BENEFITS OF RADIATION PROCESSING TO FOOD INDUSTRIES IN DEVELOPING COUNTRIES

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ABSTRACT

Benefits of radiation processing to food industries in developing countries. Recent international developments which facilitate radiation processing of food as a physical method of food preservation are described. The benefits of the treatment to food industries in developing countries are explained, which include, among other things, overcoming quarantine barriers to fruits in international trade, eliminating certain pathogens in frozen food, reduction of chemical residues in food, low-energy requirement, etc. Case studies on the economics of existing and planned commercial food irradiators are provided. Examples of commercial food irradiators which could be economical for developing countries are given.

INTRODUCTION

Food irradiation has added a new dimension to food preservation techniques. It is a broad spectrum physical treatment of food with ionizing energy from gamma rays (e.g., $^{60}$Co or $^{137}$Cs), electron ($\leq 10$ MeV) and X-rays ($\leq 5$ MeV), having energy thresholds which are unable to induce radioactivity in the treated products. Its wide application ranges from sprout inhibition of root crops, insect disinfection of cereals, dried fish, meat and fresh fruits, shelf-life extension of fresh fruits and vegetables, improving sanitation of fresh, frozen food, and spices, etc.

Three decades of research and development work on technological aspects of food irradiation have clearly demonstrated the practicality and efficacy of this technology. Ample data on animal feeding studies and radiation chemistry of food have also demonstrated that food treated by radiation up to an overall average dose of 10 kGy is safe for human consumption. Irradiation provides a proper alternative, often unique, to the use of certain chemical additives and fumigants for food preservation, which may pose hazards to consumers or workers in processing plants. Another advantage of irradiation is its modest energy requirement in comparison with conventional techniques of food preservation. As of May 1983, 26 countries have approved collectively 45 irradiated food items for human consumption, either on provisional or unconditional basis. It is the purpose of this paper to review the state of the art of this technology with special reference to its benefits to the food industries in developing countries.

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RECENT INTERNATIONAL DEVELOPMENTS

In the past few years, there have been several important breakthroughs in food irradiation which have facilitated practical application of this technology. Among these, the following are considered significant:

1. The conclusion of the 1980 joint FAO/IAEA/WHO Expert Committee on the Wholesomeness of Irradiated Food (JECFI) which stated that irradiation of any food commodity up to an overall average dose of 10 kGy (1 Mrad) presents no toxicological hazard, hence toxicological testing of food so treated is no longer required (1). Moreover, the irradiation of foods up to an overall average dose of 10 kGy (which covers most applications of food irradiation) introduces no special nutritional or microbiological problems.

2. The Recommended International General Standard for Irradiated Food, together with its Recommended Code of Practice for the Operation of Radiation Facilities for Treatment of Food, adopted by the Codex Alimentarius Commission in December 1979 (2). The Standard and the Code of Practice are currently being revised to take account of the recommendations in the 1980 JECFI.

3. The proposed policy of the US Food and Drug Administration (FDA), which states that food irradiated at a dose of 1 kGy (100 krad) or less will be considered safe and wholesome for human consumption (3).

4. The list of irradiated foods approved for human consumption in different countries is growing every year. At present, 23 countries have approved 39 irradiated food items of groups of related foods for human consumption either on an unconditional or restricted basis, according to Table 1.

The above developments have activated commercial applications in several countries, mainly in Europe and the USA. A list of commercial irradiation facilities, either completed, under construction, or planned, which are or will be used for treatment of food, is shown in Table 1.

ADVANTAGES TO DEVELOPING COUNTRIES

Most developing countries are situated in tropical and sub-tropical zones where high ambient temperature and humidity make food conducive to spoilage. In some tropical countries, losses of nutritious foods such as dried fish, grain and pulses could be in the range of 30 - 50%. Most of these losses are avoidable through proper handling, storage and preservation treatment. Thus, every effort should be used to combat avoidable post-harvest losses of food in order to make more food available to mankind.

