IAEA-TECDOC-452

PRACTICAL APPLICATION OF FOOD IRRADIATION IN ASIA AND THE PACIFIC

PROCEEDINGS OF A SEMINAR
FOR ASIA AND THE PACIFIC
ON THE PRACTICAL APPLICATION OF FOOD IRRADIATION
JOINTLY ORGANIZED BY THE
INTERNATIONAL ATOMIC ENERGY AGENCY
AND THE
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
AND HELD IN SHANGHAI, 7-11 APRIL 1986

A TECHNICAL DOCUMENT ISSUED BY THE
INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1988

PRACTICAL APPLICATION OF FOOD IRRADIATION IN ASIA AND THE PACIFIC
IAEA, VIENNA, 1988
IAEA-TECDOC-452

Printed by the IAEA in Austria
March 1988

PLEASE BE AWARE THAT
ALL OF THE MISSING PAGES IN THIS DOCUMENT
WERE ORIGINALLY BLANK

The IAEA does not normally maintain stocks of reports in this series. However, microfiche copies of these reports can be obtained from

INIS Clearinghouse
International Atomic Energy Agency
Wagramerstrasse 5
P.O. Box 100
A-1400 Vienna, Austria

Orders should be accompanied by prepayment of Austrian Schillings 100,— in the form of a cheque or in the form of IAEA microfiche service coupons which may be ordered separately from the INIS Clearinghouse.

FOREWORD

There is growing interest worldwide in practical application of food irradiation to reduce losses, facilitate trade promotion and improve hygienic quality of food. In Asia and the Pacific, active research and development programmes on food irradiation exist in many countries, mainly through the co-ordination of the Asian Regional Co-operative Project on Food Irradiation (RPFI), an RCA project. The first regional seminar on food irradiation in Asia, held in Tokyo in 1981, concluded that food irradiation holds much promise as a physical method of food preservation and wide scope exists in terms of practical application of the technology in the region.

Several significant international developments on food irradiation have occurred since the Tokyo seminar which include, among other things, an increasing number of countries which recognize food irradiation as a physical process, the adoption of the International Standard and Code of Practice of Irradiated Food by the Codex Alimentarius Commission in July 1983, the approval of specific irradiated spices and seasonings by the U.S. Food and Drug Administration, and its plan to approve the use of food irradiation up to a dose of 1 kGy, the increasing number of commercial irradiators which process food on an industrial scale, etc. A number of developing countries in Asia and the Pacific, e.g. Bangladesh, the Republic of Korea, Pakistan, the Philippines, and Thailand, have definite plans to build demonstration/commercial irradiators for treating food.

In view of the above developments, it was considered timely to convene the second seminar in this field to assess practical application of food irradiation in the region. Emphasis was placed on national public health approval of food irradiation processes, commercial utilization and international trade of irradiated food.

At the invitation of the People's Republic of China, the seminar was convened by FAO and IAEA at the International Club, Shanghai from 7 to 11 April 1986. The local organizer of the seminar was the Institute of Nuclear Research, Academia Sinica, Shanghai. It was attended by 160 participants from 23 Member States, including 60 from outside China.

A large number of papers (over 70) were submitted for the Seminar. A total of 44 papers including 8 invited lectures were selected for oral presentation, the rest were presented at two poster sessions. Eight technical sessions covering practical aspects of food irradiation (e.g. technology transfer, legislation and control, food irradiation facilities and their economics, transportation trials, market testing and consumer acceptance, commercial development of food irradiation, etc.) were included in the Seminar programme. A Working Group to assess the present situation and future application of food irradiation in the region was convened during the Seminar. The report of the Working Group is included in the Proceedings.

EDITORIAL NOTE

CONTENTS

SUMMARIES OF POSTER PRESENTATIONS

SUMMARY REPORT
AND RECOMMENDATIONS OF A WORKING GROUP

INTRODUCTION

At the suggestion of the sponsoring organizations, a working group was convened during the Seminar which met on several occasions. The group evaluated the material presented by the participants to the seminar, with emphasis on the consequences for countries in the Asia and the Pacific region. On the final day of the seminar, the working group presented its findings and recommendations for further action.

The working group comprised:

Chair person: P.A. Wills (Australian Atomic Energy Commission, Australia).

Rapporteur: P.B. Roberts (Department of Scientific and Industrial Research, New Zealand).

Members:
T. Hayashi (National Food Research Institute, Japan)
M.M. Hossain (Bangladesh Atomic Energy Commission, Bangladesh).
G.B. Nadkarni (Bhabha Atomic Energy Research Centre, India).
P. Pothisiri (Food and Drug Administration Thailand).
J.L. Wu (Department of Technical Physics, Peking University, Beijing, China).

Scientific Secretary: P. Loaharanu (Food Preservation Section, IAEA, Vienna, Austria).

THE PRESENT SITUATION

A significant role for ionizing energy in food processing technology has been demonstrated. Processing with ionizing energy can contribute to the production of foods of higher quality in which pathogens, spoilage organisms, or chemical residues are reduced or eliminated, which are quarantine secure and which stay fresher for longer. The safety of the process and its nutritional adequacy has been established since 1980 by a Joint Expert Committee on the Wholesomeness of Irradiated Food of the Food and Agriculture Organization of the United Nations, the World Health Organization and the International Atomic Energy Agency. Recent results from China have further confirmed and supplemented the findings of the Joint Committee. These results showed no harmful effect in human volunteers on an extended diet of irradiated foods.

The Asia and Pacific region can make a special contribution to the development of the use of ionizing energy in food processing, since the needs and opportunities for the process within the region are great. This is because -:

- The region contains more than one half of the world population.

- The region is undergoing the highest rate of economic growth of any region.

- Many countries within the region suffer extensive food losses or are at a considerable distance from their export markets.

- Products traded within and from the region include marine products, spices and fresh fruits and vegetables. Processing by ionizing energy has confirmed applications for such commodities.

- The Regional Project on Food Irradiation (RPFI) is well established in the region. Its existence demonstrates a capacity for cooperation among the member states. The ASEAN nations, in a workshop in November 1985, have also recognized the potential benefits of food irradiation.

The major benefits of the ionizing energy process are perceived to be:

1. An increase in trade opportunities, which will benefit both developed and developing countries.

2. Reduction of food losses.

3. Increased control over maturation and senescence of fresh products, and over shelf-life.

4. Freedom from insect pests and many pathogens.

There are now 24 commercial irradiation facilities in 11 countries which treat food as part of their throughput. Three of these facilities lie within the Asia and Pacific region. A further 14 facilities are expected in the region within 5 years. However, in spite of repeated urgings, only a few countries have taken steps to implement in national legislation or regulations the Codex Recommended General Standard for Irradiated Food and its associated Code of Practice. Clearances are still generally being given on an individual commodity basis.

BARRIERS TO FURTHER PROGRESS

Several barriers to further progress have been identified. These may be summarized as:

- A lack of commitment and investment from the food industry. This follows from:

  (a) The absence of approval for the use of ionizing energy as a food process by most governments, and from

  (b) Uncertainty about consumer reaction.

  - Limited information on the economic feasibility of the process based on actual commercial experience.

- Insufficient experience on how the process may be controlled and regulated on a commercial basis, particularly for the purpose of trade.

A few of these barriers have been examined in some detail in North America and Europe. However, sufficient data are available to suggest that there will be substantial regional differences in the nature of the barriers and their solution. The International Consultative Group on Food Irradiation is charged with solving some of these trade barriers. Seven countries from the region are members of the group.

RECOMMENDATIONS

The working group made the following recommendations:

1. The Codex General Standard for Irradiated Foods together with its associated Code of Practice is already available as a platform for a harmonized approach to the regulation of the process. Harmonization of the regulations in different countries would be a major step towards the implementation of trade in irradiated foods. Those countries that have not accepted the Codex recommendations are asked to expedite relevant measures to achieve acceptance, such as the formation of a national coordinating committee. The appropriate national authority in all countries should be urged to accept the Codex recommendations.

2.. There is a need to create awareness in the food industry of the potential economic benefits of food irradiation. Such awareness will stimulate investment in, and development of, commercial food irradiation. A catalyst for this would be the encouragement of market and economic studies of the process in countries within the region. However, it should be noted that the results of the surveys will be most effective if they are made freely available to all other government agencies and industries.

3. Countries within the region which have not joined the International Consultative Group on Food Irradiation or the Asian Regional Project on Food Irradiation are strongly recommended to join these international activities.

4. The implementation of trade depends upon the establishment of:

- Good Manufacturing Practice, and of strict hygienic standards..
- Satisfactory process control.
- Adequate documentation and records of these good practices.

It is recommended that countries in the region should participate in and support the International Dose Assurance Programme of the IAEA. A number of technical documents relating to good manufacturing and irradiation practice for several foods will be available shortly from the International Consultative Group on Food Irradiation. The widespread dissemination of these documents and their subsequent discussion is required.

5. It will assist the drafting of regulations for food irradiation and promote trade if national authorities are fully aware of the regulations in other countries. We recommend that all countries particularly those within the Asia and Pacific region forward to the IAEA copies of their regulations and draft regulations if possible at the earliest opportunity. The IAEA should then distribute copies to all member countries in the region and elsewhere, if requested.

6. The Group recognized that, wherever it is possible, it is more desirable for a country to build up credibility by introducing irradiated foods into its domestic market before embarking on exports.

INVITED PAPERS

IRRADIATION AS A POSSIBLE SUBSTITUTE TO CHEMICAL FUMIGATION OF FOOD

J.H. MOY
Department of Food Science
and Human Nutrition,
University of Hawaii,
Honolulu, Hawaii,
United States of America

Abstract

Chemical fumigants such as ethylene dibromide, methyl bromide, and ethylene oxide have been used effectively for many years around the world for insect disinfestation of grains, legumes, fruits and vegetables, and for microbial decontamination of spices and other food products. Controversy over the use of these chemicals has arisen in recent years because of: (1) increased awareness of their toxicity to the operators and consumers through the residues on the treated products; (2) documented carcinogenicity, mutagenicity and reproductive disorder in experimental animals; and (3) the potential of environmental pollution. Irradiation, in the form of gamma-radiation or accelerated electron beam, does not present these problems because it is a physical process. More than three decades of worldwide research has shown irradiated food to be safe for human consumption. The irradiation process is technically efficacious, economically feasible and can be safely used for disinfesting and decontaminating a wide variety of food products including mangoes of the seed-weevil. At the disinfestation dose, irradiation causes no phytotoxicity of fresh commodities, delivers a superior product to the consumer and provides the opportunity for production and marketing of new crops. Irradiation is therefore a possible, and the most efficacious substitute to chemical fumigation of food.

Currently, more than 13 countries have approved unconditional irradiation of cereal grain products (0.45-1.0 kGy), fruits, vegetables and dried foods (up to 1.0 kGy) for insect disinfestation, and of spices (5-10 kGy) for decontamination. More countries are soon expected to adopt similar legislations in the interest of public health, food safety and high quality products.

INTRODUCTION

Postharvest food losses due to insect infestation is a serious, costly worldwide problem. Accurate figures are not always available, but an average of 20-25% annual loss is not an overestimate, which translates into billions of dollars. It has been known that an entire silo of grains had to be burnt due to infestation beyond salvage. In another situation, illegal transport of infested fruits from a quarantined area to a non-infested area created the potential for the fruit flies to establish in the latter area. A massive aerial spray of pesticide and release of millions of radiation-sterile fruit flies in the affected area were necessary to eliminate the problem.

Accepted disinfestation practices and quarantine treatment procedures usually include chemical fumigation, heat or cold treatments, or in combination. Of these, chemical fumigation has been very effective and the most widely used, both for disinfestation and decontamination, such as for cereal grains, legumes, fruits, vegetables and spices. The term chemical fumigation, however, is generally broadly defined as the process of using a suitable chemical to sterilise or disinfest. Several commonly used chemicals for fumigation are bromides, ethylene oxide, phosphine and hydrogen cyanide. While they are very effective in achieving the technical effects of sterilisation or disinfestation, there are problems of safety (exposure hazards to workers), residue (due to the potential oncogenicity and reproductive disorder) and environmental contamination. For example, ethylene dibromide (EDB), one of the most effective and widely used pesticidal fumigants for fruits and vegetables, has become highly controversial in recent years. The problem is complex, involving the weighing of risk against benefits. EDB was subsequently banned in the USA by the Environmental Protection Agency (EPA) in September, 1984 as a fumigant for cereal grains, fruits, vegetables and soil [1].

When an effective fumigant is banned, it creates the problem of finding an alternative or substitute that can do the same job or better. Ionizing radiation in the form of gamma-radiation or high energy electrons has been studied for over 30 years around the world as a food preservation technique. It is potentially a feasible substitute for chemical fumigation of fruits, vegetables and cereal grains. Used at a very low dose level (0.10 to 0.50 kGy), gamma-radiation can cause mortality of various stages of an insect or sterility of its adult. Its action is the same as X-radiation which leaves no residual radioactivity in the food treated. Likewise, accelerated electron beams can be used for disinfesting thin packages or particulate materials such as wheat and other grains.

In this paper, the use of several common chemicals as fumigants and their problems is discussed in comparison with the use of irradiation as a physical process. The advantages of irradiation over chemical fumigation for decontamination and disinfestation are briefly explained in view of the fact that irradiation could become the most effective substitute for chemical fumigants.

CHEMICAL FUMIGATION

Chemical fumigants can achieve germicidal, sporicidal, and insecticidal effects depending on the chemical type, dose applied and the effectiveness desired. Several commonly used chemicals that have broad applications including foods are briefly reviewed.

Chemical fumigant type, dose, and effectiveness

1. Methyl Bromide (CH_3Br)

Kolb and Schneiter [2] found methyl bromide (MB) to be bactericidal for anthrax spores and recommended its use for sterilising imported wool and hair. Trickel [3] and Munnecke *et al.* [4] reported that it was effective against fungi. Saiki [5] reported its effectiveness in disinfecting ship compartments, but less so than chloropicrin or formaldehyde in destroying intestinal pathogens. The activity of the compound is measured as 1/10 that of ethylene oxide. It has the decided advantage of non-flammability.

According to Rowe [6], methyl bromide is a very useful and effective fumigant for grain products. However, its high toxicity to man and animals, and its lack of warning properties, such as odour and irritation, makes it quite hazardous to handle. Initial symptoms after excessive exposure to methyl bromide are usually headache, dizziness, nausea, vomiting, weakness and collapse. In more serious cases, lung edema develops resulting in death. The maximum allowable concentration for methyl bromide as specified by the American Conference of Governmental Industrial Hygienists is 20 ppm per an 8-hr day [6].

2. Ethylene Oxide (C_2H_4O)

Ethylene oxide is an effective sterilising agent in gaseous form. Phillips and Kaye [7] reviewed the bactericidal activity of ethylene oxide and found references to its use dating back to 1929. The compound has a pleasant etheral odour, with a medium detectable concentration of about 700 ppm [8]. The sporicidal action of ethylene oxide vapour on *Bacillus subtilis* var. Niger spores is slow, requiring 88 mg/ℓ or 5.5 g/m^3 at 25°C for 10 hr to achieve sterilisation. Doubling the concentration (or vapour pressure) will permit sterilisation in about half the time. Ethylene oxide sterilisation is most rapid at about 30% R.H. (relative humidity), and becomes progressively slower as the RH increases to 100%.

The mechanism by which ethylene oxide kills microorganisms has been linked to its chemical activity as an alkylating agent [9,10]. It attacks bacterial spores almost as readily as it does vegetative organisms. The earliest application of ethylene oxide sterilisation was in the food industry [11,12,13] where spices in particular have been so treated commercially to render them "essentially sterile."

Experimental animal diets requiring sterilisation were also treated with ethylene oxide.

Ethylene oxide is effective against insects and microflora. It is used quite extensively to sterilise medical supplies and equipment, and to prevent food spoilage.

3. Phosphine (PH_3)

Phosphine in the form of hydrogen phosphide, a colourless gas, is generated from aluminum phosphide and magnesium phosphide in the presence of moisture. It is corrosive to copper, brass and ~~other~~ precious metals.

Phosphine, while toxic to man and animals, is used for controlling insects in plant and animal commodities, especially stored products, throughout the world. In recent years, it has been used in the USA for disinfesting cotton products such as bulk, sacked or packaged cottonseeds and cottonseed hulls. The recommended concentration is 28 g/m^3 for 120 hr at 10°C or above.

4. Hydrogen Cyanide (HCN)

Hydrogen cyanide was used as one of the grain fumigants in the U.S.A. V. K. Rowe of the Biochemical Research Department of Dow Chemical Company, Midland, Michigan, USA once wrote that "... Hydrogen cyanide is probably one of the most toxic and hazardous of the fumigants commonly handled..." [6]. The action of HCN is primarily that of inhibiting certain enzymes in the organisms such as insects or the human body. HCN is highly toxic to insects and has a rapid paralysing effect on most species.

HCN is readily soluble in water. It does not penetrate well into some materials and largely because of this, a vacuum system was developed to utilise this gas for fumigation.

Chemical fumigation of foods

Besides those mentioned above as fumigants for food products, there are a number of other chemicals that have been used as grain fumigants such as:

- Carbon Tetrachloride
- Carbon Disulphide
- Chloropicrin
- Sulfur Dioxide
- Sulfuryl Fluoride
- Ethylene Dichloride
- Ethylene Dibromide (EDB)

As a fumigant for fruits, vegetables and grains, ethylene dibromide and methyl bromide have been widely used. Some fruits seem to tolerate ethylene dibromide better than methyl bromide in terms of phytotoxicity. In 1984, the peels of many Mexican oranges turned brown to black a few days after treatment with methyl bromide [14]. An earlier study by Jones [15] showed that methyl bromide-treated papayas and tomatoes exhibited the following problems: (1) the colour development of mature green fruits was retarded; (2) the taste of the fruit was slightly altered due to absorption of MB by the fruit (ca. 27 mg/kg papaya; 33 mg/kg tomato); (3) MB-treated papaya became more susceptible to fungal infections which shortened the shelf life of the fruit.

For treating fruits, vegetables, nuts, grains, cotton products etc. with various chemical fumigants, the U.S. Department of Agriculture has a treatment manual under the Plant Protection and Quarantine Programme which lists various treatment schedules. The required dose for a given pest is a function of the host, gas concentration, time and temperature [16]. For example, if asparagus grown in infested area requires treatment by fumigation to control Halotydeus destructor (the red-legged earth mite), then it could be treated with MB at 40 g/m^3 for 2 hr at 26.5° to 31.5°C, or 48 g/m^3 for 2 hr at 21° to 26°C.

Problems of chemical fumigation

While all the chemical fumigants mentioned above have been used effectively to control insects and microorganisms in our food and medical products, there are a number of hazard factors related to public health and the environment. These include:

- A certain degree of toxicity and lethality associated with all of these chemical fumigants;
- Workers being exposed to the toxic gases they are handling in the fumigation process;
- Consumers and other personnel contacing the residue on the fumigated products because some chemicals desorb slowly over a long period;
- Gradual but continual contamination of the environment each time the fumigant gas is released into the atmosphere;
- Potential fire hazards with some fumigant gases because of their flammability;
- Increased resistance of surviving insects to the chemicals leading to higher dose requirements;
- Potential long-term oncogenic effects on humans from exposure to these fumigants, and proven carcinogenicity in laboratory animals fed the chemical.

A case in point is ethylene dibromide (EDB) which has been used as an effective fumigant for fruit, grain and soil for over 40 years in the USA. EDB became a controversy in the mid-1970's when a National Cancer Institute (NCI, USA) study showed the chemical to be a cancer-causing agent in experimental animals [17]. Later studies by Midwest Research

Institute (USA) and NCI demonstrated that inhalation of EDB increased tumors in several sites in experimental animals. Evidence of the mutagenic potency of EDB and of reproductive disorders in bulls and rats induced by EDB were also cited. In December, 1980 the U.S. Environmental Protection Agency (EPA), which has the authority to cancel chemical fumigants and pesticides, announced a "position document" setting forth EPA's review of the experimental evidence on EDB.

The EPA document said "...the Agency has concluded that the presumption for oncogenicity, mutagenicity, and reproductive disorders derived from EDB have not been rebutted..." Finally, EDB was banned as a fruit, grain and soil fumigant on 1 September 1984 in the USA [1].

IRRADIATION

The effectiveness and feasibility of using ionizing radiation to preserve foods for six different applications have been proven by more than three decades of research around the world. The use of low dose radiation for insect disinfestation is emerging as a possible substitute for chemical fumigation because of recent events and controversies over chemicals and pesticides in our foods.

Technical efficacy of radiation disinfestation and decontamination of food products

Although chemical fumigation is the most effective method of disinfestation, it has its limitations as indicated earlier. Ionizing radiation, on the other hand, does not have these limitations and also can achieve disinfestation that chemical fumigants cannot. A good example is the mango seed weevil *Cryptorhynchus mangiferae* (Fabricius) which can be inactivated only by ionizing radiation.

Two food groups that are often infested and need disinfestation treatment the most are grains, and fruits and vegetables. These will be discussed separately.

1. Grains:

Grains as stored products are infested by mites, beetles and moths. Researchers in the United States Department of Agriculture (USDA) have found at least 25 species of beetles and three species of moths that infest stored products in the USA [18]. Grain losses due to storage pests in tropical countries are as high as 30% in some countries. A survey in 1962 of shipments into England of wheat from Australia and South America, barley from Australia, and maize from South America and Africa showed 50% of the 317 shipments were infested [19].

A well-organised research project on radiation disinfestation of grains was carried out at the Wantage Research Laboratory in England from 1955 to 1961 under the leadership of P. B. Cornwell [19]. The minimum effective dose for sterilising pupae and adults of the grain weevil (Sitophilus granarius) was 0.16 kGy, with death occurring 2-3 weeks after treatment. At 0.05 kGy, all eggs and larvae were prevented from maturing, and thus from reproducing. When infested grains containing all developmental stages were irradiated at 0.16 kGy, only those containing late pupae were able to produce adults, which were sterile.

Sub-sterilising doses of 0.10-0.12 kGy could suppress weevil (S. granarius) populations to a low level of 0.2-6.0% for 7 months. With small populations, irradiation at this dose level can give complete control. The mechanism is by providing the condition for fertile females to be inseminated with sterile sperms which outnumber those with fertile sperms. This competition would last for at least 4 months after radiation treatment. Thus reinfestation is greatly decreased.

