meat, milk or eggs. This represents a consumption of 11,000 primary calories to achieve an average diet level of 3,150 calories.

A great deal of work has been done to develop protein-rich foods or mixtures and some of these products appear to be near commercial development.

More exotic processes include the production of protein from the action of micro-organisms on petroleum fractions and from algae farming. These processes have long term potential only.

4. Improved Preservation, Storage and Distribution of Food Actually Produced
This subject merits more attention than it has received in order to ensure that the food produced in a given area is adequately preserved thereby reducing spoilage to a minimum and permitting a wider distribution within the food deficient area.

## FOOD SPOILAGE

Let us consider the magnitude of the food spoilage problem referred to under method (4) in order to realize the merits of improved preservation, storage and distribution.

FAO estimates that one-fifth of the world food crop planted by mankind is destroyed by insects, micro-organisms and other pests.

FAO sponsored survey reports and local appraisals indicate food losses in various regions of the Far East, Africa and Latin America amount to 30 percent or more and in some cases reach 50 percent. These figures appear to be typical for post harvest losses of fruits and vegetables, cereal grains and dried fish in specific areas.

If this great spoilage of food could be reduced significantly — say by at least one-half or more, then millions of the hungry or malnourished could be fed. For example, 55 million Africans could be fed each year from the grain which is destroyed there by pests or micro-organisms. In terms of world production of cereal grain, if the losses could be reduced by one-half, the savings in protein would amount to 9 million tons — or enough to feed nearly 300 million people. Further if at least a third of the food losses in tropical areas could be eliminated, many countries would have enough to meet their additional food requirements for a decade.

If radiation processing could contribute to reducing food losses by even as much as 10 percent, this would represent an enormous increase in effective food supplies.

## USEFUL PRESERVATION EFFECTS OF RADIATION

Radiation, a revolutionary technique for food preservation, enjoys the great advantage of being a universal treatment, i.e. it can achieve a number of useful effects. These are:

1. **Inhibition of Sprouting** or **Growth of Root Crops** such as potatoes, onions, carrots, garlic and sugar beets.

2. **Delay of Ripening,** for example, in mushrooms, bananas, papayas, mangoes.

3. **Sterilization of Parasites** (to inhibit reproduction) for the control of trichinosis in pork or the control of tapeworm in beef.

4. **Control of Insect Infestations** to inhibit reproduction of or kill insects which infest grain and grain products, fruits and dried foods. Proper packaging must be used to prevent re-infestation.

5. **Destruction of Micro-Organisms**

   *Extension of Shelf Life* (Pasteurization)
   The shelf life of foods can be extended by the destruction (99% or more) of spoilage bacteria, yeasts, fungi or molds. Best results are obtained with refrigerated storage, for example, with strawberries, fish products, fresh poultry and meats.

   *Destruction of Food-Borne Pathogens*
   Pathogens such as *Salmonellae* which cause food poisoning can be eliminated from egg products, poultry, meat and animal feeds.

   *Sterilization*
   Using high doses, one can destroy all organisms to achieve commercial sterility and lorg term storage at ambient remperatures.

6. **Modification of Physical Properties**

Reduce rehydration time of dehydrated vegetables.

Other unique advantages of radiation processing of food are:

1. **Radiation is the only treatment** that can be applied to foods through any type of packaging materials including paper, plastic, wood and metal cans. Some of these materials cannot withstand any heat processing. The fact that radiation can be applied after packaging is a great advantage since recontamination or re-infestation of the product is avoided.

2. Foods can be treated without cooking the product. The temperature rise is only a few degrees even at high-dose sterilization. This ability to treat food products in their natural state is particularly beneficial since experience has shown that consumers in developing countries will most readily accept foods which remain essentially unchanged.

To achieve the optimum benefit of radiation as a preserving technique, proper packaging and storage are essential, particularly where the product is vulnerable to insect infestation or spoilage by micro-organisms. Other well established techniques such as drying may be combined with radiation to enhance preservation.

## POTENTIAL INTERNATIONAL APPLICATIONS OF FOOD IRRADIATION

Let us now consider some examples of how radiation might be applied to help alleviate some world food problems.