Radiation processing of food provides an effective means of reducing losses of a variety of food items. In addition, it can eliminate certain public health problems originating from food borne infection and intoxication as well as replacing questionable chemical treatments of foods. In particular, the following applications of radiation processing are considered to be particularly advantageous to food industries in developing countries.
Insect Disinfestation of Dried Fish. Dried fish provides a major source of protein to many developing regions of the world, especially in Asia and Africa, and at a price within reach of most consumers. For example, production of dried fishery products in Asia is approximately 1.7 million tons dried weight annually. Unfortunately, dried fishery products are normally infested by various kinds of insects. In some parts of Africa, insect infestation is responsible for most losses from production to marketing (4). Several kinds of insecticides have been used to combat losses due to insect infestation. Irradiation is an effective physical treatment for disinfesting insects in dried fish. A small dose of 0.3 kGy would be sufficient to destroy insects in the products (5). As with other treatments, proper packaging is essential to maintain the quality of irradiated products, as well as to prevent reinfestation after the treatment.

Expanding Trade

Overcoming quarantine barriers. Many developing countries export a number of fruits, vegetables, cocoa beans, and agricultural commodities, such as tobacco leaves, copra, etc., harbouring insects pests which are quarantined by many importing countries. In order to permit importation, several countries, especially those in the Western world, demand a treatment which would prevent the establishment of quarantined insects in their territories. The present practice of fumigating these food and agricultural products with ethylene dibromide (EDB) is being questioned by environmental agencies in several countries with regard to its safety. It is likely that EDB fumigation of food will be prohibited in the near future. The Environmental Protection Agency (EPA) of the USA has already proposed that EDB fumigation should be phased out by 1 July 1983 (6). Irradiation has been proven to be more effective than EDB fumigation for insect disinfestation (7). Unlike chemical fumigation, which is essentially a batch treatment, irradiation provides a continuous treatment which would save time and money without leaving any residue. Developing countries could export more varieties and quantities of food and agricultural products which are prohibited at present because of quarantine restrictions.

Eliminating pathogens in frozen food. Developing countries export large quantities of frozen seafood and froglegs, which may be contaminated with Salmonella. In most cases, the level of Salmonella contamination in frozen food is low. Irradiation can effectively eliminate this residual contamination of frozen food while the food is in a frozen state (8).

Improving Public Health Standards

Destruction of pathogens and parasites. Populations in developing countries suffer from various types of food borne infections and intoxication caused by bacteria, fungi, protozoa, helminths, etc. In many cases, traditional foods are consumed raw or semi-cooked, which provides direct access for pathogens and parasites to the body. Low dose irradiation of 1-5 kGy can eliminate many pathogens and parasites which are associated with food, such as Salmonella, V. parahaemolyticus, T. spiralis, T. solium, T. saginata, etc. (9, 10, 11, 12). The treatment would provide safety for consumption of many traditional foods in developing countries, even in the raw state.
Reduction of chemical residues in food. Many food products, which originated from developing countries, are fumigated against insects and microorganisms. These foods include grain, pulses, dried fruits, spices, etc. Fumigation leaves undesirable residues in food. The practice of treating condiments and spices with ethylene oxide gave rise to concern about health conditions. Irradiation offers an excellent alternative to chemical fumigation (13, 14, 15, 16).

Extension of Shelf Life of Food. Shelf life of foods which provide important nutrients to humans can be extended either by proper irradiation treatment alone or irradiation plus above-zero refrigerated storage. For example, a radiation dose of approximately 3-5 kGy would double or triple the shelf life of fresh poultry and meat products at normal storage temperatures (17). Similar extension of the shelf life of fresh seafood can be obtained at slightly lower doses, i.e., 1-2 kGy (10, 18, 19). Sprouting of root crops such as potatoes, onions, sweet potatoes, yam, etc., which are important sources of carbohydrate, can be inhibited for several months or over the season by a dose as low as 0.1 kGy (20, 21, 22, 23).

Low Energy Requirement. Developing countries could not and should not adopt technologies which consume large amounts of energy. Irradiation is much superior in terms of energy requirements when compared with heat or sub-zero refrigeration treatment (24). In some cases, irradiation can be combined with heat or above-zero refrigeration to achieve better food quality at an energy requirement less than that for heating or refrigeration alone (25).

INFRASTRUCTURE AND ECONOMICS OF FOOD IRRADIATION

A successful implementation of a new technology depends on a proper infrastructure available within a given country. In general, food irradiation processing requires the same types of infrastructure as other physical processes such as canning, freezing, drying, etc. For example, a processing factory using any of these processes must be located at a central point where sufficient amounts of food are produced, transported to the plant for treatment and storage before sending it out to the market.