Based on the British study, Cornwell observed that the optimal dose rate for radiation disinfestation of grain would be between 0.00167-0.167 kGy/min (10-1000 krad/hr). Warming the grains before irradiation to above 30°C sensitises the grain weevils to killing by irradiation, but maintaining that temperature during irradiation would tend to increase resistance to killing. High temperatures after irradiation accelerate the rate of mortality only. Temperature does not modify the susceptibility of the grain weevil to sterilisation. A low oxygen tension at irradiation, sufficient to anaesthetise adult grain weevils in 30 min, increases their resistance to killing and sterilisation by irradiation.

Strains of stored-product insects vary considerably in their susceptibility to killing by irradiation. Dose of 0.16 kGy was found effective against 30 wild strains of S. granarius from various parts of the world as well as strains of weevil and flour beetle from Australia. Cole et al. [20] observed that there was no evidence to suggest that strains of insects resistant to insecticides were more tolerant to radiation. Tilton and Brower [21] suggested that if commodities were infested with many species, a dose of 0.50 kGy would control even the most resistant beetle species and the immature stages of moths.

In August, 1963, the Food and Drug Administration (FDA) of the USA approved for human consumption wheat and wheat products (later modified to wheat and wheat flour) irradiated at 0.20-0.50 kGy from a Co-60 source. The petition to FDA for clearance was submitted by Brownell and co-workers of the University of Michigan, USA [22]. A petition subsequently submitted by High Voltage Engineering Corp. (USA) for the same purpose with a 5 Mev electron accelerator was also approved.

Radiation treatment within the limits of the FDA clearance has no detrimental effects on bakery products made from irradiated wheat or wheat flour. Certain bakery products made from irradiated flour of some varieties of wheat show quality improvement [22]. At a dinner at which irradiated foods were served, Congressmen gave hearty approval to both irradiated dinner rolls and date-nut bread [23]. Extensive test results at Wantage and four U.K. cereal laboratories on English wheat treated at 0.20, 1.25, 5.0, and 10.0 kGy showed no changes in physical properties and dough behaviour at 0.20 kGy except a slight darkening of the flour, comparable to a similar change with a 0.5% change in moisture content. Treatments at 1.25 and 5.0 kGy modified the viscosity of the dough to a minor degree [19].

In the 127-page petition Brownell et al. submitted to the U.S. FDA for the use of gamma-radiation to process wheat and wheat products for the control of insect infestation [22], the issues of wholesomeness, nutritional value and safety (absence of toxicity) were addressed and experimental results documented. The conclusions were that "... Feeding, breeding and growth studies with rats, mice, dogs, and chickens in the USA and abroad indicate that irradiated whole wheat and irradiated wheat products are wholesome and as nutritionally adequate as non-irradiated wheat and wheat products...No carcinogen could be demonstrated in irradiated foods at radiation dose level of 100 krad to 10 Mrad (1-100 kGy). At the much lower dose of 20-50 krad (0.20-0.50 kGy) proposed in this petition, no significant chemical changes can be detected. Therefore, there is no possibility of creation of a carcinogen by the process. Various studies with the mammals : dogs, rats, mice, guinea pigs, and humans, and also with nonmammals : chicken and protozoa using radiation doses up to 45 million rep (ca. 42 Mrad or 420 kGy) failed to indicate any evidence of induced toxicity in irradiated wheat and wheat products or other irradiated foods and food components. Never has a process been investigated so thoroughly in this regards..."

The experimental results from various studies in support of the wheat petition clearly show the complete absence of carcinogenicity, toxicity and chemical changes in irradiated wheat, wheat products, and other irradiated food products both at low doses (0.20-0.50 kGy) and very high doses (420 kGy).

2. Fruits and Vegetables:

Many fruits and vegetables grown in the tropical and subtropical regions around the world are prone to infestation by many species of fruit flies and other insects. A selected list of fruit flies which are of major international economic and quarantine importance is shown in Table 1 [24].

Almost thirty years ago, gamma-radiation was proposed as a potential quarantine treatment for fruits [25]. In 1957, work began in the USDA Fruit Fly Investigation Laboratory in Hawaii to determine the effects of gamma-radiation on fruit flies infesting papayas and other tropical fruits. Much has been learned over the past three decades on this technology. Two excellent reviews on the effectiveness of gamma-radiation as a potential quarantine treatment technique for fruits were recently prepared by Burditt [26] and Thomas [27].

Table 1. Selected fruit fly species of major economic and quarantine importance [24]

Scientific Name and Author	Common Name	Primary Hosts	Distribution
Anastrepha fraterculus (Wiedemann)	S. America fruit fly	Citrus, mango, soft fruit	Mexico to South America
Anastrepha ludens (Loew)	Mexican fruit fly	Citrus, mango, soft fruit	Mexico, Central America
Anastrepha suspensa (Loew)	Caribbean fruit fly	Guava, citrus, Roseapple	Caribbean, Florida
Ceratitis capitata (Wiedemann)	Mediterranean fruit fly	Citrus & most fruits	Asia, America, Africa, elsewhere
Dacus cucurbitae (Coquillett)	Melon fly	Cucurbits & most fruits	SE Asia, Africa, Pacific Islands
Dacus dorsalis (Hendel)	Oriental fruit fly	Citrus & most fruits	SE Asia, Pacific Islands
Dacus tryoni (Froggatt)	Queensland fruit fly	Citrus & most fruits	Australia
Rhagoletis cerasi (Linnaeus)	European cherry f.f.	Cherries, soft fruits	Europe
Rhagoletis pomonella (Walsh)	Apple maggot	Apple	USA

The five criteria for considering the acceptance of this treatment technique by quarantine authorities can be viewed as follows:

a. Effectiveness against the pest species -

The minimum absorbed dose to control the emergence of three species of fruit flies in Hawaii (the Oriental, the Mediterranean and the melon fly) was found to be 0.26 kGy by the USDA laboratory in Hawaii to meet probit 9 security requirement (99.9968% mortality) [26]. If another concept of "the inability of the insect to produce viable offspring" is used, then a dose as low as 0.05 to 0.10 kGy will suffice [27]. For most fruit flies, the effective dose will lie between 0.10 and 0.35 kGy depending on the stage of the insect development, condition of the fruit and the security level desired.

b. Host tolerance or absence of phytotoxicity -

The feasibility of applying ionizing radiation as a disinfestation technique depends on a fruit's tolerance to a minimum disinfestation dose. At the joint FAO/IAEA panel meeting on the Use of Irradiation to Solve Quarantine Problems in the International Fruit Trade, December, 1970, several researchers presented results of their studies on irradiated bananas, papayas, mangoes, rambutans, and longans [27,28,29,30] which showed that all of these fruits could tolerate gamma-radiation treatment to 1.0 kGy without any phytotoxicity with longans tolerant to 2.0 kGy. More recent studies on the use of gamma-radiation as a potential quarantine treatment for stone fruits (peaches, nectarines and plums, etc.), citrus (oranges, grapefruits, etc.) and other fruits such as table grapes, apples, tomatoes, etc. showed that these fruits could tolerate 0.30 kGy treatment without any external or internal chemical or sensory quality changes [31,32,33]. At higher doses of 0.50-1.0 kGy, some differences in sensory qualities were noted on stone fruits, but the irradiated fruits were not rated lower than the control [34]. California oranges (var. Valencia and Navel) could actually be irradiated up to 0.50-0.75 kGy without any quality changes especially if refrigeration at 7°C followed irradiation [32]. Florida grape-fruits irradiated at 0.60-0.90 kGy were reported to show rind breakdown and some scald after storage [33].

Minimising ozone formation in the radiation field during irradiation could be an important factor to lower the chances of phytotoxicity in the irradiated fruits [34]. This can be accomplished by replacing the air in the radiation field continuously.

c. Absence of hazardous residue -

It has been demonstrated that using a proper radiation source and energy level, gamma or accelerated electrons, there is no possibility of any induced radio-activity in the food treated. Hence there is no residue, hazardous or otherwise, in the food irradiated that could be of public health concern which is monitored by health authorities such as the Environmental Protection Agency (EPA) in the USA. Brownell, a professor of chemical and nuclear engineering, had adequately summarised this fact in his wheat petition [22]. The same is true in fruits, vegetables and other food products.

d. Treatment can be applied without undue hazard to the operators -

Proper design of a quarantine treatment facility should provide safeguards to prevent or limit exposure of personnel to a fumigant or to radiation. Between the two treatment methods, the hazard of the operators being exposed to radiation is much less than to a fumigant because one is physical while the other is chemical. Proper shielding, adequate monitoring and sufficient care and precaution should provide complete safety in a radiation facility. The same is not true of chemical fumigation because of the need for the operator to handle the chemicals and fruits in the fumigation chambers.

e. Technical efficacy -

Efficacy here suggests both effectiveness and efficiency. Certainly the effectiveness of chemical fumigation and irradiation for disinfestation and decontamination have been demonstrated through either industrial applications or extensive research. The efficiency of radiation disinfestation should be superior to chemical fumigation because the former process can be carried out in a short period of time, e.g., 10-20 min while the latter normally takes 3 hr or more including aeration of the chamber. Furthermore, the irradiation process outperform chemical fumigation in the following manner:

- Irradiation is a continuous process while fumigation is a batch process;
- Commodities are packaged before irradiation, thus preventing re-contamination or re-infestation, and also allowing for efficient movement and transport;
- Commodities can be irradiated immediately after removal from cold storage, and can be refrigerated immediately after irradiation. This is not true of chemical fumigation;
- Some commodities such as climacteric fruits can be irradiated at any stage of ripeness beyond color-breaking and still meet quarantine requirement. This would actually allow the fruits to be picked at an optimally ripe stage to have a high market quality.

Besides grains, fruits and vegetables, irradiation of many other food products have been studied for its potential as a substitute to fumigation either for disinfestation or decontamination. Examples include: dried fruits [35], wheat germs and dried mushrooms [36], coffee beans and copra [37], tobacco leaves [38], dried and cured fish [39], orchids [40], pulses [41,42, 43], and spices [44,45].

The effective upper dose or dose range to control insect infestation in these food and agricultural products and to decontaminate microorganisms in spices have been found to be as follows:

Dried fruits,	1.0 kGy	Coffee beans,	1.0-1.5 kGy
Wheat germs,	0.8 kGy	Copra,	0.5-0.75 kGy
Dried mushrooms,	0.5 kGy	Dried fish,	0.3-0.5 kGy
Tobacco leaves,	0.6 kGy	Pulses,	0.8-1.0 kGy
Orchids,	2.0 kGy	Spices,	5.0-15 kGy

Economic feasibility

Any industrial process can become commercially applicable only if it is economically feasible. This is of course also true of the irradiation process for disinfestation and decontamination of food products.

Data from economic feasibility studies of food irradiation for various purposes have been scattered and somewhat limited as compared to a large volume of data amassed over the years on the technical efficacy of food irradiation. In discussing the cost of disinfesting grains with a Co-60 source, Cornwell [19] suggested that the cost of radiation processing would be most favourable when treatment was spread throughout the year, over 24 hr/day, if possible. He estimated that a grain irradiator plant should have the capacity to handle an average of two large grain cargoes per month, each of 12,000 to 15,000 metric tons (m.t.). The throughput for the irradiator is therefore about 300,000 to 360,000 m.t. per annum. This would put the handling rate at about 80 m.t./hr assuming it operates 24 hr/day for half of the year.

The handling rate indicated above may be too low because of the unlikely schedule of year-round operation. It should be 150-200 m.t./hr for the irradiator to be economically feasible. Limited information on the dual electron beam grain irradiator at Port Odessa, USSR was said to have such an hourly capacity to disinfest imported wheat.

Some other cost estimates of food irradiation have been reported in recent years, some for decontamination of frozen shrimps and chickens, some for sprout inhibition of potatoes and onions or for a combination of these products in a multi-purpose irradiator. For radiation disinfestation of Mexican mangoes and oranges to control the emergence of Mexican fruit flies at a minimum absorbed dose of 0.30 kGy, Moy et al. [14] considered two levels of throughput for each of the two Co-60 irradiator plants: 50,000 and 100,000 m.t. of mangoes irradiated per year, and 100,000 and 150,000 m.t. of oranges irradiated per year. Adding up all the annual fixed and variable costs, they found the unit costs of irradiation to be U.S. $0.026-0.041 per kg of mangoes, and U.S. $0.022 to $0.026 per kg of oranges. These cost estimates were considered to be realistic based on a number of actual local cost factors.

Still lower cost can be realised if the plant size is increased because of the availability of economies of scale.

In another study by Morrison [46] on disinfesting Hawaiian papayas by radiation at 0.26 kGy, the throughput of the plant was assumed to vary from about 6,000 m.t./yr to 44,000 m.t./yr. The unit processing costs were estimated at U.S. $0.022/kg to $0.093/kg for the high and low throughput. Another estimate by an industrial irradiator manufacturer in California, USA for irradiating Hawaiian papayas at the same dose with a throughput of 20,000 m.t./yr showed the cost to be about US $0.044/kg. All of these unit processing costs are within a reasonable range which represents the cost of radiation disinfestation in the dose range of 0.26-0.30 kGy. The variations are due to the differences in the actual or estimated fixed and variable cost factors used in each study.

The cost of U.S. $0.044/kg of Hawaiian papaya irradiated is only slightly higher than the cost of fumigation with EDB which was about $0.040/kg. The results of these recent studies have suggested that radiation disinfestation of fruits is economically feasible. Since the dose requirements for disinfesting grains is in the same range, radiation disinfestation of grains is also likely to be economically feasible.

Radiation decontamination of spices is already a commercial practice in the USA and elsewhere. Since spices are high value food ingredients, the economics of irradiation is considered favourable.

Advantages of radiation disinfestation and decontamination over chemical fumigation

The advantages of using ionizing radiation to disinfest or decontaminate various foods as compared to chemical fumigation can be summarized as follows:

- Irradiation leaves no radioactivity or toxic residues on the products treated, while chemical fumigation leaves a vapour and residue creating exposure hazards to the workers and consumers;
- Fruit irradiated at disinfestation dose is not softened, nor is ripening accelerated, whereas fumigation tends to hasten ripening because it is carried out at ambient temperature in most cases;
- Irradiation is an efficient, continuous, automated process requiring less treatment time and allowing for speedy transport to freight terminals and market destinations, while fumigation is a batch process;
- At the disinfestation dose, irradiation causes no phytotoxicity of fresh commodities treated while in many commodities, phytotoxicity results from the fumigation treatment;
- Irradiation will not contaminate the environment while chemical vapour from fumigation will;

- Irradiation delivers a superior product to the consumer because the efficacy of the process permits the fruit to be picked at the optimal ripeness;
- Irradiation can accomplish complete disinfestation including the mango seed-weevil which is not possible by chemical fumigants;
- Radiation disinfestation of fruits and vegetables is cost-competitive with fumigation. It will also provide the opportunity for production and marketing of new crops.

CURRENT STATUS OF CHEMICAL FUMIGATION VS IRRADIATION OF FOOD

Currently in the USA, several chemicals such as methyl bromide, hydrogen cyanide, phosphine are still allowed as fumigants for various plant products. For example, MB can be used to disinfest stone fruits, berries, grains, flour and dried foods according to the USDA quarantine treatment schedules. EDB is allowed at a residue level of 30 ppb for disinfesting fruits imported from Central and South America for the current year. Japan is accepting EDB-treated papayas from Hawaii. Ethylene oxide can be used on ground spices and dried seasonings.

Table 2. Irradiation of food products cleared by various countries for insect disinfestation or decontamination as of August, 1985 [48] (Unconditional except as noted)

I. Radiation Disinfestation of Cereal Grain Products (0.45-1.0 kGy)

◦ Bangladesh	◦ China
◦ Brazil	◦ Netherlands
◦ Bulgaria*	◦ USA
◦ Canada	◦ USSR
◦ Chile	◦ Yugoslavia

II. Radiation Disinfestation of Fruits, Vegetables, and Dried Foods (up to 1.0 kGy)

◦ Bangladesh	◦ Chile
◦ Brazil	◦ South Africa
◦ Bulgaria*	◦ USSR**

III. Radiation Decontamination of Spices (4-10 kGy)

◦ Bangladesh*	◦ Israel
◦ Brazil	◦ Netherlands*
◦ Canada	◦ New Zealand*
◦ Chile	◦ Norway
◦ France	◦ South Africa
◦ German Demo. Rep.*	◦ USA
◦ Hungary*	◦ Yugoslavia

*Provisional or experimental
**Dried food and dried food concentrate

For disinfesting various foods by ionizing radiation, a very comprehensive review was prepared by Loaharanu [39] covering such food groups as dried and cured fish, fruits, cereals and pulses and other food and agricultural commodities. As of August, 1985, 30 countries around the world have cleared more than 40 irradiated food items for human consumption on either an unconditional or provisional basis for various purposes [47]. Table 2 shows the countries that have approved radiation disinfestation of cereal grain products, fruits, vegetables and dried foods, and radiation decontamination of spices - most by unconditional clearance, a few on provisional or experimental basis.

While the list of countries approving radiation disinfestation of fruits and vegetables is relatively short at this writing (March, 1986), the U.S. FDA has recently announced the approval in principle of irradiation of fruits and vegetables up to 1.0 kGy for insect disinfestation and delay of maturation. This "rule change" will become official when it is published in the Federal Register which is expected to take place within a few weeks.

CONCLUSION AND OUTLOOK

Ample scientific data collected over the past several decades have shown that industrial chemical fumigants used throughout the world for insect disinfestation and microbial decontamination of various cereal grains, fruits, vegetables, dried foods and spices have become cause for concern. Most of these chemicals such as methyl bromide and ethylene oxide are toxic and oncogenic, create health hazards to the public and fumigation workers, and pollute the environment. Ionizing radiation, such as Co-60, Cs-137 or electron beams, can be a safe and efficacious substitute to chemical fumigation for the two applications indicated, which have already been approved by a number of countries.

It is expected that more countries will soon adopt similar regulations in the interest of public health, food safety and high quality products. Minimizing food losses and increasing international food trade through the application of irradiation should help improve the economy of every country. The process should help save some of the estimated 25 to 30% of the world's food supply which is lost each year because of pests and spoilage.

REFERENCES

[1] ANONYMOUS, Part VIII, U.S. Fed Register 48, 197(1983) 46228.

[2] KOLB, R.W., and SCHNEITER, R., J. Bact. 59(1949) 401.

[3] TRICKEL, R.J., Ph.D. Thesis, U. of Wisconsin (U.S.A.) (1952).

[4] MUNNECKE, D.E., LUDWIG, R.A., and SAMPSON, R.E., Can. J. Botany, 37(1959) 51.

[5] SAIKI, E., Nagoya J. Med. Sci. 15(1952) 270. Thru C.A. 48(1954) 2822.
[6] ROWE, V.K., Pest Control, 9(1957) 450.
[7] PHILLIPS, C.R., and KAYE, S., Am. J. Hyg., 50(1949) 270.
[8] JACOBSON, K.H., HACKLEY, F.B., and FEINSILVER, L., Arch. Indus. Health, 13(1956) 237.
[9] PHILLIPD, C.R., Am. J. Hyg., 50(1949) 280.
[10] PHILLIPS, C.R., Bacteriol. Rev., 16(1952) 153.
[11] HALL, L.A., Food Industries, 10(1938) 424.
[12] HALL, L.A., Food Packer, 32, 12(1951) 26.
[13] YESAIR, J., and WILLIAMS, O.B., Food Research 7(1942) 118.
[14] MOY, J.H., REYES L., J., RAMIREZ G., T., and BUSTOS R., E., IAEA Proj. Rpt. MEX/5/011-01 (1984) 42 pp.
[15] JONES, W.W., Circular No. 17, Haw. Agr. Exp. Station, Honolulu (1940) 6.
[16] ANONYMOUS, Gen. Op. Proc. M-390, USDA-APHIS, Rev. Sept (1986), Sect. 1, Part 2.
[17] WALSH, J., Science 215(1982) 1593.
[18] TILTON, E.W., and BURDITT, A.K. Jr., Preserv. of Food by Ionizing Rad. CRC Press (USA) III, Ch. 7 (1983) 215.
[19] CORNWELL, P.B., (Ed.) The Entomol. of Rad. Disinfest. of Grain, Pergamon Press, London (1966) 203, 218.
[20] COLE, M.M., LABRECQUE, G.C., and BURDEN, G.S., J. Econ. Entomol. 52(1959) 448.
]21] TILTON, E.W., and BROWER, J.H., Proc. Int. Conf. Rad. Preserv. of Food, Bombay, IAEA (1973) 295.
[22] BROWNELL, L.E., HORNE, T., KRETLOW, W.J., Petition submitted to U.S. Food and Drug Admin., HEW, Washington (1962).
[23] SNYDE, J.D., Baking Indus. (USA), Sept. 26 (1964) 59.
[24] OAKLEY, R.G., Unpublished Summary of Tephritidae, USDA-APHIS (1950).
[25] BALOCK, J.W., CHRISTENSON, L.D., AND BURR, G.O., Proc. 31st Ann. Mtg. Hawaii Acad. Sci. (1956) 18.
[26] BURDITT, A.K. Jr., Food Technol. 36, 11(1982) 51.
[27] MOY, J.H., AKAMINE, E.K., BREWBAKER, J.L., BUDDENHAGEN, I.W., ROSS, E., SPIELMANN, H., UPADHYA, M.D., WENKAM, N., HELBER, D., DOLLAR, A.M., HANAOKA, M., AND McCLISH, G.A., IAEA/STI/PUB/299/7 (1971) 43.
[28] SREENIVASAN, A., THOMAS, P., and DHARKAR, S.D., IAEA/STI/PUB/299/9 (1971) 65.
[29] PABLO, I.S., MANALO, J.A., CARDENO, V.A., IAEA/STI/PUB/299/11 (1971) 101.
[30] LOAHARANU, P., IAEA/STI/PUB/299/12 (1971) 113.
[31] RIGNEY, C.J., and WILLS, P.A., Rad. Disinfest. of Food and Agri. Prod., U. Hawaii (1985) 129.
[32] MOY, J.H., and NAGAI, N.Y., Ibid. 135.
[33] SPALDING, D.H., and DAVIS, D.F., Ibid. 160.
[34] MOY, J.H., KANESHIRO, K.Y., OHTA, A.T., and NAGAI, N., J. Food Sci. 48, 3(1983) 928.
[35] KHAN, I., SATTAR, A., WAHID, M., and JAN, M., Rad. Disinfest. of Food and Agri. Prod., U. Hawaii (1985) 207.
[36] KOVACS, E., KISS, I., and KUROLI, G., Ibid. 189.
[37] MANOTO, E.C., BLANCO, L.R., RESILVA, S.S., CARILLO, P.V., and CASUBHA, L.C., Ibid. 199.
[38] SOEMARTAPUTRA, M.H., ROSALINA, S.H., RAHAYU, A., HARSOJO, and KARDHA, S., Ibid. 226.
[39] LOAHARANU, P., Ibid. 45.