1. **Control of Insect Infestation —Irradiation of Dried Fish in Africa**
Reports from surveys in specific areas in Africa indicates tremendous losses (up to 50%) from insect infestation of dried fish, a vital protein food.

During an FAO study in Africa some preliminary experiments were conducted on the irradiation of sun-dried and smoke-dried fish. Lots of severely infested dried fish purchased in a local market were packaged in polyethylene and then irradiated over a range from low to medium doses. Two weeks later, observations indicated the irradiation treatment provided excellent control over the severe infestations and the products had good taste acceptability.

These findings are significant since the losses of dried fish in Africa would supply the animal protein needs (FAO target of 20 grams per person per day) of several million people each year.

2. Irradiation of Tropical Fruits and Vegetables

The objective of applying radiation to these products is to extend the shelf live by achieving one or more of the following:

(1) inhibition of sprouting or growth
(2) delay in ripening
(3) inhibition of fungal attack, or
(4) destruction of insects or inhibition of their reproduction.

Some encouraging results have been obtained with irradiation of selected fruits and vegetables grown in tropical regions.

*Papayas*

The College of Tropical Agriculture at the University of Hawaii has reported excellent results with the irradiation treatment of papayas.

This is an excellent example of the great potential benefits to be realized if a product, normally consumed locally, can be made available to the export trade after irradiation treatment. In fact, for developing nations, the possibility of exporting commercially attractive food products following irradiation treatment could earn valuable foreign exchange which could be applied to promote agricultural development. This important possibility should not be overlooked.

*Bananas*

Maxie in his extensive studies on fruit irradiation at the University of California has reported favourable results with bananas. When Gros Michel, the important commercial variety grown in Central America was irradiated to low doses prior to initiation of the ripening process, a significant delay of 16 to 20 days in ripening occurred. An added benefit was that when fruit did ripen, it remained in an eating ripe condition 2 or 3 days longer than normal. These finding are important because bananas that ripen during shipment are very susceptible to impact and vibration injury and the radiation treatment makes it possible to delay the ripening process until shipments are completed.

In India, Dharkar and Sreenivasan have taken a different approach with the irradiation of bananas in work conducted at the Atomic Energy Establishment, Trombay. Bananas which were semi-dried (40%) moisture, packaged in polyethylene and irradiated at medium doses kept well for at least 3 months.

*Other Tropical Fruits and Vegetables*

Other work in India has shown favourable results with mangoes, tomatoes, guavas, sapotas and potatoes.

Pakistan conducted a very comprehensive study of potato irradiation with very favourable results under storage at ambient temperature and humidity.


Dr. K.F. MacQueen speaking on food irradiation.

Work in the United States and Israel has indicated some promise for the irradiation of citrus fruits to reduce losses from harvest to consumer.

Other products showing particular promise for radiation processing include onions, mushrooms, strawberries, apricots, peaches and plums.

3. **Radiation Control of Salmonellae in Foods and Animal Feeds**
Salmonellosis, frequently responsible for food poisoning outbreaks in humans, is a major public health problem affecting countries in both the developed and developing parts of the world.

Radiation has been studied extensively as a method of controlling *Salmonellae* in food and animal feeds in Canada, Denmark, the Netherlands, United Kingdom and the United States. This important subject was discussed in a panel sponsored by the IAEA to report on the radiation control of harmful organisms transmitted by food and feed products with particular reference to *Salmonellae*.

The results of the studies on the use of radiation to control *Salmonellae* have been most encouraging. In general, it has been found that medium or pasteurizing doses of radiation will effectively destroy *Salmonellae* in fresh, frozen or dried foods and animal feeds. The organoleptic acceptability and the wholesomeness of these products appear satisfactory after these treatments. When fresh poultry meat is treated with radiation to

control *Salmonellae*, for example, there is the added advantage that the shelf life of the iced product is extended from the normal 6 to 8 days to 18 to 20 days.

In 1961, the total world production of fish meal was approaching 2 million metric tons. Salmonella contamination could easily take place at any point in the widespread international distribution chain. Any salmonella contamination must be avoided during distribution if possible, or eliminated, if detected, before incorporation into animal feeds.