Understandably, any treatment of food would add cost to the product. Like other physical processing of food, the irradiation technique has high capital costs and requires a critical minimum capacity of the irradiation facility for economical operation (26). But unlike other physical processes, irradiation has a low operating cost, especially with regard to the energy required for treating food. In advanced countries, the infrastructure required for setting up food processing plants already exists, as demonstrated by many canning and freezing plants. Similar infrastructure also exists in many developing countries, which can or freeze foods on a large scale, several of these foods being for export purposes.

To demonstrate the economics of food irradiation, it may be useful to look at the following case studies.

Commercial Potato Irradiator, Hokkaido, Japan. A joint effort of the Japanese Ministry of Agriculture, Hokkaido, the Provincial Government and the Shihoro Agricultural Cooperative led to the establishment of the world’s first commercial food
irradiator in 1973. This irradiator was equipped initially with 300 kCi of $^{60}$Co at a total cost of approximately US $1.5 million. It has a capacity of treating 10,000 tons of potatoes per month.

Hokkaido produces approximately 80% of the total production in Japan, which is 2.5 million tons annually. Shihoro Agricultural Cooperative is the largest among 300 agricultural cooperatives in Hokkaido. This cooperative owns and operates a large vegetable processing complex, including potato processing facilities. The irradiator was integrated in the complex of potato warehouses (16, each having a capacity of 4,000 tons) and processing plants. As chemical sprout inhibitors are not permitted in Japan, irradiation is the only feasible method for controlling sprouting of potatoes. Although the quantity of potatoes irradiated at Shihoro is relatively small (15,000 - 20,000 tons per season), irradiated potatoes contribute directly to the price stability of potatoes during off-seasons in Japan as well as providing good quality potatoes for processing by the Shihoro Agricultural Cooperative with year round operation (27). The successful establishment of the commercial potato irradiator in Hokkaido has activated interest of other governments to start commercial operation of food irradiation facilities.

*The Fucino Cooperative, Italy.* The Italian Government has granted a fund of approximately US $3 million to Fucino Cooperative to build a commercial irradiator for treating potatoes, onions and garlic to satisfy the demand of its processing facilities during off-seasons. The irradiator is now under construction at the vegetable processing complex of Fucino Cooperative. The facility will have a capacity of treating 25,000 tons of potatoes per season (28).

*Republic of Korea.* The Government of the Republic of Korea is now considering the establishment of a commercial food irradiator for treating potatoes, onions and chestnuts under the same principle as the one built in Hokkaido (29).

From the developments mentioned above, it is reasonable to expect that food irradiation technology can be successfully employed in developing countries. Countries such as Brazil, Chile, Egypt, Ghana, India, Peru, etc., which produce large quantities of root crops (potatoes, onions, yam, etc.) and other cash crops such as cocoa beans and coffee, and need to keep the crop for year round consumption can develop a successful commercial programme on food irradiation based on available technology of food irradiation.

*Possible Commercial Food Irradiation Facilities for Developing Countries.* The following commercial food irradiation plants could be set up in certain developing countries, which would not only be economic in operation, but would make positive contributions to the nutrition of the population.

*Dried fish irradiator.* Several developing countries, especially those in South East Asia produce large quantities of dried fishery product practically all year round. An economic food irradiation plant for treating dried fish should have a minimum capacity of 5,000 tons per year, or 2.5 tons per hour (assuming only 8 hours of operation per day). The treatment cost at a mean dose of 1 kGy would be approximately US $16-20 per ton, which is not more than 1% of the product cost (30). The economy of this plant would be much better if the plant were operated either
Fruit irradiator to overcome quarantine barriers. Regulations in several advanced countries do not permit importation of tropical and sub-tropical fruits from infested areas unless treated against certain species of insect pests. As irradiation is likely to be used to treat fruits to overcome quarantine barriers in the near future, there seems to be an excellent opportunity for developing countries which export large quantities of fruits to consider establishing a commercial plant for this purpose. The economics for setting up such a plant seem to be obvious in view of the large quantities of fruits to be treated. For example, the estimated cost of a two million lb/day capacity citrus irradiator is about US $ 3.2 million. The total irradiation operation cost to overcome quarantine barriers is estimated at $ 0.0028/lb (31).

Multipurpose irradiator. An irradiator which is more versatile may meet the needs of developing countries better than those built for specific purposes, as many food crops tend to be seasonal, and the need to treat certain food items may vary in different countries. This type of irradiator could also be operated as a servicing unit to treat food according to specific needs.