[40] PIRIYATHAMRONG, S., CHOUVALITVONGPORN, P., and SUDATHIT, B., Ibid, 222.
[41] BHUIYA, A.D., AHMED, M., REZAUR, R., SEAL, D.R., NAHAR, S.G., ISLAM, M.M., and ISLAM, M.S., Ibid. 214.
[42] BHUIYA, A.D., AHMED, M., REZAUR, R., NAHAR, G., HUDA, S.M.S., and HOSSAIN, S.A.K.M., IAEA/STI/PUB/695 (1985) 163.
[43] EL-KADY, E.A., Ibid. 164.
[44] ITO, H., WATANABE, H., BAGIAWATI, S., MUHAMAD, L.J., and TAMURA, N., Ibid. 171.
[45] WETZEL, K., HUEBNER, G., and BAER, M., Ibid. 35.
[46] MORRISON, R.M., IAEA/STI/PUB/695 (1985) 407.
[47] ANONYMOUS, FAO/IAEA Food Irrad. Newsletter, 9, 2(1985) 32.

IAEA-SR-129/21

IRRADIATION AS A METHOD FOR INCREASING SAFE FOOD SUPPLIES AND REDUCING FOOD LOSSES

W. BÖGL
Federal Health Office,
Institute for Radiation Hygiene,
Neuherberg, Federal Republic of Germany

Abstract

This report demonstrates the absolute necessity of achieving a better control of foodborne pathogens and to take action against high food losses. One method to improve the situation is the increased use of irradiation technology. The different methods of application are described and consist mainly of radicidation of meat, poultry, fish and shellfish with doses up to nearly 7 kGy, the radurization of the same products and, additionally, of fruits and vegetables with approximate radiation doses of 2 to 3 kGy, and the radicidation and radurization of dry food ingredients with doses up to 10 kGy. Other applications are insect disinfestation with doses between 50 and 200 Gy, the delay in ripening and physiological decay of fruits and vegetables normally performed with doses between 0.5 and 2 kGy, and sprout inhibition of tubers and bulbs using doses between 30 and 120 Gy.

1. Introduction

A comparison between the world-wide production of food and the total food consuming population allows the assumption that under prevailing conditions we produce a sufficient amount of food to supply the total world population. The fact that many population groups are still starving today is mainly due to the unsatisfactory storage and distribution of surplus food produced in specific regions and at certain seasons. In order to gain a better control of food storage and distribution, the infrastructure of the most adversely affected developing countries must be improved in the same manner as the cooperation between industrialized and developing countries in establishing a better system of surplus food distribution.

One contribution towards the solution of the storage- and distribution problem is provided by the method of irradiation, since it is effective in slowing the spoilage process caused by microorganisms, delaying the ripening process of fruits and vegetables, and in largely preventing food losses by insects. All of these factors have the advantage of allowing food to be stored for longer periods of time and, consequently, facilitating more time for food distribution. A study by FAO from the year 1976 showed losses from non-protected dry foods during storage and distribution that could amount to 50-70 % in many parts of the world (1). Another example is stated by the loss in food supply contributed to the fruitfly. Rhode (2) reports a loss from such damage in the Central American countries Costa Rica, Nicaragua and Panama in 1970 that amounted to about 2.5 million US Dollars in an area of approximately 10,500 km^2. An additional study (3) calculated food losses, provided a fruitfly infestation would occur in Mexico, which would amount to about 100 million US Dollars. The losses of staple foods in Africa are summarized in Table 1. For 1980, the total loss of 39,650 kt is in contrast to an import of 5,658 kt.

In addition to establishing an improved quantitative supply of food to many areas of the world, the problem of decreasing the danger from foodborne infections and intoxications must be considered as equally important (4, 5). This, however, is not a problem characteristic only of developing countries but of industrial nations as well, and is briefly outlined and exemplified in the following tables and figures. During the latter part of 1980, the WHO Surveillance Programme for Control of Foodborne Infections and Intoxications in Europe was introduced. For the first time, regular data reporting on an European basis allowed an overview of foodborne diseases in several European

TABLE 1: LOSSES IN STAPLE FOODS (AFRICA)

STAPLE FOODS	REPORTED RANGE OF LOSSES [%]	ESTIMATED LOSS 1980 [kt]
Roots and tubers		16.718
Cassava	20 - 60	
Yams	15 - 60	
Potatoes	8 - 95	
Cereals		
Maize	10 - 30	2.719
Sorghum	6 - 40	2.250
Millet	10 - 50	
Rice	6 - 24	1.011
Plantains and bananas	35 - 100	
Fish		
Fresh	20 - 50	
Dried	20 - 35	
Fruits		
Citrus	20 - 95	
Pineapple	20 - 70	
Mango	20 - 50	
Papaya	40 - 100	
Avacados	43	
Vegetables		
Tomatoes	20 - 50	16.897
Onions	16	
Pepper	15	
Lettuce	62	
Cauliflower	49	
Cabbage	37	
Carrots	44	

From *Chinsman, B.*, IAEA, STI/PUB/695 (1985)185 (modified)

TABLE 2: FOOD BORNE DISEASES IN SOME EUROPEAN COUNTRIES 1980 –TOTAL NUMBER OF REPORTED OUTBREAKS AND CASES–

	TOTAL NUMBER
FINLAND	1 517
FR GERMANY	57 945
GREECE	255
SWITZERLAND	2 086
ENGLAND, WALES	10 856
SCOTLAND	2 043
YUGOSLAVIA	22 278

From *Gerigk, K.*, Bundesgesundhbl 26 (1983)336 (modified) countries. For some of these countries the number of foodborne diseases in 1980 is given in Table 2. It must be emphasized, however, that these data are based on reported cases only . The difference between reported and actually occurring but unknown cases may be quite large; it has been estimated, at least for some countries, that only between 1 and 10 % of the foodborne diseases will be reported.

Which are the main organisms responsible for these infections? The most important organisms leading to foodborne diseases are compiled in Table 3. From these data it becomes immediately apparent that animal-produced food and food products are primary responsible for foodborne diseases and infections. One of the most important microorganisms is the bacterium Salmonella, since about 80 % of all foodborne infections and intoxications were caused by Salmonellae, according to a survey conducted in the Federal Republic of Germany (Fig. 1). Figure 2 clearly shows that the number of Salmonellosis cases was on the increase, at least during the past decades. From a study published in the Federal Republic of Germany in 1983, it is calculated that 60 % of Salmonellosis occurring in 1977 were not known, so that actual figures are considerably larger. For the same year, the economic cost to the Federal Republic of Germany from Salmonellosis in man was estimated to have been about 120 million DM (6). A further study in the Federal Republic (Fig. 3) points out the main sources of Salmonellosis. It is clearly demonstrated that foods, mainly meat, poultry and seafood, are still the essential sources. Only about 10 % of infections originate from other sources. These data clearly indicate Salmonella control to be one of the most important areas of food safety. Considering the fact that Salmonella control can be easily achieved by irradiation, the potential value of this method for the purpose of an increased microbial safety of foods is clearly in evidence. Figure 4 shows a dose-effect-curve for Salmonella inactivation in ground meat which indicates that a radiation dose of about 2.5 kGy is capable of reducing the amount of Salmonellae by a factor of 10^4.

TABLE 3: SOME AGENTS OF IMPORTANT FOODBORNE DISEASES AND SALIENT EPIDEMIOLOGICAL FEATURES

Agents	Important reservoir/carrier	Transmission[a] by water	food	person-to-person	Multiplication in food	Examples of some incriminated foods
BACTERIA:						
Bacillus cereus	Soil	-	+	-	+	Cooked rice, cooked meats, vegetables, starchy puddings
Brucella species	Cattle, goats, sheep	-	+	-	+	Raw milk, dairy products
Campylobacter jejuni	Chickens, dogs, cats, cattle, pigs, wild birds,	+	+	+	-[b]	Raw milk, poultry
Clostridium botulinum	Soil, mammals, birds, fish	-	+	-	+	Fish, meat, vegetables (home preserved)
Clostridium perfringens	Soil, animals, man	-	+	-	+	Cooked meat and poultry, gravy, beans
Escherichia coli						
Enterotoxigenic	Man	+	+	+	+	Salad, raw vegetables
Enteropathogenic	Man	+	+	+	+	Milk
Enteroinvasive	Man	+	+	0	+	Cheese
Mycobacterium bovis	Cattle	-	+	-	-	Raw milk
Salmonella typhi	Man	+	+	±	+	Dairy produce, meat products, shellfish, vegetable salads
Salmonella (non-typhi)	Man and animals	±	+	±	+	Meat, poultry, eggs, dairy produce, chocolate
Shigella	Man	+	+	+	+	Potato/egg salads
Staphylococcus aureus (enterotoxins)	Man	-	+	-	+	Ham, poultry and egg salads, cream-filled bakery produce, ice-cream, cheese
Vibrio cholerae 01	Man, marine life?	+	+	±	+	Salad, shellfish
Vibrio cholerae, non-01	Man and animals, marine life?	+	+	±	+	Shellfish
Vibrio parahaemolyticus	Seawater, marine life	-	+	-	+	Raw fish, crabs, and other shellfish
Yersinia enterocolitica	Water, wild animals, pigs, dogs, poultry	+	+	-	+	Milk, pork, and poultry
VIRUSES:						
Hepatitis A virus	Man	+	+	+	-	Shellfish, raw fruit and vegetables
Norwalk agents	Man	+	+	0	-	Shellfish
Rotavirus	Man	+	0	+	-	0
PROTOZOA:						
Entamoeba histolytica	Man	+	+	+	-	Raw vegetables and fruits
Giardia lamblia	Man, animals	+	±	+	-	0
HELMINTHS:						
Taenia saginata and T. solium	Cattle, swine	-	+	-	-	Undercooked meat
Trichinella spiralis	Swine, carnivora	-	+	-	-	Undercooked meat
Trichuris trichiura	Man	0	+	-	-	Soil-contaminated food

[a] Almost all acute enteric infections show increased transmission during the summer and/or wet months, except infections due to rotavirus and Yersinia enterocolitica, which show increased transmission in cooler months.

[b] Under certain circumstances some multiplication has been observed. The epidemiological significance of this observation is not clear.

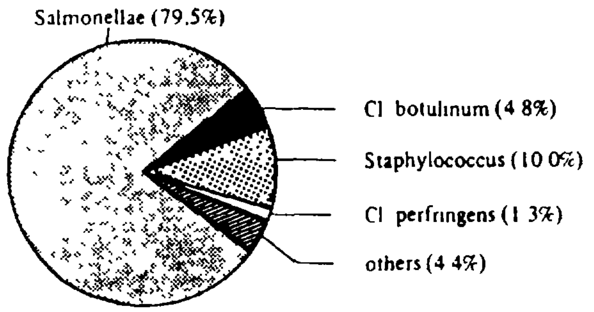
\+ = Yes

± = Rare

\- = No

0 = No information

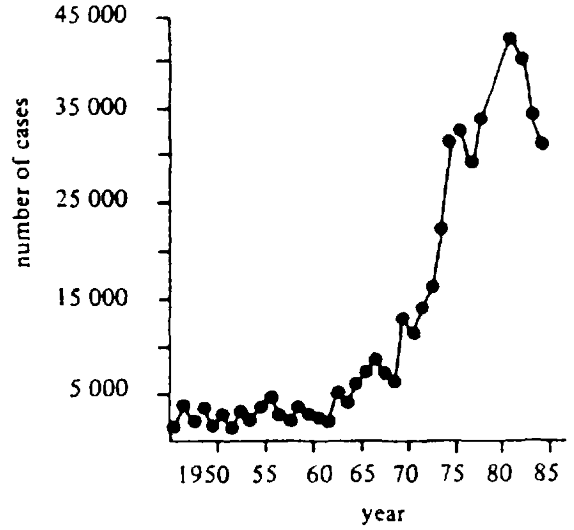
From Report of a Joint FAO/WHO Expert Committee on Food Safety, The role of food safety in health and development, WHO Technical Report Series 705 (1984) 14



From *Kampelmacher, E H*, IAEA-STI/PUB/568 (1981) 265

FIGURE 1:

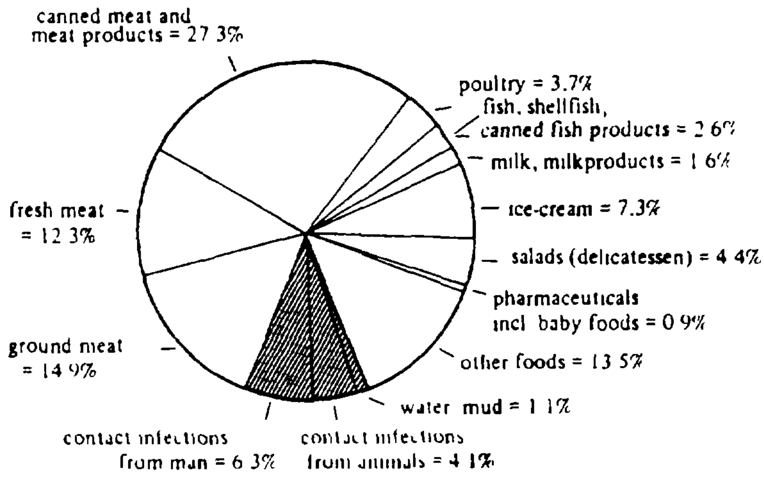
FOOD-BORNE INFECTIONS AND INTOXICATIONS
(FEDERAL REPUBLIC OF GERMANY 1968 - 1978)



From *Kampelmacher, E.H.*, IAEA-STI/PUB/568 (1981) 265 and *Gerigk, K*, BGA-Schriften 5 (1985) 35, MMV Medizin Verlag Munchen (modified)

FIGURE 2·

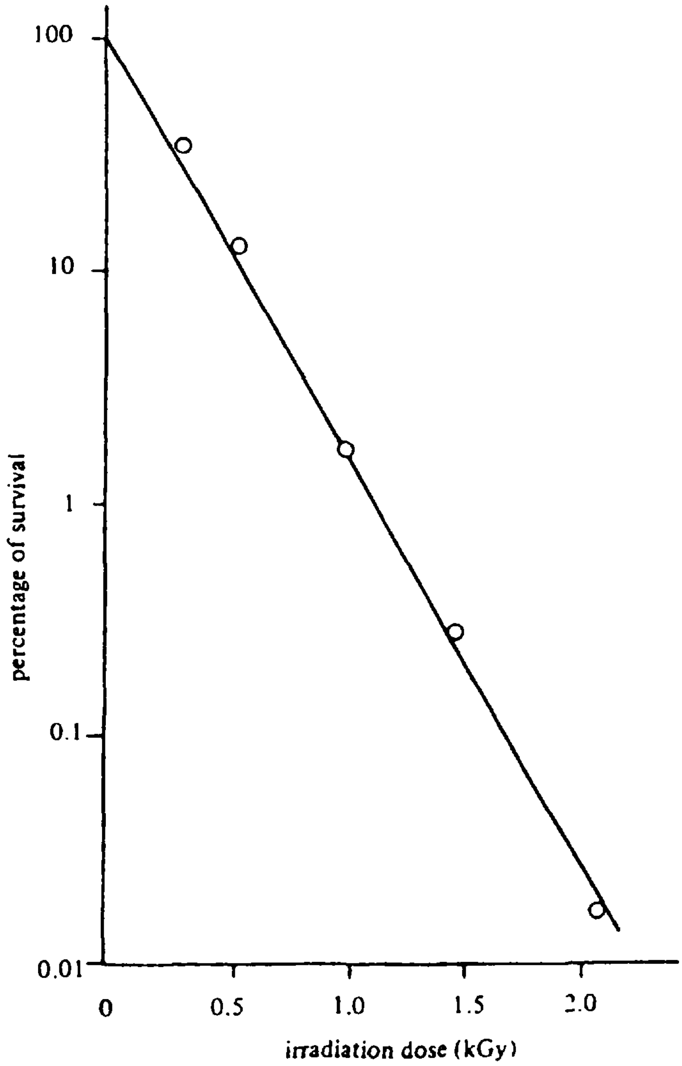
SALMONELLOSIS IN HUMANS
(FEDERAL REPUBLIC OF GERMANY)



From *Pöhn, H-P*, Bundesgesundhbl 26 (1983) 326

FIGURE 3·

SUSPECTED SOURCES OF INFECTION AT 1020 INITIAL SALMONELLA ISOLATIONS 1981



From *Simard, C., Lachance, R.A., Moreau, R.R.*, Can. Inst. Food Sci. Technol. J. 6 (1973) 250

FIGURE 4:

EFFECT OF IRRADIATION ON SALMONELLA TYPHIMURIUM IN GROUND BEEF; 7 D_{10} = 3.85 kGy

Beginning in 1980/81, the situation slowly changed. The number of Salmonellosis cases is declining, whereas Campylobacter jejuni, Staphylococcus aureus, Clostridium perfringens and Bacillus cereus are on the increase. Thus the control of those microorganisms by use of radiation technology also is of steadily increasing interest.

2. Radurization and Radicidation

Radurization is the "treatment of food with a dose of ionizing radiation sufficient to enhance its keeping quality by causing a substantial reduction in the numbers of viable specific spoilage microorganisms". Radicidation is "treatment of food with a dose of ionizing radiation sufficient to reduce the number of viable specific non- sporeforming pathogenic bacteria to such a level that none is detectable in the treated food when it is examined by any recognized bacteriological testing method" (7).

2.1. Meat and Poultry

The main purposes of radiation treatment of meats and poultry with low doses are the destruction of pathogenic microorganisms and helminths, and the extension of product life. In order to have good microbiological safety and product quality, the meats have to be refrigerated after the process. The main interest may be the irradiation of fresh beef, veal, pork, lamb and chicken. The radurization of processed perishable products such as sliced cuts or sausages may also be of interest. Protection from atmospheric oxygen (to prevent lipid oxidation) and possible recontamination vacuum packaging is needed, because irradiation alone does not result in an acceptable extension of product life. With vacuum packaging, product life of 30 days or more is possible. Ordinarely, however, vacuum packaging is not suited to fresh red meats, since it severely darkens them.

It is important to note that the effect of radiation on various types of red meat and meat products varies and affects product quality. Additionally, irradiation can also cause undesired side effects, such as an "irradiated flavor". Table 4 shows the threshold doses for this "irradiation flavor" to be different for red meats and chicken. The irradiations were performed between 5 and 10^{o}C. However, the use of lower temperatures will reduce this flavor. In the experiments by Sudarmadji and Urbain (Table 4), the flavor was determined after cooking and the dose at which the flavor was detectable depended on the species used. Additionally, radiation doses can discolor meat.

TABLE 4: THRESHOLD DOSE FOR COMMON RED MEATS AND CHICKEN FOR AN IDENTIFIABLE "IRRADIATION FLAVOR"

FOOD	THRESHOLD DOSE [kGy]
PORK	1.75
BEEF	2.5
LAMB	6.25
CHICKEN	2.5

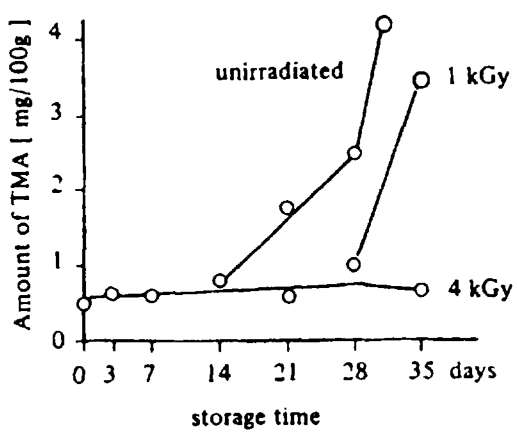
From *Sudarmadji, S. and Urbain, W.M.*, J. Food Sci., 37 (1972) 671

As mentioned earlier in reference to inactivating microorganisms by irradiation, the pathogens of greatest concern in raw red meats and poultry are the bacteria Salmonella and Campylobacter. A reduction factor of about 10^7 may be necessary to remove these organisms from meats. Doses between 5 and 8 kGy have been proposed (8, 9) for securing a 10^7 reduction of nonspore-forming microorganisms with poultry meat, red meats and sea foods. Because of the "irradiation flavor", this treatment can be done only when temperatures are kept below 0^oC.

A second group of organisms to be controlled by irradiation are the helminths, especially Trichinella spiralis. The dose for immediate inactivation of meat-borne Trichinella spiralis is about 6 kGy (10), but 0,02 to 0,03 kGy of ionizing radiation is enough to prevent maturation (11).

2.2. Fish and Shellfish

As with meat and poultry, the advantages of treating seafood by radiation can be seen in a quantitative and qualitative improvement of the available product, combined with lower spoilage losses on one hand, and on the other hand, due to reduction of the numbers of pathogenic microorganisms, on improved safety. Normally, even under the best of conditions, it is not possible to keep fresh fish and shellfish in unfrozen condition for consumption longer than one week. The alternative process of deep freezing is not possible in many countries for economical and technical reasons. The shelf life extension of seafood by irradiation is effected mostly by the reduction of the Pseudomonas population to an insignificant level. Doses within the range of 0.1 to 0.2 kGy can inactivate 99 % of the Pseudomonas population (12). Data on the composition of the remaining microbial contamination after irradiation cannot be given on a general basis, since this contamination depends on the qualitative and quantitative microbial load before irradiation. This initial contamination however, may vary for the same type of fish, depending on seasonal conditions, different fishing grounds and methods, the length of time fish was kept aboard ship, and temperature and possible contamination aboard ship. After radiation treatment with doses ranging from 1 to 3 kGy, the microflora is usually dominated by Achromobacter (13-17). Figure 5 shows the extension of storage time for trout by irradiation. For this experiment, the trimethylamine content was used as a quality criterion; fresh fish was vacuum packed prior to irradiation in plastic foil impermeable to gases and water vapor, irradiated with 10 MeV electrons and subsequently stored in melting ice.