4. *Radiation Preservation of Fresh Fish and Marine products*

World fisheries constitute an immense source of animal protein food since the growth in the world catch of fish (100,000 million pounds in 1964) and in the international trade of fish and fisheries products in the postwar period has exceed world population growth.

However, distribution of fresh fish is severely restricted by the rapid rate of spoilage which takes place even at refrigerated temperatures. Better methods of preservation are vital to improve the distribution of this high-protein food.

Studies conducted in Canada have shown that the iced shelf life of scallops, haddock, lobster and freshwater white-fish may be doubled by a medium low dose of gamma radiation.

The United States Atomic Energy Commission is conducting an extensive programme on fish irradiation and has reported promising results on a wide spectrum of marine product s including shrimp, crab, haddock and clams.

Work conducted in India has also shown encouraging results on local fishery products. Bombay duck (a fish of commercial importance) keeps only a few hours at ambient temperatures and 2 to 3 days when packed in ice. When irradiated to a pasteurizing dose the shelf life is extended to 3 weeks at ambient and 6 weeks at refrigerated temperatures. When Bombay duck is semi-dried (40% moisture) and irradiated the shelf life is prolonged even further to over 150 days at ambient temperature storage.

Promising results have also been found with shrimps in India as in the United States. Studies there have shown that if a low pasteurizing dose is combined with a mild heat treatment the storage life is extended from a few days to several months.

Studies conducted in the Union of Soviet Socialist Republics have shown very encouraging results with precooked vacuum packed fish products which are sterilized by radiation. The quality of the product, both immediately after irradiation and after a year of storage did not differ from the quality of unirradiated fish and was better than the quality of autoclaved

samples. These preserved products sterilized by gamma radiation could be kept for more than 2 1/2 years without refrigeration.

5. *Radiation as a Quarantine Control Measure to Inactivate Foot and Mouth Virus in Carcasses of Infected Animals*

FAO stated in 1962 that if the animal diseases which plague a vast majority of the world's livestock could be brought under control, there would be no difficulty in achieving future animal protein requirements at least to 1975. Total losses in areas with no animal health programmes appear to exceed 40 percent.

Foot and mouth disease is almost constantly present in the Continent of Europe and in the countries of South America and is indigenous in many parts of Africa and Asia. Since humans, under certain conditions, are also suceptible to this disease, consumption of meat from infected animals could present a health hazard.

This is the basis of the study undertaken by Massa in Italy. The objective is not eradication which is almost impossible to achieve in some parts of the world because of wild life and the widespread nature of the problem, but the radiation treatment of products from infected animals such as meat, bones, glands, hair, and hides in order to inactivate the foot and mouth disease virus. Massa reported encouraging results. He found that a sterilizing dose of radiation would successfully inactivate the foot and mouth virus in the tissues of experimentally infected animals.

The implications of this finding are important for developing countries. For example, there are large regions in Africa which could supply large quantities of meat for export to other countries. However, the import of their products is restricted because of the health situation of their animals. Further, radiation appears to be the only technique available at present which is capable of eliminating viral agents from the animal products and, at the same time, maintaining them in the original raw state.

The radiation technique has already been employed successfully in Australia to treat baled goat's hair to eliminate the anthrax organism.

The few examples of possible international applications discussed above indicate the great potential that radiation processing of foods offers to reduce unnecessary spoilage and to improve the distribution from areas of production to areas of great need. Many other examples could be listed demonstrating the potential of this technology. For example, the United States has conducted an extensive programme to develop high dose radiation sterilized meat items, vital sources of animal protein, and other food items which can be stored up to two years without refrigeration.

## WORLD FOOD IRRADIATION PROGRAMMES

From early investigations on food irradiation initiatived about 20 years ago, we have seen more and more countries initiate studies in this field as more and better designed irradiation facilities became available.

Perhaps the best recent indicator of progress is the Proceedings of a Symposium on Food Irradiation held at Karlsruhe, Germany, in 1966, jointly organized by the IAEA and FAO. This largely attended Symposium reported the results of various research programmes, the majority of which are underway in developed countries. It was encouraging to note that some research programmes had been initiated in developing countries where the greatest benefits likely will be realized from this new technique.