TRADE IN IRRADIATED FOOD
Since 1973, several irradiated foods have entered into commercial channels on a national basis. These foods include potatoes, onions, spices, strawberries, mangoes, chicken, shrimp, frozen froglegs, etc. Several countries such as Belgium, Hungary, Japan, the Netherlands, South Africa and Thailand already market certain irradiated foods on varying scales.

In the absence of an international agreement on trade in irradiated food, undisclosed amounts of irradiated foods have already entered international trade. This type of activity should be done more openly once an international standard for all types of irradiated food has been adopted by the Codex Alimentarius Commission and endorsed by its member countries.

CONCLUSIONS
Radiation processing of food offers a wide range of applications for reducing post-harvest losses of food and increasing food availability to mankind. Its applications make direct contributions to improving nutrition and health of populations in developing countries. Its modest energy requirements and environmental cleanliness are also important assets to developing countries. It provides more and better quality foods at reasonable cost, and most of all, better nutrition to consumers.

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<table>
<thead>
<tr>
<th>Country</th>
<th>Commercial irradiator</th>
<th>Status</th>
<th>Products treated</th>
<th>Approx. capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>MEDIRIS 1)</td>
<td>completed</td>
<td>spices, animal feed</td>
<td>100 m³/month</td>
</tr>
<tr>
<td></td>
<td>Fleurus</td>
<td>(1980)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>Pallet irradiator</td>
<td>planned</td>
<td>food in general</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2 million Ci ⁶⁰Co)</td>
<td>(1982)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hungary</td>
<td>AGROSTER Joint Co</td>
<td>planned</td>
<td>spices, onions, potatoes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Budapest</td>
<td>(1982)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>Commercial Vegetable</td>
<td>under</td>
<td>potatoes, onions, garlic</td>
<td>25,000 tons/year</td>
</tr>
<tr>
<td></td>
<td>Irradiator, Fucino</td>
<td>construction</td>
<td></td>
<td>garlic season</td>
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<td></td>
<td>Cooperative, Fucino</td>
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</tr>
<tr>
<td>Japan</td>
<td>Shihoro Potato</td>
<td>completed</td>
<td>potatoes</td>
<td>10,000 tons/month</td>
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<td></td>
<td>Irradiator, Tzaneen</td>
<td>(1973)</td>
<td></td>
<td></td>
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<tr>
<td>Netherlands</td>
<td>Pilot Plant for Food</td>
<td>completed</td>
<td>frozen chicken, floglegs, organic</td>
<td>1,500 tons/year</td>
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<td></td>
<td>Irradiation, Wagening</td>
<td>(1968)</td>
<td>dyes, spices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GAMMASTER 1)</td>
<td>completed</td>
<td>spices, frozen floglegs, shrimp</td>
<td>1,000 tons/year</td>
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<tr>
<td></td>
<td>Ede</td>
<td>(1972)</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>GAMMASTER</td>
<td>under</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ede</td>
<td>construction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Africa</td>
<td>Fruit and Vegetable</td>
<td>completed</td>
<td>mangoes, strawberries, potatoes, onions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Irradiator, Tzaneen</td>
<td>(1981)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U.S.A.</td>
<td>Multipurpose 1)</td>
<td>completed</td>
<td>spices, poultry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>West Memphis, Arkansas</td>
<td>(1981)</td>
<td>(will treat food when permission is</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>received)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Commodity Irradiator</td>
<td>planned</td>
<td>fruits and vegetables</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stockton, California</td>
<td></td>
<td></td>
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</table>

1) Mainly used for sterilizing medical supplies.
A. MATSUYAMA:

Comment:

1. In connection with a previous question presented from a staff of University of Indonesia I would mention that water contents in food to be irradiated affect the quality of the products and the cell killing effect of radiation based on the fundamental knowledge of radiation chemistry and biology. There may be two different, direct and indirect effects of radiations.

2. As for the present status of legal permission in different countries on irradiated food, it is noted that irradiated onions have not yet been accepted in Japan.

ROCHESTERY SOFYAN:

As we know irradiation is a physical process. None of other physical processes is mentioned in the label, even food additives. Although at present more is known about the effects of ionizing radiation of foodstuffs than about conventional processing methods, what is the reason that for irradiated food we have to label the product. For a country like Indonesia this will invite problems with respect to the consumer acceptance.