From *Ehlermann, D., Münzner, R.*, IAEA-STI/PUB/196 (1970)65 (modified)

FIGURE 5: CHEMICAL EVALUATION OF TROUT DURING STORAGE ON ICE AFTER IRRADIATION: TRIMETHYLAMINE (TMA)

The microbiological safety of fresh fish and shellfish largely may be determined by the presence or absence of pathogenes. Of non-sporeforming pathogenic bacteria, among others there are Salmonella, Shigella, E.coli, Staphylococcus aureus, Vibrio cholera and Vibrio parahaemolyticus. Of the sporeforming pathogens, the genus Clostridium, and mainly Clostridium botulinum, is of primary concern when dealing with radiation treated fish products. While Pseumonads, the microorganisms which normally cause spoilage in seafood, are reduced by a factor greater than 10^6 with a radiation dose of 1.5 kGy, the same dose reduces C. botulinum type E by a factor of only 10. Concern has been expressed that a large reduction of Pseudomonads will prevent or delay the development of the characteristic spoilage odour on storage of the fish, while the small reduction of C. botulinum may make the product toxic before it is recognized as spoiled.

The level of contamination of C. botulinum generally is low, one finding (18) beeing 17 spores per 100 g of fish. At low levels of contamination, toxic formation may be slow to happen, and it has been suggested that this will ensure safety, since detectable spoilage would occur first (19). To assist in this, it has been proposed to use a relatively small amount of radiation in order to limit the product life extension to less than that needed for toxic formation.

While such approaches may seem reasonable, they are in fact not sufficiently certain to assure safety. The only procedure that provides adequate safety is to hold the irradiated products at temperatures below 3.3^{o}C. Below this temperature toxin production does not occur.

Similar to the irradiation of meats, it should be noted that undesirable organoleptic changes may also occur with irradiation of seafood, particularly with lean fish. Most non-frozen fish and fish products cannot be irradiated with doses higher than 3 kGy; exeptions are smoked products or very fat fish, as for instance mackerel, in which possible radiation induced organoleptic changes may not be noted due to their relative strong odor and flavor. Therefore, when choosing the optimum dose, the absence of detectable organoleptic changes must be substantiated. A second criterion in choosing the optimum dose is the adjustment of the dose to the desired storage time and temperature. Seafood is generally irradiated in packaged condition. Cold storage extends the product life considerably, as shown in Table 5.

TABLE 5 THE MAXIMUM SHELF LIFE VALUE (IN DAYS) OF IRRADIATED AND NONIRRADIATED COMMERCIAL-QUALITY COD FILLETS

RADIATION DOSE [kGy]	STORAGE TEMPERATURE [°C]				
	0.6	3.3	5.6	8.8	12.8
0	12 - 14	11	7 - 8	5 - 7	3 - 4
0.75	23 - 40	11 - 27	9 - 11	8 - 11	6 - 7
1	30 - 49	15 - 30	11 - 15	10 - 12	6 - 9
2	45 - 50	29 - 32	22 - 23	13 - 15	8 - 10

From *Ronsivalli, L.J., King, F.J., Ampola, V.G.*, and *Holston, J.A.*, Bureau of Commercial Fisheries Technological Laboratory, for U.S. Atomic Energy Commission Contract No. AT(49-11)-1889, Gloucester, Mass., 1970

TABLE 6: OPTIMAL RADIATION DOSE LEVELS AND SHELF LIFE AT 0.6°C FOR FISH AND SHELLFISH AEROBICALLY PACKED IN HERMETICALLY SEALED CANS

SEAFOOD	OPTIMAL IRRADIATION DOSE [kGy]	SHELF LIFE [WEEKS]
OYSTERS	2.0	3 - 4
SHRIMP	1.5	4
SMOKED CHUB	1.0	6
YELLOW PERCH FILLETS	3.0	4
PETRALE SOLE FILLETS	2.0	2 - 3
PACIFIC HALIBUT STEAKS	2.0	2
KING CRAB MEAT (COOKED)	2.0	4 - 6
DUNGENESS CRAB MEAT (COOKED)	2.0	3 - 6
ENGLISH SOLE FILLETS	2.0 - 3.0	4 - 5
SOFT-SHELL CLAM MEATS	4.5	4
HADDOCK FILLETS	1.5 - 2.5	3 - 4
POLLOCK FILLETS	1.5	4
COD FILLETS	1.5	4 - 5
OCEAN PERCH FILLETS	1.5 - 2.5	4
MACKEREL FILLETS	2.5	4 - 5
LOBSTER MEAT (COOKED)	1.5	4

From *Slavin, J.W., Nickerson, J.T.R., Goldblith, S.A., Ronsivalli, L.J., Kaylor, J.D., Licciardello, J.J.*, Isot. Radiat. Technol. 2(1966)365

In Table 6, the optimum radiation doses are compiled together with the respective achievable product life for fish and shellfish products.

Various combination techniques have been examined. It was shown, for instance, that the inactivation of microorganisms can be improved by a combination of heat and irradiation (20-22). The irradiation of products while frozen, and the exclusion of atmospheric oxygen avoid off-flavor development.

2.3. Fruits and Vegetables

The many diverse preservation techniques applied today to fresh fruits and vegetables may well lead to a longer life of these products but, in most cases, they are accompanied by a loss in quality. In spite of some problems arising from the radiation treatment of these products (e.g. some softening and loss of flavor), this method nevertheless improves the situation, because it permits a longer life of fresh and not otherwise treated products. The major applications of irradiation are desinfestation and shelf-life extension, while radicidation is of lesser importance. Insect disinfestation will be discussed in Section 3. Some particular aspects of radurization are described herewith.

The use of ionizing radiation to obtain preservation of fruits and vegetables is more limited than with other foods. With doses necessary for radurization - mostly between 2 and 3 kGy, sometimes also between 5 and 6 kGy - these foods may undergo quality loss (e.g. softening).

Another reason is the extremely diversified microbial contamination of fruits and vegetables from a qualitative as well as quantitative view point. Added to this is the fact that the results from radiation treatment also depend on the product's state of maturation. The absence of suitable rapid methods for microbial status determination is a further obstacle. In addition, the radiobiology of fungi has

TABLE 7: STORAGE LIFE OF CERTAIN IRRADIATED FRUIT-ACCELERATED SPOILAGE BECAUSE OF INFECTION AFTER IRRADIATION

IRRADIATION DOSE BEFORE INFECTION [kGy]	STORAGE LIFE (d) BEFORE SPOILAGE OCCURS FOR:							
	STRAWBERRIES	CHERRIES	PEACHES	APRICOTS	TOMATOES	APPLES	TANGERINES	GRAPES
UNIRRADIATED CONTROL SAMPLE	3	9	6	3	3	5	5	6
1	3	9	6	3	3	5	5	6
2	3	12	6	3	3	5	5	6
3	3	12	6	3	2	5	4	6
4	3	12	4	2	2	2	3	6
5	0.2	7	2	1	1	2	2	5
6	0.2	7	2	1	1	1	2	5

From *Rogachev, V.I.*, IAEA, STI/Doc/10/54 (1966) 123 several characteristics which render the control of fungal growth more difficult (23-28). A further problem is exemplified in Table 6. At doses greater than about 2 to 4 kGy subsequent contamination will lead to accelerated spoilage. For the example in Table 7 various yeasts and molds were used to cause infection. However, the problems just described do not lessen the value of irradiating fruits and vegetables to obtain extension of their shelf life when otherwise not treated, and may improve the supply situation in many parts of the world. For certain products, the diseases responsible for their spoilage, and the radiation doses required for shelf life extension, are listed in Table 8. Within the range of these doses undesirable side

TABLE 8: DOSE REQUIREMENT AND EFFECTS OF RADURIZATION ON SELECTED FRUITS AND VEGETABLES FOR POSTHARVEST DISEASE CONTROL

FRUIT/VEGETABLE TYPE	DISEASE	DOSE REQUIRED [kGy]
BERRIES		
Strawberry	Gray mold	1.86 - 4.00
	Leak	2.00
	Rot	2.00 - > 3.00
CITRUS		
Orange, etc.	Green mold/Blue mold	1.40 - 1.86
	Stem-end rot	> 3.00
	Citrus brown rot	2.00
STONE		
Apricot, cherry, peach, plum and nectarine	Brown rot	2.50 - 3.00
	Gray mold/ Blue mold/ Rot (sweet cherry)	2.00 - 3.00
POME		
Apple, pear	Blue mold/Gray mold	1.86 - 2.00
	Black mold	2.00 - 3.00
TROPICAL		
Papaya, mango, banana	Stem-end rot	3.00 - 6.00
	Surface rot	3.00 - 6.00
TOMATO	Alternaria rot	2.50 - 3.00
	Rhizopus rot	2.00 - 3.00
TUBER		
Potato	Soft rot	0.18 - 4.77
	Late blight rot	0.46
	Pythium soft rot	1.37

From *Moy, J.H.*, Preservation of Food by Ionizing Radiation, Vol. III, CRC Press (1983)83 (modified)

TABLE 9 SUGGESTED CONDITIONS FOR INCREASING STORAGE LIFE OF CERTAIN IRRADIATED FRUITS

TYPES OF FRUIT OR BERRIES	RECOMMENDED STAGE OF RIPENESS BEFORE HARVESTING	RECOMMENDED RADIATION DOSE [kGy]	STORAGE LIFE (d) AT 25°C:	
			IRRADIATED	UNIRRADIATED
Strawberries	Normal	3 - 4	5 - 7	1 - 2
Raspberries	Normal	3 - 4	3 - 5	1
Cherries	Normal	2	20 - 30	6 - 7
Apricots	Normal and technical	2 - 3	7 - 8	2 - 3
Peaches	Normal and technical	2 - 3	12 - 15	5 - 6
Tkemali (a kind of damson)	Unripe	0 3 - 0 4	30	7 - 10
Grapes	Normal	2	15 - 30	4 - 7
Red tomatoes	Normal	2 - 3	20 - 30	3 - 7
Green peas (hulled and in pods)	Unripe	1 - 2	1 5 - 2	0 1 - 1
Tangerines	Normal	2	15 - 30	7 - 10

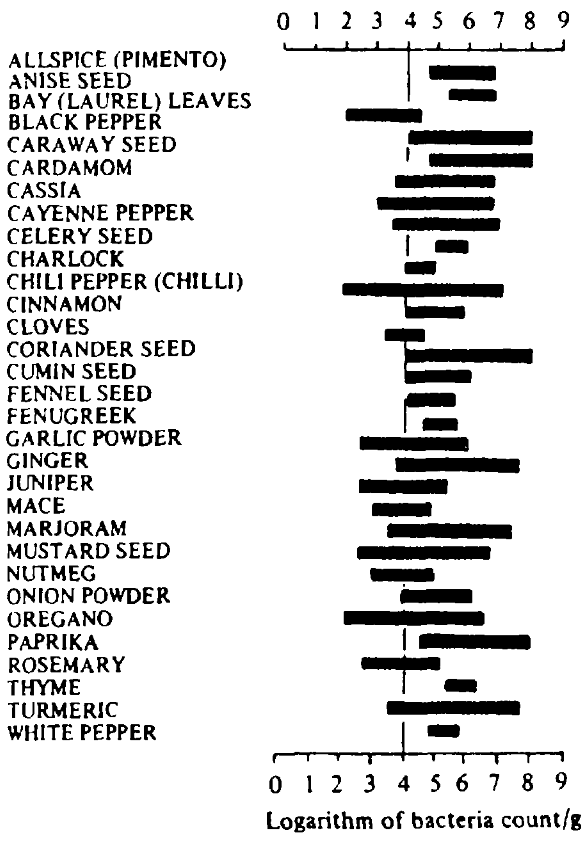
From *Rogachev, V I*, IAEA, STI/Doc/10/54 (1966) 123 (modified)

effects may, however, occur, e.g., some softening and loss of flavor in stone fruits. For certain selected fruits and berries Table 9 shows the storage time extension obtained by specific doses of radiation.

A combination treatment of ionizing radiation and heat shows promise for an elimination of undesirable side effects from the irradiation of fruits and vegetables. A study of the control of grey mold by gamma irradiation in strawberries is an appropriate example (29). The needed dose of 2 kGy resulted in a softening of the berries. By a brief period of heating (40°C; 10 min.) prior to irradiation, the dose could be reduced to 1 - 1.5 kGy. After this combined treatment, the berries showed no side effects. Similar experiments using radiation in combination with chemicals, controlled atmosphere, or UV radiation proved to be less successful.

2.4. Dry Food Ingredients

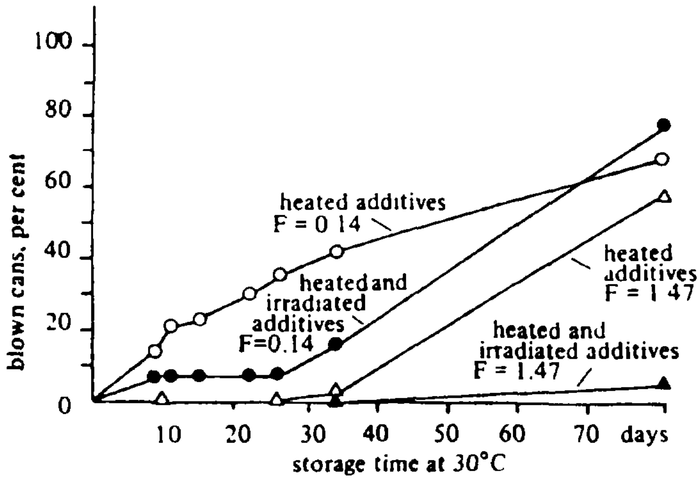
Dry food ingredients, such as spices, condiments, dehydrated vegetables and cereals are widely used in different categories of food and in food industry. One example is the use of large quantities of spices in the meat industry and by soup manufacturers. Especially in some parts of the food industry (e.g. butter containing different herbes, pepper-salami, some milk-products), it is necessary to use spices with no more than 10^4 microorganisms per gram. This means these spices cannot be used in their original form, since most of them have a much higher content of heatresistant bacterial spores, and especially of molds. Figure 6 shows the contamination of various spices by mesophylic aerobic bacteria. The figure quite clearly shows the necessity for this microbial contamination to be reduced in most cases. In addition to different types of molds (between 10^2 and 10^5 cfu per gram) such as Penicillum species, Aspergillus glaucus, Aspergillus niger and Aspergillus flavus, the majority of the microbial flora of spices consists of aerobic sporeforming bacteria; common examples are Bacillus cereus and Clostridium perfringens, both being foodborne pathogens.



From *Farkas, J.*, Preservation of Food by Ionizing Radiation. Vol. III, CRC Press (1983) 109

FIGURE 6: CONTAMINATION OF VARIOUS SPICES BY MESOPHYLIC AEROBIC BACTERIA

An example showing what may occur if spices undergo further process without having been sufficiently decontaminated is given in figure 7. This product, an additive mixture, consisted of ground rice, common salt, french herbes and powdered onions (6.6 % of product weight). Two experiments were performed one in which the product was heat-treated at about only one hundredth (f = 0,14) and the other at about one tenth (f = 1,47) of the heat treatment applied for sterilization (f = 13 to 15) in the food industry. In two further experiments, in addition to the heat treatment, a radiation treatment of french herbes with a dose of 15 kGy was used. The figure shows that the product storage stability produced by the irradiated additives is considerably better than that of the control group.



From *Farkas, J.*, Aspects of the Introduction of Food Irradiation in Developing Countries, IAEA, Vienna (1973) 43 (modified)

FIGURE 7: THE PERCENTAGE OF BLOWN CANS OF CANNED PORK LIVER PASTE AS A FUNCTION OF HEAT TREATMENT, DECONTAMINATION OF THE ADDITIVES AND STORAGE TIME

Because of the heat sensitivity of most spices and other dry food ingredients, heat sterilization is not possible in most cases. Compared with other methods for reducing the microbial contamination, e.g. fumigation with ethylene or propylene oxide, irradiation seems to be the more suitable method, in view of the possible adverse effects from fumigation and the applicability of radiation treatment for nearly all of the different spices. The doses necessary for the reduction of the total aerobic cell count by a factor 1000 are listed in table 10 for different spices and condiments.

TABLE 10: DOSE REQUIREMENT FOR 3 LOG-CYCLES REDUCTION OF TOTAL AEROBIC CELL COUNT IN SPICES AND CONDIMENTS

PRODUCT	DOSE REQUIREMENT [kGy]
Allspice (pimento)	> 5.0 - < 7.5
Anise	5.0
Basil	≥ 4.0 - < 10
Bay	< 8.0
Caraway	< 10.0
Cardamom	≤ 8.0
Cayenne	< 8.0
Celery leaves	> 4.0 - < 8.0
Celery seeds	> 5.0 - < 7.5
Charlock	8.0
Chive	8.0
Cinnamon	> 5 0 - < 10
Clove	> 5.0
Coriander	< 5.0
Cumin	5.0 - 6.0
Curry	≥ 4.0 - < 8.0
Dill tips	10.0
Fenugreek	10.0
Garlic powder	≥ 5.0 - ≤ 7.5
Ginger	≥ 5.0 - ≤ 10.0
Juniper	> 7.5 - < 10.0
Mace	> 5.0
Marjoram	> 5.0 - ≤ 10
Mustard seed	> 4.0 - ≤ 10
Nutmeg	≤ 5.0
Onion powder	≥ 8.0 - ≤ 10.0
Oregano	> 4.0 - < 10.0
Paprika	≥ 2.0 - < 8.0
Parsley	≥ 4.0 - ≤ 10.0
Pepper, black	> 4.0 - ≤ 6.0
Pepper, white	≥ 5.0 - < 10.0
Red pepper	< 6.5
Sage	> 4.0
Thyme	5.0
Turmeric	5.0
Spice mixtures	3.0 - 5.0

From *Farkas, J.*, Radiat. Phys. Chem. 25 (1985) 271

A comparison of Table 11 with figure 6 shows the reduction of microbial contamination by a factor 1000 is not always sufficient. However, if radiation doses are used that are too high, the sensory quality of the irradiated spices will be impaired. The threshold doses for organoleptic changes

TABLE 11: THRESHOLD DOSES FOR CHANGES IN SPICES AND HERBS DETECTABLE BY AN ORGANOLEPTIC PANEL

PRODUCT	THRESHOLD DOSE [kGy]
Allspice (pimento)	~ 15
Basil	> 10.0
Caraway seed	~ 12.5
Cardamom seed	~ 7.5
Celery seed	> 10.0
Charlock	~ 10
Chive	> 4 0 - < 8 0
Cinnamon	> 10 0
Coriander	~ 7 5 • < 5 0 (odour)
	varied. < 5.0 but also > 10 0
Cumin seed	~ 8.0
Curry	> 10 0
Dill tips	> 10 0
Fenugreek powder	< 5.0
Garlic powder	> 10.0
Ginger	> 5.0 • > 45 0
Juniper	> 15.0
Lemon peel	< 10 0
Marjoram	< 5 0 (odour) • > 10 0
	> 5 0 - < 10 0 • > 7 5 - < 12.5
Mustard seed	> 10 0
Nutmeg	> 10 0 • > 45 0
Onion powder	~ 8 0
	< 10 0 (optical index) • > 10 0 (smell and taste)
Orange peel	> 5 0 - < 10 0 (flavour)
Oregano	> 10 0
Paprika	> 8 0 - < 10 0 • > 10 0 • > 15 0
Pepper, black	1 5 • > 7 5 • > 10 0 • ≤ 10 0 • ~12 5
Pepper, white	> 10 0
Red pepper	> 6 5
Thyme	< 5 0 • > 10 0
Turmeric	> 5 0 - < 10 0

From *Farkas, J.*, Radiat. Phys. Chem 25 (1985) 271

in spices and herbes are summarized in Table 11. For some spices, e.g. paprika and black pepper, data from several authors are listed. The table shows a radiation dose of 10 kGy to be suitable for most spices. For practical purposes this dose is almost always sufficient. There are, however, some spices for which 10 kGy may lead to a significant impairment of flavor. All information currently available indicates that only very few chemical changes occur whith doses up to 10 kGy (30, 31). A recently published investigation of about 30 spices, however, found irradiation-caused changes in the solid body structure detectable by luminescence measurements longer than 6 months after radiation treatment (32, 33).

When irradiating thickening and gelling agents, doses of only 5 kGy may cause undesirable side effects, e.g. reduction of viscosity. On the other hand, higher doses may produce new characteristics in starches, for example, which are interesting from a technological standpoint.

3. Insect Disinfestation

Especially for grain, fruits and dried or smoked fish it is necessary to have methods for the efficient control or elimination of insects in order to prevent food losses. One example is the loss of dried and smoked fish. In many countries it is impossible to arrange the transport of fresh fish from the fishing grounds to the marketing centers. Since deep freezing or refrigeration is very often unavailable or too expensive, the products are dried or smoked. It is also more economical to transport the dried or smoked fish because an equally nutritional value is concentrated in a product of lesser weight. The Mali authorities (34) estimated the total loss of dried and smoked fish due to insect infestation as amounting to about 40 to 50%. This demonstrates how important good disinfestation methods can be.

Until now, fumigation is the most effective method for disinfestation. The disadvantages of this method include lack of penetration of the fumigant into the food in sufficient concentrations, possible problems from product damage and undesirable residues. Other methods, for example the storage of grain at a temperature of 10°C, are not practicable in many parts of the world. Therefore, radiation technology could be a vehicle for better insect disinfestation of foods. Some problems in that field are the large number of insect species that may be present, the different radiosensitivity during an insect life cycle, and the effect of various pre-radiation treatments. The radiosensitivities of different insects are summarized in Table 12. A dose of about 0.5 kGy is capable of controlling all of the insect species, except some Lepidopteras.