It is noted that 22 out of the 24 countries for which we possess details of their food irradiation programmes are conducting studies on fruits and vegetables. The most popular products receiving attention appear to be potatoes and onions with 15 countries reporting studies. Other programmes receiving major attention include studies on disinfestation, fish, grain and grain products, and meats. All 24 countries indicate some activity on the microbiology of irradiated foods.

## WHOLESOMENESS

There is overwhelming evidence available that irradiated foods are wholesome i.e. safe and nutritionally adequate for human consumption. The best evidence of this fact is the results of the comprehensive programme to evaluate wholesomeness conducted by the Surgeon General, United States Department of the Army. In this massive programme conducted in the period 1954-1965, 21 representative gamma irradiated foods were subjected to long term animal feeding tests through several generations or for 2 years. The conclusions of this study were that foods irradiated up to absorbed doses of 5.6 megarads with a cobalt-60 source of gamma radiation or with electrons with energies up to 10 million electron volts have been found to be wholesome.

At least 14 countries are conducting wholesomeness studies. Again, irradiated potatoes are receiving major attention with at least 5 countries reporting studies on the wholesomeness of this product.

At least 4 countries have received clearances from their health authorities permitting the sale for human consumption of specific irradiated food items.

It is hoped that developing countries, in particular, will be prepared to accept wholesomeness data produced elsewhere, when applicable to their specific products, and can therefore devote more effort to developing the technology of irradiation on foods under their local conditions.

IRRADIATED FOOD CLEARANCES BY COUNTRIES

| Country | Product | Dose |
|---|---|---|
| Canada | Potato | 15,000 rad (max) |
| | Onion | 15,000 rad (max) |
| Israel | Potato | 15,000 rad (max) |
| U.S.A. | Potato | 5,000 — 15,000 rad |
| | Wheat and Wheat Flour | 20,000 — 50,000 rad |
| | Bacon | 4.5 — 5.6 Mrad |
| | Food Contactants | 1 Mrad or 6 Mrad depending on type |
| U.S.S.R. | Potato | 7,000 — 10,000 rad |
| | * Dried Fruits and Vegetables | 100,000 rad (max) |
| | * Fresh Fruits and Vegetables | 300,000 rad (max) |
| | * Meat | 500,000 rad (max) |

* limited quantities

To summarize the status of the wholesomeness or irradiated foods, it is probably fair to state that the process of radiation treatment of foods has been more thoroughly tested for safety of consumption than has any other food preservation technique.

## CONCLUSIONS AND RECOMMENDATIONS

As with any new process, there are some problems still to be resolved: nevertheless, the real potential of food irradiation will not be realized unless more research and development programmes are initiated and more people are trained in the associated disciplines.

With about 50 countries conducting programmes on food irradiation, there is obviously a great deal of activity in this field. Therefore, the following recommendations are offered in order to improve the co-ordination of all the effort internationally and to accelerate the development of this new technology so that more countries, particularly the developing nations, may benefit as early as possible from this important peaceful use of the atom.

At this point it should be made clear that the following recommendations are mine and are not necessarily those of any government or agency.

1. The IAEA or some appropriate international agency should act as a clearing house for the distribution of scientific data related to the wholesomeness of irradiated foods. This would include the distribution of successful petitions with complete supporting data which are prepared by various countries to secure clearances for specific irradiated food items.

   For developing countries, in particular, it is hoped that they will be prepared to accept wholesomeness data produced elsewhere when applicable to their specific products and can therefore devote more effort to developing the food technology aspects of food irradiation required for their local conditions.

2. In my view, the IAEA should receive appropriate support to sponsor more training courses on food irradiation technology for students and scientists from developing countries.

3. Developing countries planning to initiate programmes on food irradiation or to expand existing one should be encouraged to work through the IAEA to secure the desired assistance

4. I further believe that the IAEA should be encouraged and supported to expand all its food irradiation activities.

Practical solutions to the problems of the food deficient countries are possible if man in a spirit of good will makes efficient use of the potential resources of nature and knowledge at his command. The next few decades will be critical in terms of increasing food supplies to serve the needs of increasing populations and of improving the diets of the million suffering from malnutrition. With increasing support for research and training, we can expect that the new technology of food irradiation could make a useful contribution to help alleviate these world food problems.