P. LOAHARANU:

It is correct that food irradiation is a physical process of food preservation. In the opinion of an international group of experts, labelling should not be applied to the process but only to the products. However, health authorities in several countries are still demanding that food treated by irradiation must be labelled as "irradiated food". It may take some time to convince health authorities that there is no special or scientific reason to require labelling for food treated by irradiation.

NELLY:

Different doses were used to irradiate several types of food, e.g. potatoes 15 krad, wheat 100 krad, onion 15 krad, chicken 700 krad. Is there any relation between dose and water content in each of the food commodity mentioned above?

P. LOAHARANU:

Different doses are recommended for treating different types of food to achieve different purposes. There is no direct correlation between doses and water content of these food items treated to achieve specific purposes.

GUSNADI HASAN:

1. As far as I know, irradiation installation is a product of advance technology and requires high capital investment. If developing countries use it widely, don't you think that the developing countries themselves will be more and more dependent on that advanced technology?

2. Generally, the utmost critical problem in developing countries is poor sanitation and hygiene, and also most of the food losses are caused by poor treatment.
Do you agree with me, if I say, that introduction of advanced technology for food preservation is less important (lower priority) than improving the sanitary environment?

P. LOAHARANU:
1. This a philosophical question which requires careful consideration. Developing countries should use only technologies which are appropriate to them under the prevailing condition. Irradiation is a proper technology for preserving food in developing countries as it is safe, environmentally clean, modest in energy requirement and as effective as other processes for a wide variety of food items. The technology is very simple. I therefore do not believe that developing countries would be more dependent on advanced countries if they adopt this technology.

2. Yes, I agree with you 100%! Irradiation cannot replace bad handling and poor sanitation practices of food. Irradiation could, however, maintain or lengthen significantly the storage quality of properly handled food.

DEDDY MUCHTADI:
You have shown that food preservation by irradiation is much cheaper than pasteurization or sterilization (canning). How is this cost compared with the utilization of chemical preservatives, particularly for fruits?

P. LOAHARANU:
The energy cost for irradiation is lower than that of heat treatment to achieve the same purpose. The cost of irradiation could be comparable or competitive with chemical treatment if sufficient quantity of food (fruits) is collected and treated at one point, e.g. 100,000 tons/year.

C.J. SOEGRIAarto:
In developing countries, the problem of irradiation of fresh fruit and vegetables is the way of gathering the commodity from scattered sources. What is the practice done in South Africa?

P. LOAHARANU:
Irradiation is a physical process of food preservation comparable to heating and freezing. Therefore, an irradiation facility for treating food requires the same infrastructure as canning and freezing plants. This means that sufficient products must be collected at a central point for treatment by physical methods. The economics of the treatment, therefore, depends quite a bit on the quantity of the products to be treated. Fruit industry in South Africa is well organized in the form of cooperatives. Therefore, it is relatively easy to apply irradiation to fruits from these cooperatives.

E.G. SIAGIAN:
According to my opinion, it is better if irradiation is applied to animal feed, than to food for human consumption, to overcome the protein deficiency in human. What is your comment of this, thank you.
P. LOAHARANU:
Irradiation can be used both for human food and animal feed, depending on the purpose of the treatment. With regard to protein deficiency in human, irradiation can reduce spoilage losses of fish and meat products, as well as destroying certain pathogenic microorganisms which may be present in these foods. Irradiation can also improve hygienic quality of animal feed which, in turn, will provide a better source of nutrition for animals.

NAZIR ABDULLAH:
Could you give us some examples of irradiation food commodities which are already available in international trade. What is the reaction of the importing countries?

P. LOAHARANU:
I am not aware of irradiated foods which are subject to international trade. Nationally, several irradiated food items are being marketed in the Netherlands, Belgium, South Africa. These items are strawberries, mangoes, papaya, spices, frozen shrimp, frozen forglegs, etc.

K. MIKAELSEN:
What are the doses (dose range) applied for spices and what are the main sources of spoilage in different spices. Is it a uniform legislation for irradiation treatment of spices.

P. LOAHARANU:
The dose range for irradiation of spices for hygienization is from one to five Mrad. These spices are used for food processing industries such as sausages, canned meat, etc. Normally, most countries have standards for spices to be incorporated into processed foods, e.g. not more than 10 spores per g of spices. Irradiation at the dose range mentioned above can easily achieve this purpose. Only a few countries have legislation on irradiated spices. The tendency seems to be approval of irradiated spices up to a dose of 5 Mrad.