TABLE 12: SENSITIVITY OF STORED-PRODUCT INSECTS TO GAMMA RADIATION (THE SEX IRRADIATED IS NOT SPECIFIED)

SPECIES	HIGHEST DOSE [Gy] PERMITTING REPRODUCTION
	Acarina
Acarus siro L	500
	Coleoptera
Attagenus megatoma (F.)	132
Callosobruchus maculatus (F.)	50
Cathartus quadricollis (Guérin-Méneville)	200
Gibbium psylloides (Czenpinski)	200
Gnathocerus maxillosus (F.)	100
Lasioderma serricorne (F)	175
Latheticus oryzae Waterhouse	100
Oryzaephilus mercator (Fauvel)	100
O. surinamensis (L.)	100
Palorus subdepressus (Wollaston)	300
Rhyzopertha dominica (F)	132
Sitophagus hololeptoides (La Porte)	50
Sitophilus granarius (L.)	50
S oryzae (L.)	<132
S. zeamais Motschulsky	50
Tenebrio molitor (L.)	100
T. obscurus (F)	50
Tenebroides mauritanicus (L.)	50
Tribolium castaneum (Herbst)	100
T. confusum Jacquelin du Val	132
T. destructor Uyttenboogaart	50
T. madens (Charpentier)	200
Trogoderma glabrum (Herbst)	175
T inclusum (LeConte)	200
T. variabile (Ballion)	200
	Lepidoptera
Ephestia cautella (Walker)	500
Plodia interpunctella (Hubner)	1000
Sitotroga cerealella (Olivier)	1000

From *Tilton, E.W., Burditt, A.K.*, Preservation of Food by Ionizing Radiation, Vol. III, CRC Press (1983) 215 (modified)

4. Delay in Ripening and Physiological Decay of Fruits and Vegetables

There are different causes for the loss of about 1/3 of the harvest of fruits and vegetables before it reaches the consumer. After losses due to insects and microorganisms, postharvest ripening and physiological decay are of equal importance. Delay of the two latter processes would provide more time for foods to be transported to the consumers.

Postharvest ripening can be altered only in fruits, which normally do not stop ripening after harvest (i.e. green bananas). Other fruits (i.e. oranges) do not undergo a postharvest ripening process. A physiological breakdown occurs in both types of fruits and vegetables. The following three questions are of major importance before undertaking to alter the ripening process or the physiological decay of specific fruits and vegetables by irradiation:

- Can the desired effect be achieved?
- Can the effect be achieved without injury to the fruits and vegetables?
- Is the microbiological condition of the fruits or vegetables known, and is this condition considered to be the crucial factor for shelf-life?

Taking all of these parameters into account, Ackermine and Moy prepared a table in which the radiation response of 27 fruits is summarized (Tab. 13). This table shows quite clearly that only in bananas, mangos, papayas, sweet cherries and apricots a delay of postharvest ripening and physiological decay can be achieved. The microbiological storage decay can be controlled in tomatoes, strawberries and figs. For the majority of the fruits, the desired effect is not achieved, or is combined with quality loss. The radiation doses vary and are ranging from about 0.5 to 2 kGy. A combination process of hot water treatment and irradiation

TABLE 13: THE RESPONSE OF 27 FRUITS TO IRRADIATION

Ripening is delayed in	Physiological decay is delayed in	Storage decay is controlled in	Lack of tolerance in	Ripening is accelerated in	No ripening or physiological effect in
bananas	sweet cherries	tomatoes	pears	peaches	pineapples
mangoes	apricots	strawberries	avocados	nectarines	lychees
papayas	papayas	figs	lemons		honeydew melons
			grapefruit		
			oranges		
			tangerines		
			cucumbers		
			summer squash		
			bell peppers		
			olives		
			plums		
			apples		
			table grapes		
			cantaloupes		

From *Akamine, E.K., Moy, J.H.*, Preservation of Food by Ionizing Radiation, Vol. III, CRC-Press (1983) 129 (modified) has been tested with papayas and may help to solve some of the problems because it permits reduction of the radiation dose.

5. Sprout Inhibition

Three main reasons are responsible for storage losses of tubers and bulbs: sprout growth, shriveling due to moisture losses and disease, or storage rot (35 - 37). Sprouting can be controlled very easily by low-dose irradiation. Since sprouting of tubers causes water loss, irradiation also reduces moisture loss. Greatest interest has been in the irradiation of potatoes and onions, but a radiation induced sprout inhibition is also possible with carrots, shallots, garlic, yams, sweet potatoes, ginger, sugar beans, chestnuts and others. The doses required are between 30 Gy (minimum) and 150 Gy (maximum), preferably 100 - 120 Gy. Different varieties require different doses. With higher dose rates, a lower dose may be used for the same effect. Increased storage life of foods irradiated for sprout inhibition, may be obtained by reduced storage temperatures, high humidity and good ventilation. The time of the irradiation treatment is important. Onions should be irradiated very early after harvest, at least within one or two months, whereas potatoes may be irradiated several months later. Using doses lower than 150 Gy will protect the products from unfavourable side effects, such as darkening or browning, decreased wound healing and increased storage rot. Today, in most countries, potatoe sprouting is controlled by chemicals. Compared to radiation treatment, this is an inexpensive and very simple method. The main limitations are a degree of ineffectiveness and the toxicological risk from chemicals.

Conclusion

It has been shown that food irradiation is a method which can contribute to the reduction of food losses and increase safety food supplies. In that connection, the main purposes of food irradiation are: destruction of viable specific non-spore forming pathogenic bacteria, reduction of other pathogenic and spoilage microorganisms, control of helminths, insect disinfestation, delay in ripening and physiological decay and sprout inhibition. Different doses are necessary for the different applications. Some possible applications of food irradiation have encountered problems with unwanted side effects; examples are undesirable organoleptic changes of meats and softening and loss of flavor of fruits. In those cases, combination processes can be helpful. The irradiation of poultry while frozen and the combination of hot-water treatment and irradiation to increase the storage life of papayas are practical examples of combined treatment procedures. In summary it can be stated that the radiation technology should not be introduced to the food industry as a solution for all its problems, but should find its place among all of the different methods of food treatment. Irradiation of a food should be the method of choice if the desired effect cannot be produced by another method of treatment, or if the radiation treatment can substitute for a doubtful technologies such as fumigation. In this context, it is important to point out that of the necessity for a specific food irradiation application may be different in different parts of the world.

References

(1) Watermann, J.J., The production of dried fish, FAO Fisheries Technical Paper No. 160, Food and Agriculture Organization, Rome (1976).

(2) Rhode, R.H., A medfly eradication proposal for Central America, in: Controlling Fruit Flies by the Sterile-Insect Technique, Proceedings of a Panel, STI/PUB/392, IAEA, Vienna (1975) 159.

(3) Vail, P.V., Moore, I., Nadel, D., The Mediterranean fruit fly in Central America, IAEA Bull. 18(3/4), (1976) 42.

(4) Käferstein, F.K., The Global Problem of Foodborne Infections and Intoxications, Zbl. Bakt. Hyg., I. Abt. Orig. B 180 (1985) 335.

(5) Allen, R.J.L., Käferstein, F.K., Foodborne Disease, Food Hygiene and Consumer Education, Archiv für Lebensmittelhygiene 34 (1983) 81.

(6) Krug, W., Sozioökonomische Auswirkungen der Salmonellose, Bundesgesundhbl. 26 (1983) 330.

(7) Teufel, P., Microbiological implications of the food irradiation process, Food Irradiation Information, Published by the International Project in the Field of Food Irradiation, Karlsruhe, FRG, No. 11 (1981) 33.

(8) Licciardello, J.J., Nickerson, J.T.R., Goldblith, S.A., Elimination of Salmonella in poultry with ionizing radiation, in: Elimination of Harmful Organisms from Food and Feed by Irradiation, IAEA, Vienna (1968) 1.

(9) Quinn, D.J., Anderson, A.W., Dyer, J.F., The inactivation of infection and intoxication microorganisms by irradiation in seafood, in: Microbiological Problems in Food Preservation by Irradiation, IAEA, Vienna (1967) 1.

(10) Gould, S.E., Van Dyke, J.G., Gomberg, H.J., Effect of X-rays on trichina larvae, Am. J. Pathol. 29 (1953) 323.

(11) Gibbs, H.C., MacQueen, K.F., Pullin, J.W., Studies on the effects of gamma radiation on pork infected with Trichinella spiralis, Can. J. Pub. Health 55 (1964) 191.

(12) Niven, C.F., Jr., Microbiological aspects of radiation preservation of food, Ann. Rev. Microbiol. 12 (1958) 507.

(13) Lerke, P.A., Farber, L., Huber, W., Preservation of fish and shellfish by relatively low doses of beta radiation and antibiotics, Food Technol. (Chicago) 15(3), (1961) 145.

(14) Shewan, J.M., Liston, J., Experiments on the irradiation of fish with 4 MeV cathode rays and Cobalt-60 gamma rays, in: 2nd Int. Conf. Peaceful Uses Atomic Energy (United Nations), Geneva (1958).

(15) Corlett, D.A., Jr., Lee, J.S., Sinnhuber, R.O., Application of replicate plating and computer analysis for rapid identification of bacteria in some foods. II. Analysis of microbial flora in irradiated Dover sole (microstomus pacificus), Appl. Microbiol. 13(5), (1965) 818.

(16) Shiflett, M.A., Lee, J.S., Sinnhuber, R.O., Microbial flora of irradiated Dungeness crabmeat and Pacific oysters, Appl. Microbiol. 14(3), (1966) 411.

(17) Kazanas, N., Emerson, J.A., Effect of gamma irradiation on the microflora of freshwater fish. III. Spoilage patterns and extension of refrigerated storage life of yellow perch fillets irradiated to 0.1 and 0.2 megagrad, Appl. Microbiol. 16(2), (1968) 242.

(18) Goldblith, S.A., Nickerson, J. T.R., The effect of gamma rays on haddock and clams inoculated with Clostridium botulinum Type E, Rep. from MIT, Cambridge, No. MIT-3325, to U.S. Atomic Energy Commission (1965).

(19) Learson, R.J., Schwartz, M.S., Ronsivalli, L.J., Study of irradiated-pastuerized fishery products, Final rep. by National Marine Fisheries Service, Gloucester, Mass., to U.S. Atomic Energy Commission, No. TID25544, Contract No. AT(49-11)-1889, October 1970.

(20) Wood, T.H., Influence of temperature and phase state on X-ray sensitivity of yeast, Arch. Biochem. Biophys. 52 (1954) 157.

(21) Licciardello, J.J., Effect of temperature on radiosensitivity of Salmonella typhimurium, J. Food Sci. 29(4), (1964) 469.

(22) Pallas, J.E., Hamdy, M.K., Effects of thermoradiation on bacteria, Appl. Environ. Microbiol. 32(2), (1976) 250.

(23) Brace, K.C., Effects of X-rays on size of yeast cells, Proc. Soc. Exp. Biol. Med. 74 (1950) 751.

(24) Berk, S., The effects of ionizing radiation from polonium on the spores of Aspergillus niger. Mycologia 45 (1953) 488.

(25) Vasudeva, R.S., Bajaj, B.S., Chatrath, M.S., Granju, P.J., Stimulating effect of ionizing radiation on certain microorganisms, Indian Phytopathol. 12 (1959) 19.

(26) Uber, F. M., Goddard, D. R., Influence of death criteria on the X-ray survival curves of the fungus Neurospora, J. Gen. Physiol. 17 (1934) 577.

(27) Beraha, L., Ramsey, G.B., Smith, M.A., Wright, W. R., Effects of gamma radiation on brown rot and Rhizopus rot of peaches and the causal organisms, Phytopathology 49 (1959) 354.

(28) Sommer, N.F., Creasy, M., Romani, R.J., Maxie, E.C., Recovery of gamma irradiated Rhizopus stolonifer sporangiospores during autoinhibition of germination, J. Cell. Comp. Physiol. 61 (1963) 93.

(29) Sommer, N. F., Buckley, P.M., Fortlage, R.J., Coon, D.A., Maxie, E.C., Mitchell, F.G., Heat sensitization for control of grey mold of strawberry fruits by gamma irradiation, Radiat. Bot. 8 (1968) 441.

(30) Schüttler, C., Bögl, W., Behandlung von Gewürzen mit ionisierenden Strahlen - Chemische, organoleptische, mikrobiologische und toxikologische Aspekte. Report of the Institute for Radiation Hygiene of the Federal Health Office, ISH-Heft 35 (1984) FR Germany.

(31) Schüttler, C., Bögl, W., Behandlung von Gewürzen mit ionisierenden Strahlen - Chemische, sensorische, mikrobiologische und toxikologische Aspekte. Teil II. Report of the Institute for Radiation Hygiene of the Federal Health Office, ISH-Heft 49 (1984) FR Germany.

(32) Bögl, W., Heide, L., Chemiluminescence measurements as an identification method for gamma-irradiated foodstuffs, Radiat. Phys. Chem. 25 (1985) 173.

(33) Albrich, S., Stumpf, E., Heide, L., Bögl, W., Chemiluminescent- and thermoluminescent-measurements to identify radiation-treated spices. A comparison of the two methods. Report of the Institute for Radiation Hygiene of the Federal Health Office, ISH-Heft 74 (1985) FR Germany.

(34) Boisot, M.H., Ganzit, M., Disinsectization of African dried and smoked fish by means of irradiation, IAEA STI/DOC/10/54 (1966) 85.

(35) Atomic Energy of Canada Ltd., An Application to the Food and Drug Directorate, for the approval of the use of gamma radiation from Cobalt-60 for the prevention of sprouting in potatoes, Department of National Health and Welfare, Ottawa (1962).

(36) Atomic Energy of Canada Ltd., An Application to the Food and Drug Directorate, for the approval of the use of gamma radiation from Cobalt-60 for the prevention of sprouting in onions, Department of the National Health and Welfare, Ottawa (1962).

(37) U.S. Army Natick Laboratories, Irradiation of white potatoes for sprout inhibition with Cobalt-60, the Army Petition for Clearance and Approval to the Food and Drug Administration, Natick, Mass. (1963).

INTERNATIONAL DOSE ASSURANCE SERVICE PROGRAMME OF THE INTERNATIONAL ATOMIC ENERGY AGENCY

J.W. NAM
Division of Life Sciences,
International Atomic Energy Agency,
Vienna

Abstract

In order to execute normalization of high-doses on an international scale and to further promote dosimetry as quality control measures in radiation processing, the International Dose Assurance Service (IDAS) has recently been initiated in the framework of a high-dose standardization programme. IDAS is being provided on the basis of an "Agreement Concerning the Provision of a Dose Assurance Service by the IAEA to Irradiation Facilities in its Member States". The aim of the IDAS programme will be to meet stringent requirements for standardization of dosimetry, and to achieve concerted international efforts for quality assurance of radiation processing. Details of the programme and the achievements made to date are discussed.

Radiation processing offers technological advantages in the fields of sterilization, food preservation, processing of plastics and a variety of other products widely used in modern society. For food irradiation, in particular, the number of irradiated food items approved for consumption has considerably been increased in recent years. It is envisaged that, in the near future, food irradiation will become a regular commercial process as more countries come to recognize the safety and economic importance of this technology. It has recently been well recognized that a reliable dosimetry is a key requirement for good irradiation practice and quality assurance of the irradiated products. Accurate dosimetry is, therefore, a prerequisite for correct, safe, and legally acceptable plant operation in radiation processing.

For development of quality control measures by standardizing radiation dosimetry for radiation processing, the International Atomic Energy Agency (IAEA) has executed a new programme on high-dose dosimetry since 1977, and the International Dose Assurance Service (IDAS) to the irradiation facilities in its Member States has recently been started. The direct aim of the IDAS programme will be to meet stringent requirements for standardization of dosimetry, and to achieve concerted international efforts for quality assurance of radiation processing.

In order to first select a suitable transfer standard dosimetry system to be used for the service, dose intercomparisons have been performed with 19 laboratories in 14 countries and 1 international organization participating. In parallel, a coordinated research programme on the subject with activities concentrated on the study of influence quantities affecting reliability and accuracy has been organized for necessary investigations. Throughout a series of dose intercomparison studies with several candidate dosimeters, the alanine/ERS dosimetry system was found to be the most appropriate system for this particular purpose. This system has shown consistent and stable behaviour to cover the entire dose range of gamma radiation from 10 Gy (1 krad) to 100 kGy (10 Mrad) for radiation processing practices.[1,2]

Prior to the commencement of the service on an international scale, a pilot service project with 15 selected commercial radiation processing plants in 14 countries was executed. The result was excellent in general; whereas the mean ratio between nominal dose and estimated dose was 0.98; however, the overall deviation varied between -23% and +26%. The necessity of the international dose assurance service was demonstrated, an so far, no organization problems involved in the operation of the service and the problematic behaviour of the alanine/ESR dosimetry system under practical conditions have been found.

IDAS is being provided on the basis of an "Agreement concerning the Provision of a Dose Assurance Service by the IAEA to Irradiation Facilities in its Member States". Commercial and non-commercial irradiation facilities as well as high-dose applied research institutes dealing with gamma radiation doses extending from 10 Gy up to 100 kGy are invited to participate.

The Member States of the IAEA are invited to designate the irradiation facilities to participate in the service and to indicate its acceptance of the Agreement. Necessary data on each participating facility relevant to the provision of the service are requested to be provided with such notification. The designated facilities, however, may be screened due to a limited capacity of the service.

The Member State Party to this Agreement that imports irradiated goods will recognize a certain dose assurance as an internationally acceptable standard; the Agreement, however, does not go beyond that. The State Parties are therefore not obligated to import certain irradiated goods under the present Agreement.

Within 3 months of receipt by the IAEA of the notification for participation, the particulars of the appropriate service for each participating facility will be determined, and mailing to the facilities of the required number of dosimeters in accordance with an agreed schedule will be commenced. Conditions of use of dosimeters and of mailing them back to the evaluating laboratory designated by the IAEA will be provided in detail. The dosimeters reutrned after irradiation will be read out by means of an electron-spin-resonance analysis of radiation induced free radicals in alanine. The evaluated result will be communicated, together with a certification, to the respective facilities within a period not exceeding 20 days after receipt of the relevant irradiated dosimeters.

Operation of the alanine/ERS dosimetry laboratory is being provided under a contract with the Gesellschaft für Strahlen- und Umweltforschung m.b.H. (GSF, Munich, F.R. Germany). The IAEA is, therefore, subsidizing GSF for the production of dosimeters, ESR read-out, mailing dosimeters and related work under the "Agreement between the IAEA and GSF on a Joint Programme concerning the Standardization of High-doses through an

International Dose Assurance Programme" (Data of entry into force: 1 June 1985).

According to the cost-recovery principle for the service provided by the IAEA, participating facilities will be requested to reimburse part of the immediate expenditure incurred by the IAEA for the provision of the srvice whih is US$ 20,000 per year in total. The participants will be directly invoiced by the IAEA for a service charge to be paid every day. Since this service agreement has been made between the IAEA and its Member States, the government will accordingly be responsible for assuring such payment in the case of any outstanding debts of participating facilities.

All data communicated to the IAEA for the provision of the service from the participating facility will be kept in confidence. In particular, the results of the service will be kept entirely confidential, and are not to be published or otherwise made known to unauthorized persons.

In providing the service under the Agreement the IAEA will not assume any liability for compensation of damages as a result of dose assurance given.

The Agreement has entered into force on the date on which the Director General of the IAEA has received notification of acceptance from one Member State (12 July 1985). With respect to each Member State accepting the Agreement thereafter, it will enter into foce on the date of receipt of the notification of such acceptance. The Agreement will remain in effect with respect to a Party unless it notifies the Director General of the IAEA of termination of the Agreement by giving in writing 6 months' notice.

For the several months since the service has been in operation, 44 dose checks have been performed for 20 Co-60 and 1 Cs-137 irradiation facilities which are being operated at 19 institutes/plants in 13 countries. It has been observed by this date that the results are very good in general; however, the overall deviation varied between -28.8% and +22.7%.

The International Dose Assurance Service in force now is dealing only with photons. The service for electron beams will be implemented in the near future. For selection of a transfer standard dosimetry system to be used for the service, a series of intercomparison studies using calorimeters under standardized conditions in 10 MeV electron beams was recently completed. Two national laboratories will provide standardized 10 MeV electron beams in order to supply two dose ranges (low: 0.01- 3 kGy, and high: 5-100 kGy) for dose intercomparison. Following the normalization of electron accelerators, a series of electron dose checks using candidate dosimetry systems supported by a coordinated research programme is presently in progress with 4 national dosimetry laboratories participating. A comprehensive IDAS for both photon and electron irradiation facilities is expected to be carried out from 1988 onwards.

In view of the importance of accurate and reliable dosimetry as a quality control measure in radiation processing, the FAO/IAEA/WHO Expert Committee for Wholesomeness of Irradiated Food particularly noted that the operation of irradiation facilities should be subject to supervision by the appropriate national authorities in order to ensure that proper dose control is exercised. In this regard the high dose standardization programme of the IAEA was noted for calibration of dosimeter and dose assurance.[3] The Codex Alimentarius Commission stated, in the Codex General Standard for Irradiated Foods and the Recommended International Code of Practice for the Operation of Radiation Facilities used for the Treatment of Foods, that the control of the process within the facility shall include the keeping of adequate records including quantitative dosimetry using a recognized and calibrated dosimetry system in order to ensure the correct operation of the process. [4] It was also stressed by the International Association for Industrial Irradiation (AIII) in its Professional Regulation for Industrial Irradiation that a record of the irradiation doses should be kept by the plant operator.[5] Applying the appropriate dose is thus the key to the technologically and economically proper application of food irradiation. Proper determination of "average dose" and "maximum overall average absorbed dose (10 kGy)" can therefore be fulfilled by doing standardized dosimetry.

Until recently, there has been no concerted international effort to achieve measurement standardization of dosimetry and dose assurance for large radiation sources. It is, therefore, the objective of IDAS organized by the IAEA within the framework of the high-dose standardization programme. It is envisaged that the outcome of IDAS can be used by national authorities for quality control of radiation processing as well as for licensing and inspection of the facility. Further, the standardization of radiation processing dosimetry provides a justification for the regulatory approval of irradiated products and the basis of the international clearance for free trade.

The initiation of IDAS by the IAEA has met positive official response from many Member States, and a number of facility operators have shown interest in participating. The service which is provided on the basis of the Agreement has been well accepted by the participants, and so far no problem has arisen on either organizational or technical aspects. In order to allow interested facilities to test better the usefulness of this new service, the IAEA decided to extend its cost-free operation until the end of 1986. Accordingly, from January 1987 on, the IAEA will introduce reimbursement of a part of immediate expenditure incurred for the provision of the service. The cost for participants at each dose check would be about US$ 100. Any problem encountered in implementing IDAS will be improved for future development of the programme.

References

1. Report, Advisory Group on High-Dose Pilot Intercomparison (IAEA, Vienna, 9 - 13 November 1981).

2. Research in Radiation Processing Dosimetry, IAEA-TECDOC-321, (IAEA, Vienna, 1984).

3. Wholesomeness of Irradiated Food, Report of a Joint FAO/IAEA/WHO Expert Committee, Technical Report Series 659, (WHO, Geneva, 1981).

4. Codex Alimentarius, Volume XV, Joint FAO/WHO Food Standards Programme; Codex General Standard for Irradiated Foods, and Recommended International Code of Practice for the Operation of Radiation Facilities used for the Treatment of Foods, (FAO/WHO, 1984).

5. International Association for Industrial Irradiation (AIII) Newsletter 14, Professional Regulations for Industrial Irradiation, (1986).

SETBACKS AND PROGRESS IN THE COMMERCIALIZATION OF FOOD IRRADIATION IN THE NETHERLANDS

J.G. LEEMHORST
Gammaster B.V.,
Ede, Netherlands

Abstract

The developments on food irradiation in The Netherlands from the early stage to practical application at present were reviewed. These developments included an establishment of a Pilot Plant on Food Irradiation in 1968 for test marketing of a number of irradiated products such as strawberries, potatoes, mushrooms, chicken, fish, etc. A publicity campaign on food irradiation was initiated alongwith the test marketings. To enable the consumer to identify an irradiated product, a special label was designed by the Pilot Plant, with a description of radiation source, product and shielding walls. This facility was used for limited commercial scale irradiation of food until 1978 when Gammaster B.V., a commercial contract irradiator owned by the Dutch Pharmaceutical Co-operation OPG, was approached for processing food by irradiation. A new multipurpose irradiator which was designed for treating products having different densities, packed in containers of different dimensions, using a wide range of doses for different applications, etc., was put into operation in 1979. A computer control system was installed to programme different doses to be given to each carrier containing products with all important process data. Such efficient irradiator has resulted in an attractive incentive for food company to process their products by irradiation. For example, the cost of powder products (e.g. spices) having a density of 0.4 and irradiated at 8 kGy would be 0.1 US cent/kg. An average of 200 tons of food is being processed by irradiation at Gammaster per week. The future of food irradiation in The Netherlands will depends on the acceptance of irradiated food in its neighbouring countries as most of its agricultural products are geared towards export.

Introduction

For a good understanding of the circumstances influencing food irradiation in the Netherlands, some background information is of importance.

The Netherlands is one of the smallest countries in the world. Surrounded by three large nations; Germany, France and Great-Britain, we must behave carefully to avoid any conflict. This is even reflected in our education, most Dutch people have learned up to three foreign languages.

The total area of the Netherlands is 4.15 million hectare, of which only 2.02 million hectare is used for agriculture. Much of the land is below sea-level and has to be protected by dunes and dikes. Without our famous water protection systems, almost half the country would be under water at high tide.

This small piece of land is very densely populated. The production of enough food for 14.4 million inhabitants is a major challenge but our agricultural industry has dealt very successfully with it. By utilising the land to an optimal level, combined with modern technology and machinery and the high standard of education of our farmers, food production per unit arable land has become the highest in the world. We not only produce enough food for our own consumption, but are even able to export large amounts of it.

After the USA, the Netherlands is the second largest food exporter in the world. This export trade is obviously of very great importance and every effort is made to protect it.

Our major customer is the Federal Republic of Germany. Almost 30% of our food is exported there. Another 45% is exported to the other member-countries of the European Community (EC). In the free market system of the EC much of our export success depends on mutual goodwill and every effort is made to comply with the demands and regulations of our export markets.

The fact that the Federal Republic of Germany has placed a total ban on the use of ionising radiation for food treatment, and other EC countries have only a limited number of clearances is of decisive importance to the application of food irradiation in the Netherlands.

The Dutch Pilot Plant on Food Irradiation

In the continuous search for methods to improve food production and food-quality, a Dutch research centre was set up, at a very early stage, to investigate the possibilities of radiation applications. Radiation effects on organic substances were of main interest and optimistic studies concerning plant mutations, harvest improvements, shelf-life extension, etc. were soon being published.

It was in this atmosphere of optimism and expectation that in 1967 the construction of a Pilot Plant for Food Irradiation was started.

The Pilot Plant for Food Irradiation is a joint project of the Dutch Ministry of Agriculture and Fisheries and various commodity boards. The objective of the project is to investigate the practical application of the process, to familiarise future users and to inform the public and initiate large-scale industrial application.

At the commissioning of the project in 1967, the plant was equipped with two facilities:

- a gamma irradiation unit, consisting of a source with a maximum capacity of 250,000 Ci Cobalt 60 and an automatic transport system with tote boxes of 40 litres.
- a "Van de Graaff" electron accelerator of 3 MeV beam power and an automatic transport system.

To initiate legislation for the clearance of irradiated foods, the Dutch health Authorities introduced a specific clearing policy. Only after thorough investigation by a Committee of Experts were individual food items and food groups cleared for irradiation. This scrutinising body was composed of experts in fields such as microbiology, nutrition, toxicology, etc. Most members were officials of organisations like the Ministry of Health, the Ministry of Agriculture, Food and Feed Inspection Services, etc.

The Committee was organised by the Health Council and directly advised the Under secretary of Health on the authorisations of applying the irradiation process to foods.

The system of petitioning, investigation and clearance in different categories as developed by this Committee has been of major importance to the developments in the application of the food irradiation process in the Netherlands. It has created the basis for our leading position in the large-scale application of the process to a variety of food products.

The Pilot Plant on Food Irradiation came into operation in 1968. Soon the first irradiated food products for human consumption reached the market. Test marketings were done with several products, such as strawberries, potatoes, mushrooms, chicken, fish, etc. Many efforts were made to inform the public.

The media contributed a great deal to this information campaign and consumer organisations also supplied objective information to their members. In general, consumer reaction, if any, was positive and a number of reports were published. Of course there were also negative results, as with the mushrooms offered in a chain of supermarkets. The housewife there was given the choice between irradiated and fresh mushrooms. It is obvious that most buyers decided in favour of the fresh ones and irradiated ones were only bought out of curiosity.

To enable the consumer to identify an irradiated product, a special label was designed. This label (Fig. 1) symbolises the process, source (1), product (2) and shielding walls (3).

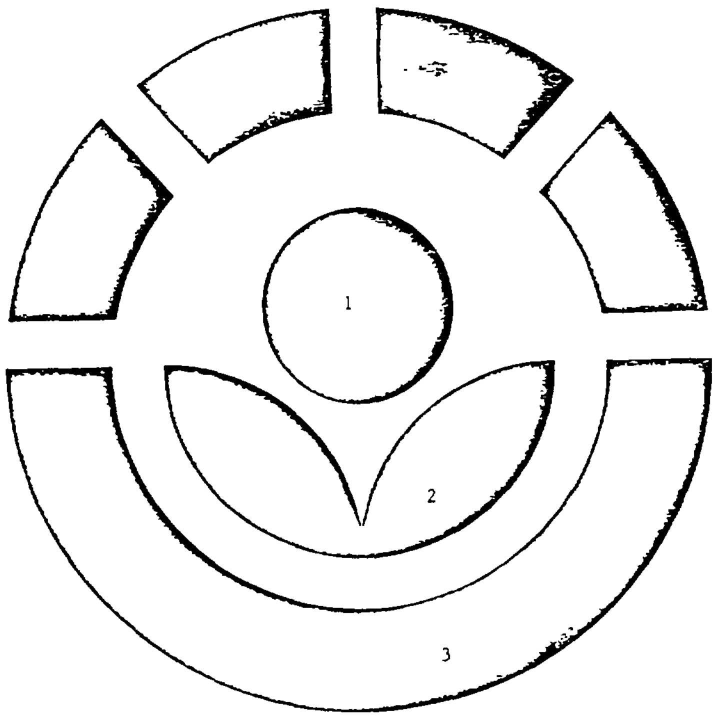


FIG.1. Symbol of irradiated food.

In the clearances for the irradiation of products for consumer presentation, the condition was incorporated that this label had to be applied. No such obligation exists in the Netherlands to label bulk or second generation products.

The labelling obligation proved to be an enormous obstacle for the acceptance of the process by the food industry. The fear of negative consumer reactions has prevented the application of the process to first generation (consumer presentation) products.

The fact that most of our food industry also produces for export markets, together with the possibility that the marketing of an irradiated product in the Netherlands could result in rejection in another, not yet opened, negative market, has limited the application of the process to bulk products and ingredients.

This fear was supported by very negative publicity in the German media especially. In 1980, one of the largest popular magazines "Der Stern" published the untrue story that all chickens imported from the Netherlands were irradiated. The most ridiculous and prejudiced article appeared in 1985, in a magazine that claims to give information on health aspects. The article is illustrated with a picture of a child, sitting on a supermarket-trolley. The purchases in the trolley emit a kind of radiation. The article mentioned many false and negative aspects.

The way in which German consumers should protect themselves against the so-called "radioactive irradiated food products" is illustrative of the writer's attitude:

So können Sie sich schützen. Bestrahlte Lebensmittel sind nicht gekennzeichnet. Trotzdem können Sie sich schützen:	This is how to protect yourself. Irradiated foods have not been marked. However, you can protect yourself:
- Nur Fleisch aus Deutschland ist garantiert nicht bestrahlt. Auch nicht deutsches Gemüse und Obst.	- Only meat from Germany is guaranteed to be non-irradiated. The same applies to German vegetables and fruit.
- Vorsicht bei Obst: Meist ist bestrahlte Ware an ihrer unnatürlichen Farbe zu erkennen.	- Be careful of fruit: You can usually recognise irradiated products because of their unnatural colour.
- Bestrahlte Zitronen duften nicht mehr typisch - sondern riechen nach Heu.	- Irradiated lemons no longer smell of lemons - but of hay.
- Bestrahltes Fleisch riecht wie "nasser Hund".	- Irradiated meat smells of "wet dogs".

It was in this environment that the Pilot Plant failed to fulfil its objective to initiate large-scale application in agricultural areas. After the first years of major efforts, interest faded, budgets decreased and activities had to be limited. The electron accelerator which proved to be impractical for food irradiation was sold and replaced by a small gamma source.

The Pilot Plant now performs test-irradiations for research institutes and private organisations. It is used as a training facility for the International Facility on Food Irradiation Technology (IFFIT) and accepts research projects in the field of food irradiation. Even though the original target has not yet been reached, the Pilot Plant still contributes significantly to national and international application of the food irradiation process.

Commercial application in the Netherlands

Until 1978, food irradiation in the Netherlands was only performed by the Pilot Plant. At that time, however, the food industry was beginning to show an interest in the process. Especially the spice industry and importers of tropical marine products sometimes offered large volumes for treatment. An investigation has shown, that this interest was due to the laws regarding product liability being changed and to the growing concern about the use of chemicals in food.

The production capacity of the Pilot Plant was too limited for the large volumes of deep frozen products that had to be treated and Gammaster B.V., a commercial contract-irradiator owned by the Dutch Pharmacists Cooperation OPG, was approached to do the job.

Since 1971, Gammaster B.V. has operated a one Million Curie capacity medical gamma-sterilizer. In addition to the high-dose sterilisation of medical supplies, several other applications such as the lower dose treatment of laboratory utensils and packings for milk-products have been developed and applied by this organisation.

In cooperation with the Pilot Plant, the medical tote box irradiator was used in test runs for lowering the contaminant level of spices and to eliminate Salmonellae in marine products. It soon became apparent that the tote box had several disadvantages when used for these applications: the process was very inefficient and labour-intensive. The concept of the facility, based on the high-dose treatment of large quantities of similar products and optimalisation of radiation efficiency, proved to be limiting in low-dose applications.

The growing demand for the gamma sterilization of medical supplies and the extension of these activities to other application areas led Gammaster B.V., in 1979, to extend the operation by building an additional irradiation facility.

Based on experiences with the tote box irradiator, a completely different concept was needed. Gammaster B.V. demanded a real multi-purpose irradiator, suitable for very low-dose irradiations as well as for high-dose irradiations. There must be no limitation because of product dimensions, and inefficiencies when changing the dose must be avoided. The irradiator must also be suited to the irradiation of dense product, and product handling must be limited.

The equipment-manufacturer did not welcome our list of demands very enthusiastically. Our requirements conflicted with existing design theories. We were willing to offer radiation efficiency for savings in labour and process flexibility and this required a completely different approach.

After long discussions, we were eventually able to convince the Atomic Energy of Canada Limited (AECL) that we were serious and so they designed a completely new irradiator, the pallet-irradiator (Fig. 2).

In this unit, large carriers, hanging on an overhead-rail system, are used for product transport. Each carrier can contain two pallets with dimensions of 100 x 120 x 180 cm. So the total product volume per carrier is 2 x 2.16 m^3 = 4.32 m^3.

The transport system can handle one carrier every two minutes, which equals a total process capacity of 130 m^3 an hour. The maximum source capacity is three Million Curie Cobalt 60, which even with this fast transport system could create a limitation on the lowest

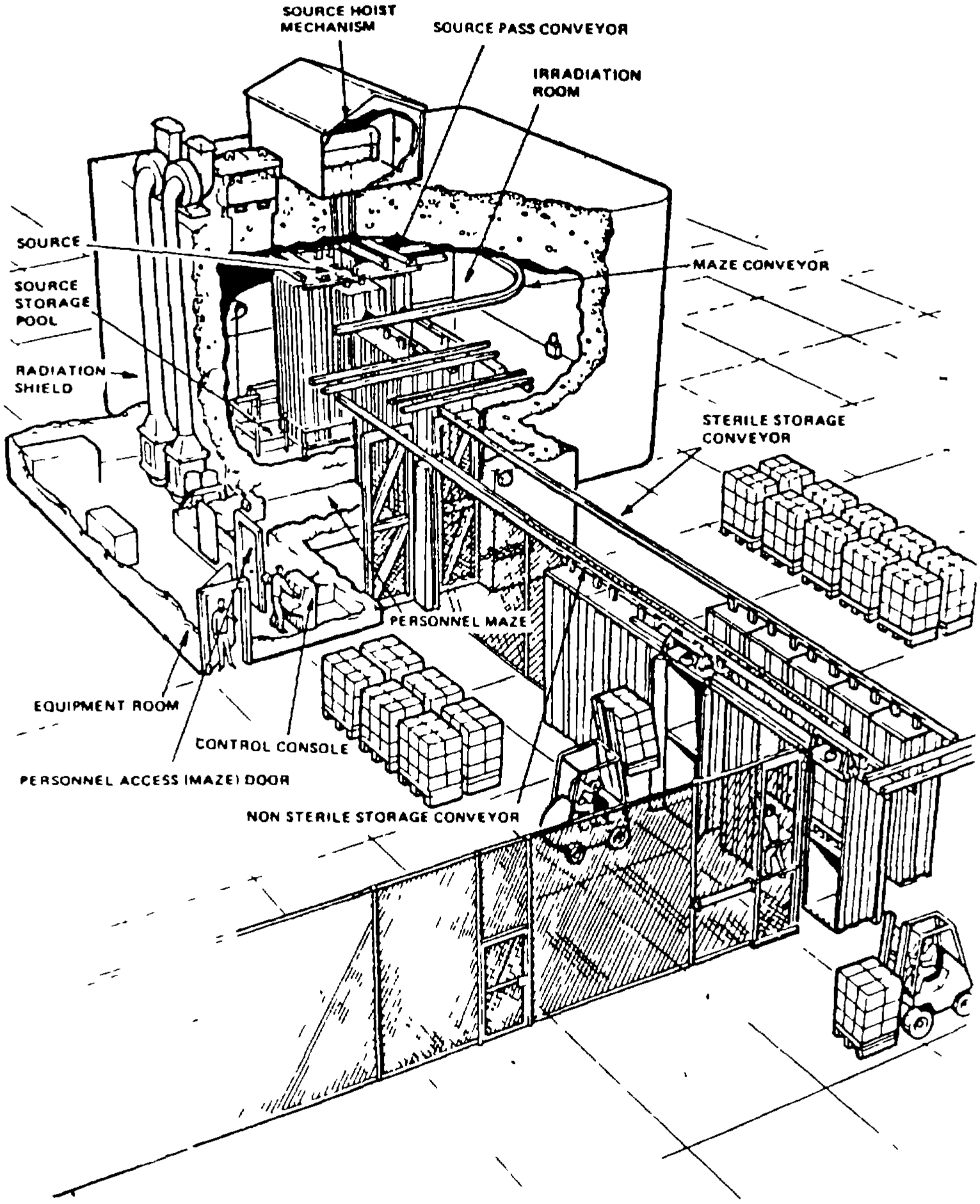


FIG.2. A prototype of a pallet irradiator.

dose to be applied. Therefore, a special source-rack, consisting of two cylinders (Fig. 3), had to be designed. Depending on the dose to be applied, the inner and outer of both cylinders can be raised into the radiation position. To improve dose uniformity, this source, with its length of 4.50 m, overlaps. The source is stored in a 9.00 m deep water basin.

To minimise inefficiencies caused by the use of dummy boxes, when changing over from one dose to another, Gammaster B.V. has extended the operation with a computer-control-system.

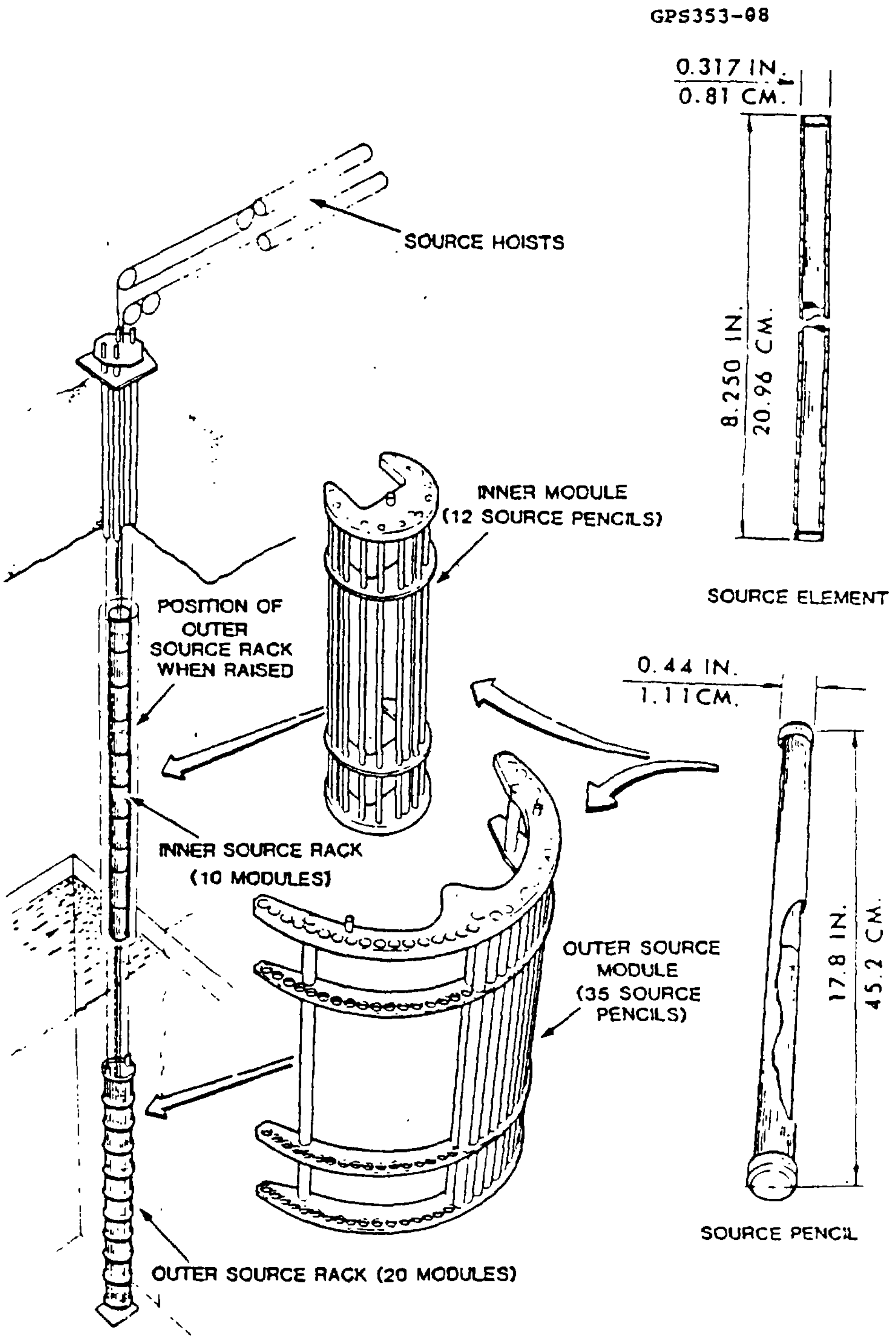


FIG.3. Source rack and modules.

Using this system, it is possible to program per carrier the number of cycles to be made around the source; so different doses can be given to each individual carrier, on condition that the final dose is a multiple of the dose received during one cycle.

The computer-control-system also generates for each carrier a process history file containing all important process data. Through the application of data handling equipment it is possible to request, even from a distance, all important actual and stored process- and control-data.

The application of the pallet-irradiator and the combination of different applications also makes it possible to perform food irradiation at a reasonable price. Table 1 gives some tentative prices in US dollars, depending on dose and density.

TABLE I.

Density	Max. weight per pallet	Dose in kGy 0.5	1	2	4	8
0.2	432 kg	24.5	32.3	38.9	53.7	77.8
0.4	864 kg	31.1	37	44.7	64	99
0.6	1,296 kg	38.9	43.5	52.5	77.8	120.5

When the pallet is used optimally, the price per kg is, for example:
- for various powders, density 0.4, dose 8 kGy 0.1 cent/kg
- for various powders, density 0.4, dose 2 kGy 0.05 cent/kg

The application of the food irradiation process has always suffered from the emotional association with the atomic bomb and radiation hazards. This association is the cause of over cautious behaviour of the legislators and, even in liberal-thinking countries, regulations for irradiated foods have been developed that are in no way comparable to the regulations normally applied to physical treatments. These strict regulations also accentuate the concern people may have and make them reluctant to consume irradiated products.

This emotional situation was considered when the Pilot Plant started its activities and an information and education programme was implemented. All media were involved in the information campaign, information booklets were distributed and food irradiation became a subject in the programme of several schools involved in food industry.

Once Gammaster B.V. became involved, a symposium on food irradiation was organised and an open door policy was applied. Anyone who showed interest was welcome and shown around the facility. When the pallet-irradiator came into operation interest increased, also on an international level. In the first three years of operation, in addition to many national visitors, more than two thousand foreign visitors were shown around.

In mid-1985 a well-known non-profit-making organisation, active in transferring knowledge concerning new developments and technology, published a booklet on food irradiation. In this booklet, authors from different disciplines gave their objective opinions on the process. This publication attracted the attention of the media again and a continuous stream of articles appeared in newspapers and magazines.

Television and radio also paid some attention to the subject on several occasions. Leading scientists and high-ranking officials have given their comments and even when their reactions were not always positive, the general attitude was rational and objective.

After the symposium in 1981, Gammaster B.V. started and advertising campaign. All food magazines placed advertisements showing examples of applications. In addition, background information on the process and legal status were given. Many of these magazines published articles on the process and so the food industry became familiar with it.

It was probably this continuous stream of information and the open door policy that has avoided negative public reactions. We hope that if we are allowed to continue in this way, food irradiation will be accepted just like any other physical process.

Actual situation

As already mentioned, the application of the process in the Netherlands depends on the situation in the neighbouring large countries. France already has several clearances and has started building a food irradiation facility. The fact that we have been visited twice by French delegations headed by a Minister clearly shows their interest.

We also have a continuous stream of visitors from industry and are in contact with several groups who intend to operate a food irradiation facility.

The development in Great Britain is somewhat behind compared with France. Irradiation of food for human consumption has not been cleared in the United Kingdom. Developments are being delayed by the fact that legislation is awaiting the report of a scientific committee. British industry is also showing great interest and much attention is being paid by the media.

The situation in Western Germany remains stable. The spice industry, forced by a ban on the use of ethylene oxide gases, has petitioned for a clearance on spices and herbs. The research institute concerned with spices has published a study in which the use of irradiation was recommended and the Federal Health Institute has stated that from a wholesomeness point of view there are no objections. But still nothing happens! The fact that the law has to be changed for clearance of spices, is easily used by the opponants to obstruct any development.

This situation, especially with regard to the Federal Republic of Germany, strongly influences progress in the Netherlands. As a result of the very negative German publicity, Dutch officials were afraid that we were becoming too advanced in the application of the process. The fear that rejection of our products could harm our export trade caused a dramatic change in the attitude of the Ministry of Agriculture and Fisheries. From being an active supporter it became the main opposition. For several years no new clearances have been granted and there is even a tendency to become more restrictive.

In the Netherlands, we are now waiting for other countries to catch up with us. Only when the process is legalised in other countries, will our government move again, but in the meantime Dutch industry has discovered the advantages of the process.

Weekly, an average of 200 tons of food for human consumption are being irradiated. All foods are still second generation, but some producers are preparing the marketing of labelled first generation products and we hope that these products will soon be appearing in the Dutch supermarkets.

We have acquired much expertise in the seven years of food-irradiation on an industrial scale. Our experience is that in many situations the process and process-conditions have had to be adapted to the product. We have found that sometimes positive laboratory experiments are no guarantee of successful large-scale application.

Our experience has shown that for a number of the applications developed in the first years of the Pilot Plant, there are less expensive alternatives and there is no economic justification for the application of the irradiation process.

As a pioneer in the field, we have had to develop our own acceptance, process control and product release procedure. Based on our experience in medical sterilisation we have implemented strict control procedures especially for decontamination processes. Our staff has been augmented by a food technologist and a quality assurance officer, and records are kept which are similar to the medical sterilisation procedures.

Our facilities are now equipped with computerised data generation equipment and we can give proof on each batch that the process has been applied correctly.

We view the future optimistically. Within the Netherlands, food irradiation is becoming an accepted process and we trust that the neighbouring countries will soon follow our lead. We are willing to share our experience with others, while believing that general acceptance of the food irradiation process will benefit all of us.

This general acceptance can only be achieved when honest information reaches all concerned, especially the consumer. This symposium will certainly help to spread this information and I am very grateful that I have been given the opportunity to contribute.

REFERENCES

1. The Pallet Irradiator, a Contractor's Approach to the Demands of the Market, by J.G. Leemhorst, Third Gamma Processing Seminar, June 6-9, 1983.
2. Irradiation of Foodstuffs - Technological Aspects and Possibilities, by D.Is. Langerak, Proceedings of the symposium Food Irradiation Now, October 21, 1981.

COSTS OF PICOWAVE PROCESSING

A. BRYNJOLFSSON
Department of Applied Biological Sciences,
Massachusetts Institute of Technology,
Cambridge, Massachusetts,
United States of America

Abstract

The cost of picowave processing of food, i.e., exposing food to x-rays, gamma-rays and fast electrons from electron accelerators, is calculated as a function of the type of source, the dose absorbed, the rate of throughput, as well as the annual throughput. When the annual throughput is in excess of 10000 tons per year the costs are usually between 1 and 10 cent per kg.

INTRODUCTION

Picowave* processing of food may improve the hygienic quality of food, expand distribution area, or extend the storage life so that it can be processed further or distributed during off-season times [1-5]. These benefits must be weighted against the cost of the process.

The cost of picowave processing food depends not only on the cost of the sources, the buildings, the material handling, and the quality control necessary to assure proper processing and recordkeeping, but also on the scale or the size of the operation, the form and size of the packaged food, and the amount of material handling.

The material handling costs are a significant fraction of the total processing costs. Therefore, the general layout of the processing, the storage facilities and distribution channels before and after the processing are important factors.

---

* In this article "picowave" processing of food is used rather than "irradiation" processing of food, because the word "irradiation" does not characterize the processing well and sometimes leads to misconceptions. We may irradiate food with light, with infrared radiation, with microwaves, and with particles such as electrons. We may irradiate non food items with neutrons, and many other radiations that induce radioactivity. Lay people sometimes confuse food "irradiation" facilities with nuclear reactors. Picowave facilities for processing food (food irradiation facilities) contain no fissionable materials, such as uranium, and no neutrons, both of which are basic to nuclear reactors and atomic bombs. There are no radioactive gases in picowave facilities, and the power levels are many orders of magnitude smaller than in nuclear reactors. For the sake of keeping the communication clear and for preventing misconception FDA has suggested use of the word picowave processing for the exposure of food to gamma-rays from Co-60 and Cs-137, to x-rays below 5 Mev, or to fast electrons from accelerators with energy less than 10 Mev. The wavelength of cobalt-60 gamma-rays is on the order of a picometer ($=10^{-12}$ meter).

For example, the picowave processing may be a link between the processing and packaging section of the food and the warehouse or storage rooms. In this case the additional material handling costs would be minimal.

In central picowave processing facilities, on the other hand, the transportation costs to and from the production facilities and storage facilities must be added. Interim storage facilities must be available at the picowave processing plant. The product must be loaded onto the conveyor. For each item the quality control requires that the sources and the conveyor settings be adjusted to meet the required dose. The dose and dose distribution must be measured, controlled and recorded. Further, the scheduling of shipments to and from the processing plant must be adjusted to fit the available capacity in the picowave processing plant.

PAST EXPERIENCE

Cost estimates for processing in cobalt-60 facilities are based on experiences gained from a few cobalt-60 pilot plant food processing facilities and several facilities for sterilizing disposible medical products [6-20]. The cesium-137 facilities are very similar to cobalt-60 facilities, and the cost of processing in these facilities is very similar to that of cobalt-60 facilities [21-23].

Cost estimates for processing with electron accelerators with electron energy less than 4 Mev and x-rays below 5 Mev are usually based on the extensive uses of these low and medium energy accelerators for polymerizing monomers and for crosslinking plastic materials. The operational reliability and operational costs are known, therefore, with reasonable certainty [24-26].

Traveling wave linear accelerators, both S-band and L-band have been used extensively in research and in a few cases for sterilizing medical products. Some of the world largest accelerators, such as the Stanford Linear Accelerator, use the same or similar components. The reliability and costs are therefore fairly well established [27-30].

The reliability and the operational costs are less well established for some of the newer types, such as the continuous wave (CW) linear accelerator [31],the cassitron [32],and the induction accelerator[33], but these types of accelerators, especially the CW accelerators, are likely to become less expensive in large facilities of the future.

The costs of processing each kg of food become significantly less as the annual throughput rate increases. In CASE STUDIES 1 and 2, we list the detailed cost estimates for cobalt-60 facilities and a 10 Mev traveling wave linear accelerator for products irradiated with a dose of 1 kGy and 10 kGy.

The physical characteristics of the radiation sources are very important in selecting the sources to be used and will be discussed first.

PHYSICAL CHARACTERISTICS OF THE RADIATION

The gamma-rays from the cobalt-60 and cesium-137 sources are much more penetrating than the electrons from the accelerators. About 75% of the gamma-ray energy is absorbed in the first 30 cm of water, while about 75% of the electrons energy is absorbed in 3.2 cm of water. Thus, the gamma-rays are about 10 times as penetrating as the electrons. Electron irradiation is usually less costly than gamma-rays, but its limited penetration, 3.2 g/cm^2 at 10 Mev, means that it can be used only for packages less than about 3.2 g/cm^2, such as slices of meats, fillets of fish, while gamma-rays can penetrate a sack of potatoes or a box 30-40 g/cm^2 thick. When the thickness is given as 30 g/cm^2, it means that the product of the thickness in cm and the density in g/cm^3 is 30 g/cm^2. When the density of the product is less than 1 g/cm^3 the thickness that can be irradiated increases. Therefore, for example, if the average density of potatoes is 0.6 g/cm^3, then the thickness of 50 cm corresponds to 30 g/cm^2. Sometimes, larger thicknesses are irradiated. This will result, however, in significant increase in dose variation in the product, or large D_{max}/D_{min} ratio, especially, if the product thickness is more than 50 g/cm^2. In case of electron irradiation, it is possible to irradiate the product from two sides and thereby about double the thickness that could be irradiated. However, quality control, i.e., assurance of dose, then becomes more difficult.

Penetration of gamma-rays.

The penetration in water for cobalt-60 gamma-rays is given by:

$$d_{Co-60} = \frac{1.26\ 10^{-1} \cdot C}{R^2} \cdot [B_e \cdot \exp(-0.0632\ r)]\ \text{kGy/hr} \qquad (1)$$

and for cesium-137 gamma-rays by:

$$d_{Cs-137} = \frac{2.73\ 10^{-2} \cdot C}{R^2} \cdot [B_e \cdot \exp(-0.082\ r)]\ \text{kGy/hr} \qquad (2)$$

where

- d = the incremental dose rate from the small source element C measured in curies,
- R = distance in cm from between the source and the point where the dose is measured,
- B_e = the energy absorption build-up factor, which varies with the thickness, and is slightly different for the two radionuclides, and
- r = thickness in cm of the material between the source and the point of dose measurements.

The functions inside the brackets are illustrated in Figs. 1 and 2 for water where the abscissa shows the penetration thickness, r, in water and the ordinate the value of the brackets in Eq.(1) and Eq.(2) for Co-60 and Cs-137, respectively.

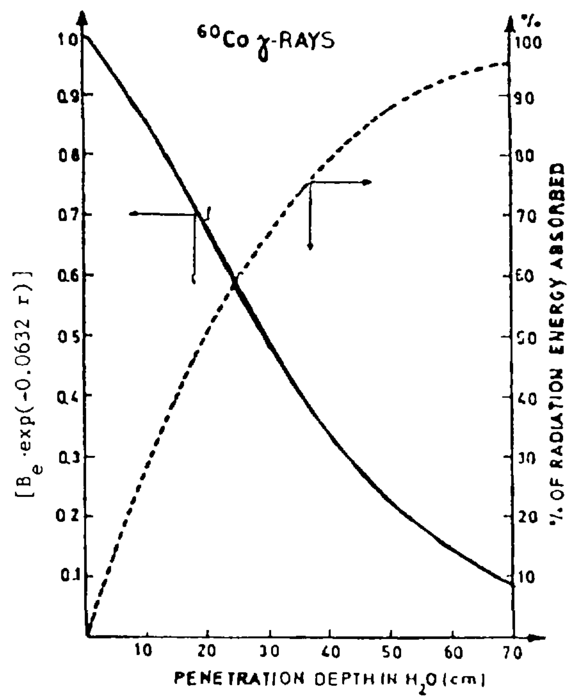
An example of simple calculation of dose from a gamma-source.

If: C = 10000 Ci (= 3.7 10^{14} becquerels); R = 30 cm; and r = 20 cm, then the values within the brackets, according to Figs. 1 and 2, are 0.68 and 0.73 respectively, and the dose rate increments from these source elements are then:

$$d_{Co-60} = \frac{1.26\ 10^{-1} \cdot 10000}{30^2} \cdot [0.68] = 0.953\ \text{kGy/hr}$$

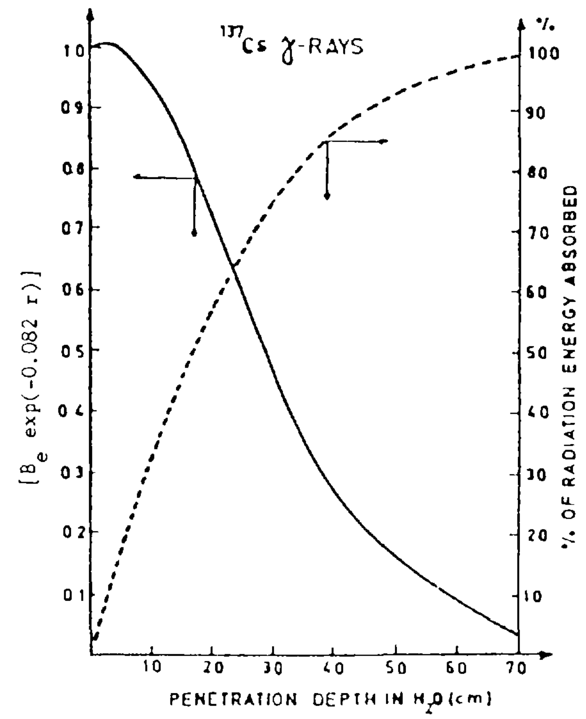
$$d_{Cs-137} = \frac{2.73\ 10^{-2} \cdot 10000}{30^2} \cdot [0.73] = 0.221\ \text{kGy/hr}$$

For each position in the sample, the dose rate from the different source elements can be added together to give the integrated dose rate, d, from the entire source.



The dose in water from a cobalt-60 source. The ordinate shows the relative dose multiplied by R^2 (see Eq. 1). The abscissa shows the depth in water.

Fig. 1.



The dose in water from a cesium-137. The ordinate shows the relative dose multiplied by R^2 (see Eq. 2). The abscissa shows the depth in water.

Fig. 2.

Penetration of electrons.

The dose at different depths in water for different electron energies is shown in Figs. 3, 4 and 5, and in Fig. 6 are shown similar curves for aluminium.

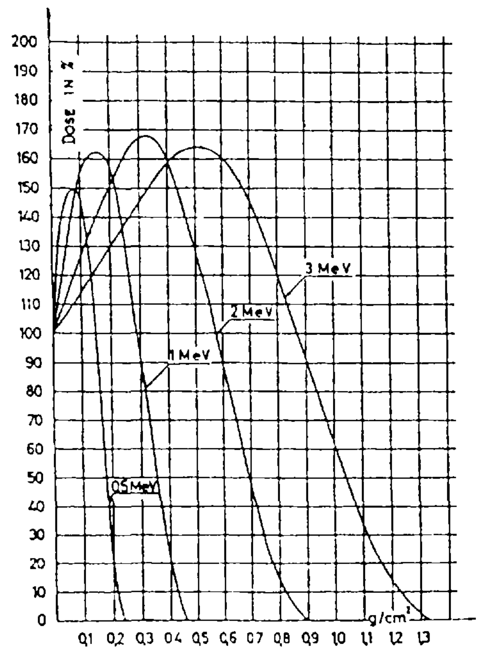


Fig. 3. The dose distribution in water irradiated by electrons with initial energies of 0.5, 1, 2 and 3 Mev, respectively. The ordinate shows the dose in arbitrary units. The abscissa shows the depth in water in units of g/cm^2.

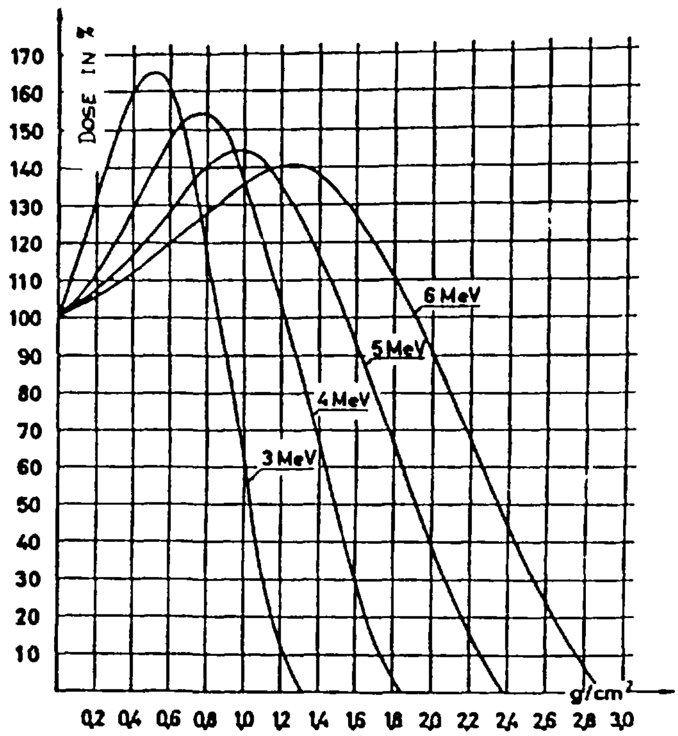


Fig. 4. The dose distribution in water irradiated by electrons with initial energies of 3, 4, 5 and 6 Mev, respectively. The ordinate showsn the dose in arbitrary units. The abscissa showsn the depth in water in units of g/cm^2.

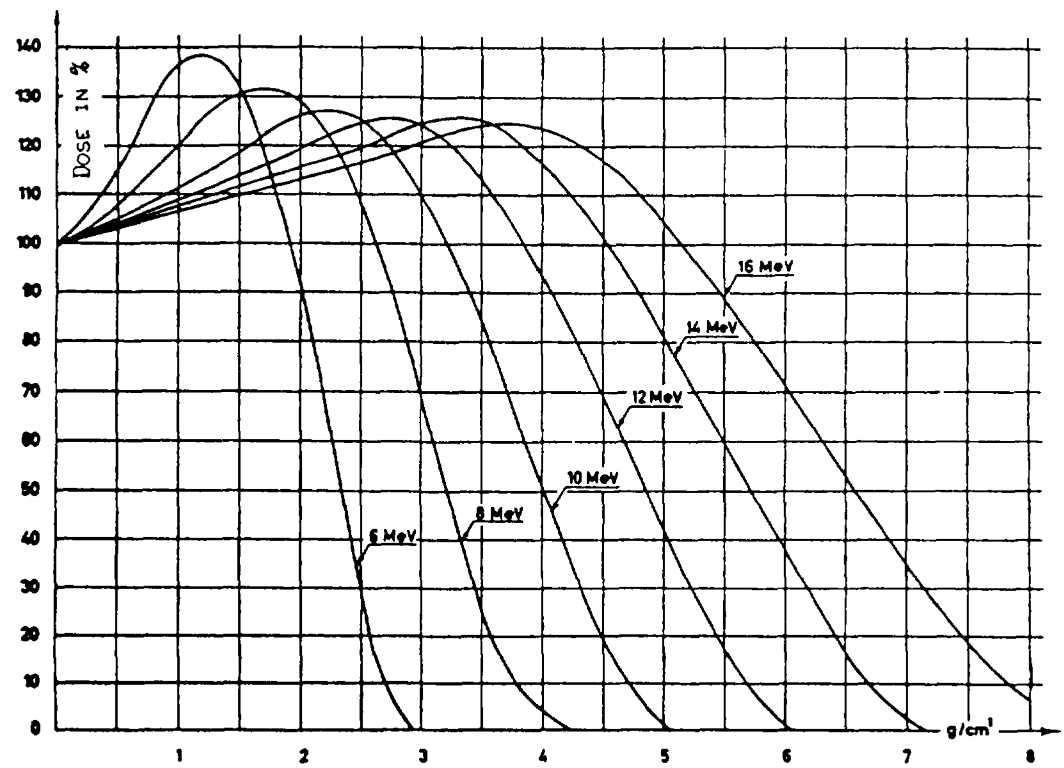


Fig. 5. The dose distribution in water irradiated by electrons with initial energies of 6, 8, 10, 12, 14 and 16 Mev, respectively. The ordinate shows the dose in arbitrary units. The abscissa showsn the depth in water in units of g/cm^2.

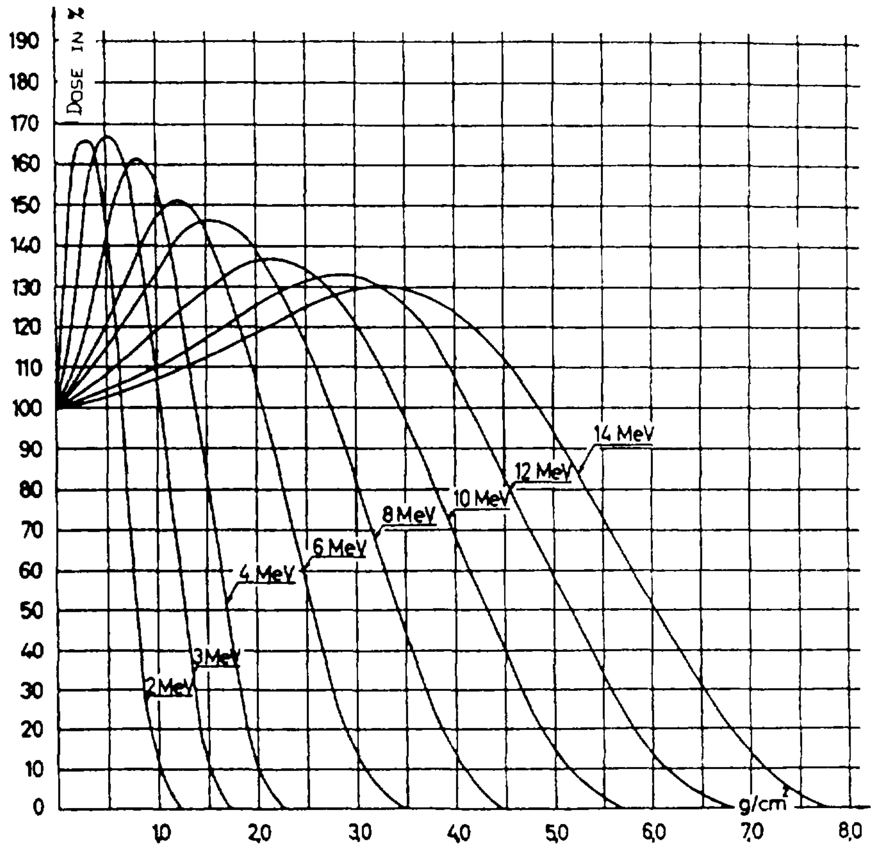


Fig. 6.

The dose distribution in aluminum irradiated by electrons with initial energies of 2, 3, 4, 6, 8, 10, 12 and 14 Mev, respectively. The ordinate shows the dose in arbitrary units. The abscissa shows the depth in aluminum in units of g/cm^2.

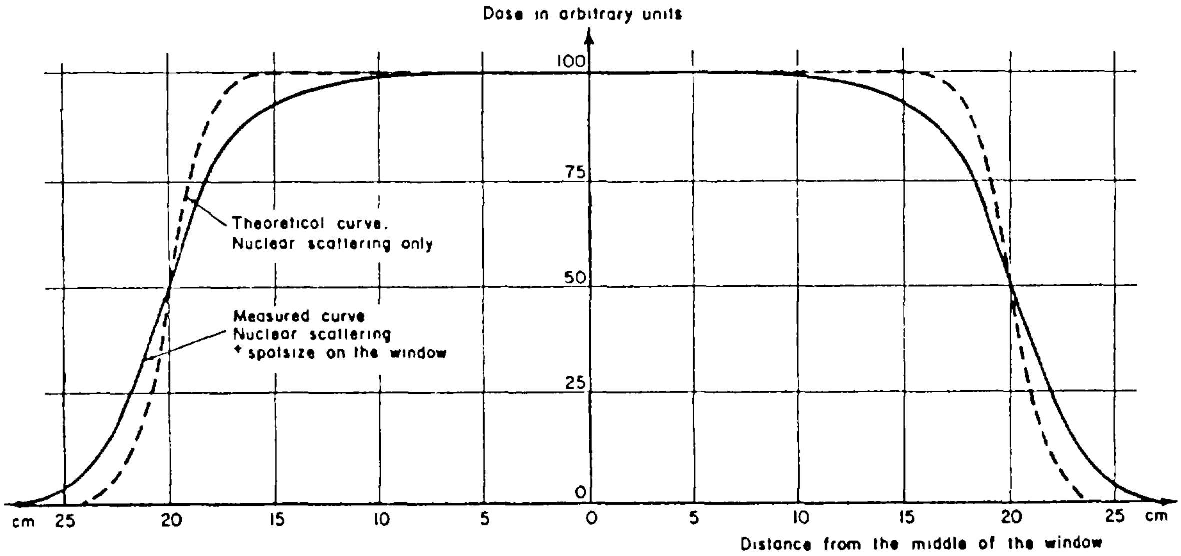


Fig. 7.

The dose distribution at the surface of the sample. The theoretical curve assumes that the diameter of the bean as it hits the window is very small and, thus, it includes only the nuclear scattering of the 10 Mev electrons. The measured curve tapers off more slowly at the edges because of the finite diameter of the beam, and because of the energy spread.

The electron beam is usually swept (scanned) back and forth at a right angle to the motion of the product on the conveyor. At the ends of the scan the dose will usually taper off gradually due to nuclear scattering of the electrons as they penetrate the accelerator window. Fig. 7 shows the dose distribution at the surface where the electrons enter the sample.

The electrons will also be scattered out of the sample at the edges of the sample. This will cause the dose to be lower at the edges of the samples as shown in Fig. 8.

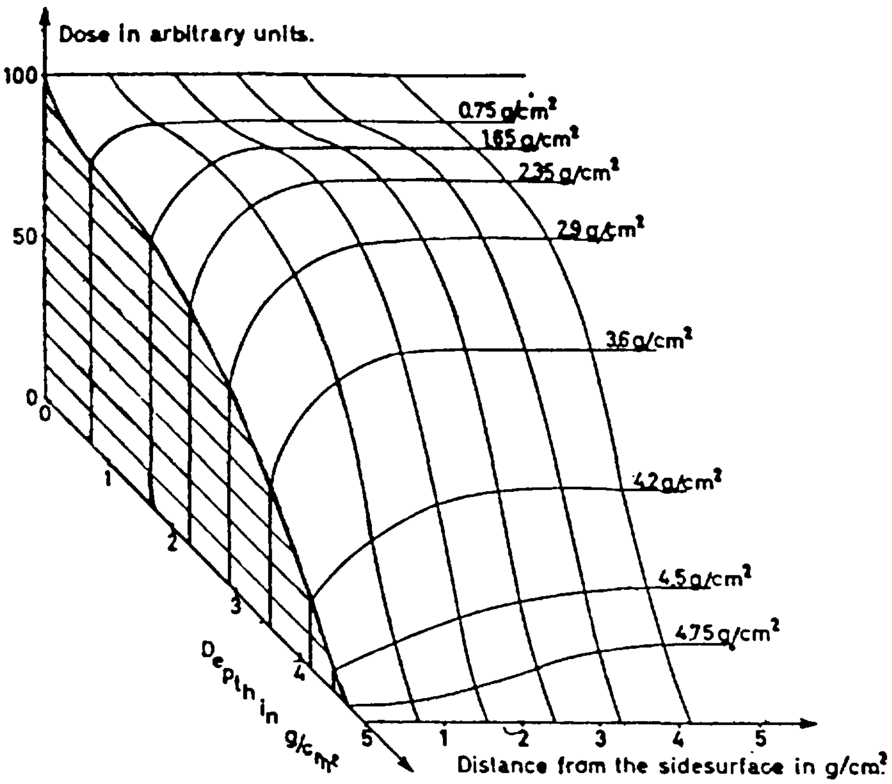


Fig. 8. The three-dimensional dose distribution in wood.

THROUGHPUT AND SOURCE SIZE

The size of the source will increase with the required dose, D, and the hourly throughput rate, X. If we measure the source size in kilowatts (kw), the dose in kilogray (kGy), and the throughput rate in kilograms per hour (kg/hr) then the relation that ties these quantities together is:

$$W = \frac{1}{3600} \cdot \frac{X \cdot D}{F} \text{ kilowatts of radiation energy} \qquad (3)$$

where F is the fraction of the source's radiation energy that is absorbed in the product. It is usually called the efficiency factor, and it is often in the range of 0.2 to 0.5.

If we measure the source size in curies (Ci), we have that 67300 Ci of cobalt-60 and 312000 Ci of cesium-137 correspond to one kilowatt of radiation energy. Instead of Eq.(3) we then have:

$$W_{Co-60} = \frac{67300}{3600} \cdot \frac{X \cdot D}{F} = 18.7 \cdot \frac{X \cdot D}{F} \quad \text{curies of CO-60} \qquad (3a)$$

$$W_{Cs-137} = \frac{312000}{3600} \cdot \frac{X \cdot D}{F} = 86.7 \cdot \frac{X \cdot D}{F} \quad \text{curies of Cs-137} \qquad (3b)$$

Example: Let us assume that we want to irradiate 10 tons of potatoes per hour with a dose of 0.1 kilogray, that is, X=10000 kg/hr and D=0.1 kGy. We assume that the design of the facility is such that F=0.2. The source size required, therefore, is: W = 1.39 kilowatts = 93500 curies of Co-60 = 433000 curies of Cs-137

COST RELATIONS

We must estimate the costs of investment in the sources, the buildings and the equipment that are needed to operate the facilites. Some examples of such analyses are given in CASE STUDIES 1 and 2. To the operational costs, we must add the interests on investment capital, as well as depreciation costs for sources, buildings and equipment. We must also add costs of taxes and insurances.

The operational costs are estimated on the bases of manpower required to operate the sources and to perform the quality control. Included also are costs of repair, maintenance, and spare parts replacement, as well as the costs of power and water.

The quality control includes, among other things, assurance and documentation that every package has received the required dose.

We must also estimate the material handling costs, which include unloading and loading the product from the trucks if required as well as loading and unloading the irradiation conveyor. In an in-house facility these material handling costs may be very small. CASE STUDY 2 and Fig. 10 show the costs when this material handling costs can be neglected.

All the relevant costs are added together and the sum for the entire year constitutes the annual costs, P, for operating the facilities. When P is divided by the annual throughput, (X·T), where X is the throughput in kg per hour, and T is the number of hours operated per year, we derive p, the irradiation costs per kg of product. We thus have that:

$$p = \frac{P}{(X \cdot T)} \qquad (4)$$

COSTS OF PICOWAVE PROCESSING

The Organizational Structure.

The structure of an organization may sometimes be divided into the following major components:

I. Management

1. Personnel office
2. Purchasing office
3. Accounting and data processing office
4. Legal office
5. Public relations office

II. Marketing

1. Marketing
2. Marketing research
3. Product research
4. Sales
5. Contracts
7. Distribution of products

III. Production

1. Engineering
2. Inventory control
3. Production scheduling
4. Production
5. Quality control
6. Warehousing

In the following CASE STUDIES, the focus is on item III above, the cost of production or picowave processing. The picowave processing costs as calculated in the CASE STUDIES summarized in Figs. 9 through 12 include 40% overhead charges to cover the management services, (see Tables X and XI of CASE STUDIES 1 and 2) which include charges for the management and the marketing. These overhead costs vary from one plant to another, and the 40% charge must be adjusted accordingly.

For example, if a poultry processing plant is already processing and distributing raw poultry products at refrigerated temperatures, then the overhead costs would be rather minor. The poultry products are irradiated as they leave the processing floor for the storage rooms or the shipping trucks. The irradiation facilities would be an additional link in the stream of products through the processing line. On the other hand, the overhead may be much greater if a central processing plant serves many customers in competition with other facilities.

The synchronization of shipments with irradiation schedule is usually more difficult in a central processing facility than in an in-house facility. The unloading of the products from the trucks as these arrive, loading of the trucks when the products are shipped, the accountability for the product to and from the central processing plant, the cost of an additional storage space will all add to the product handling costs.

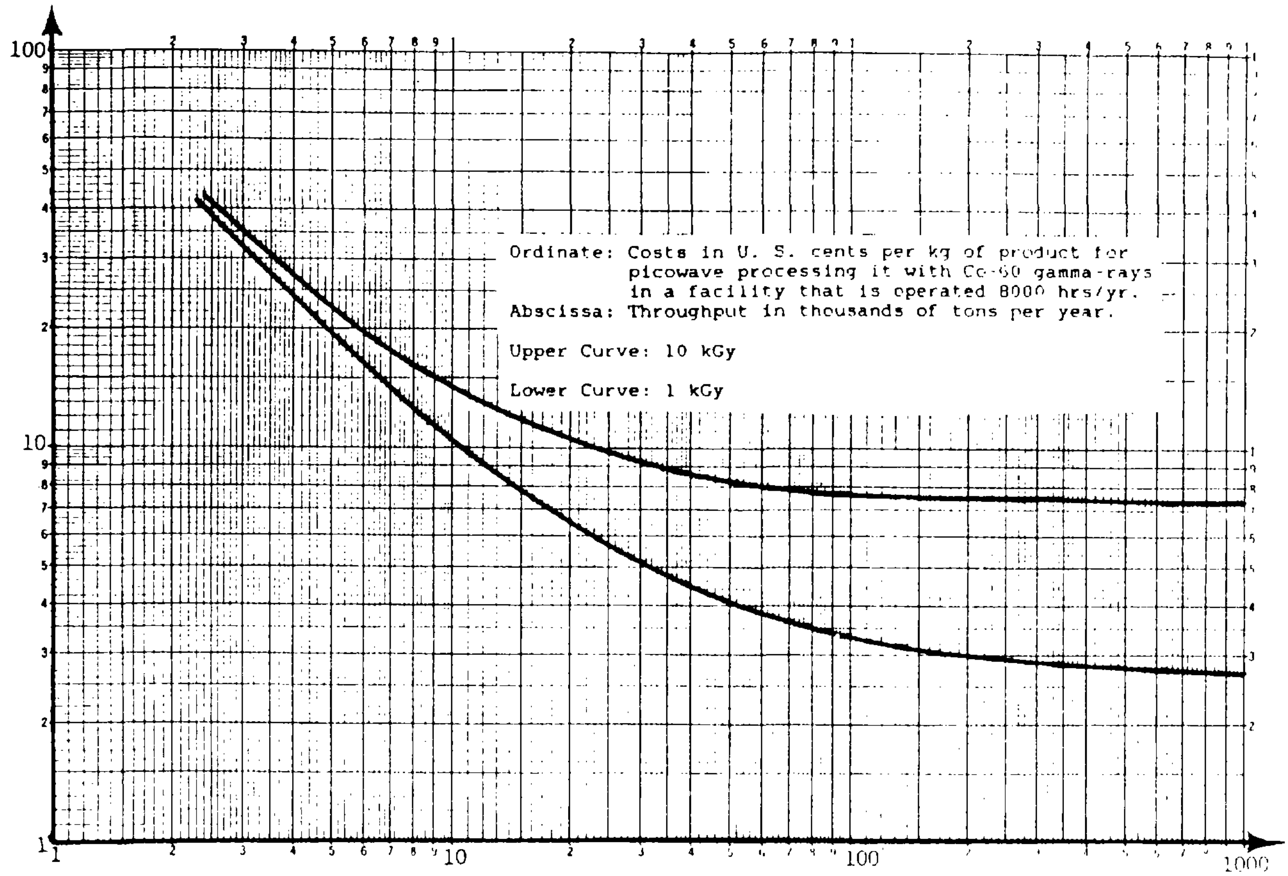


Fig. 9. Case studies on processing costs.

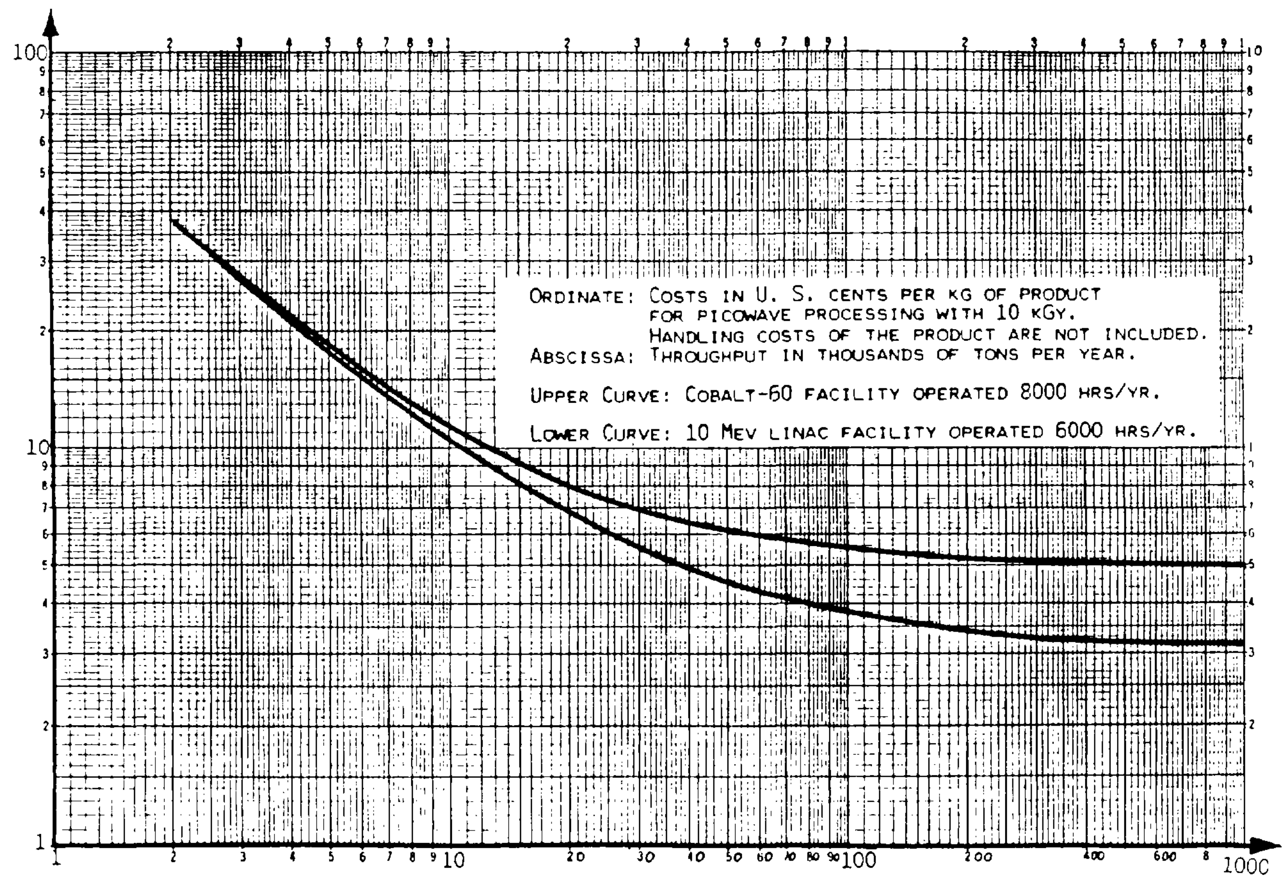


Fig. 10. Case studies on processing costs.

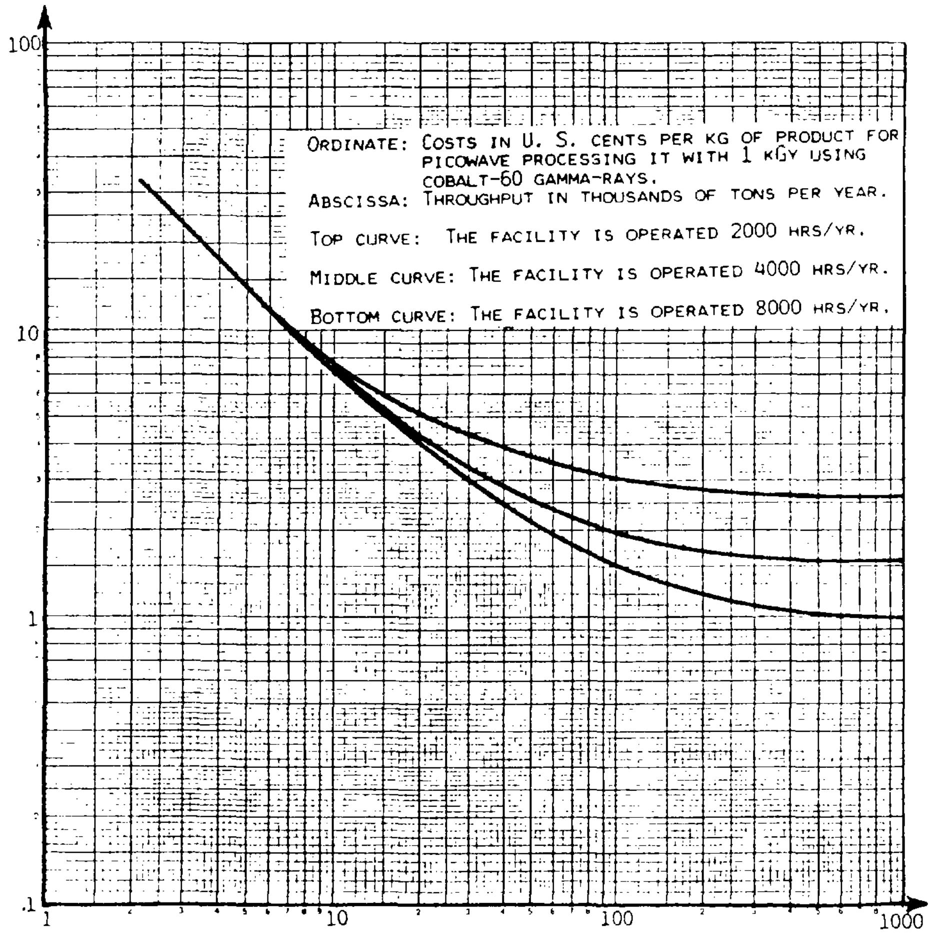


Fig. 11. Case studies on processing costs.

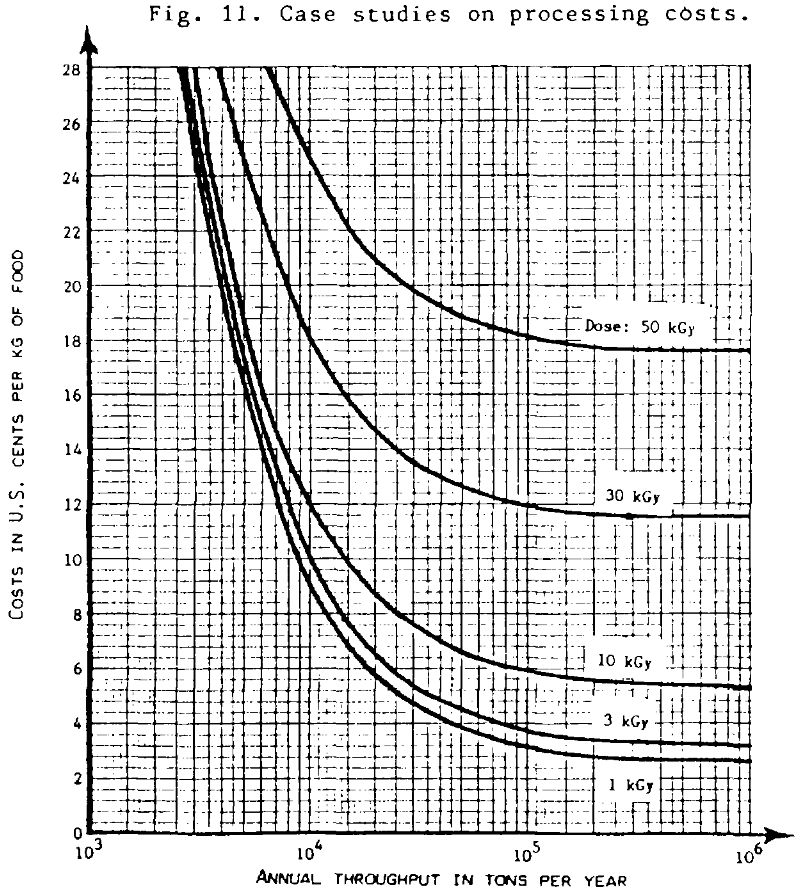


Fig. 12. Case studies on processing costs.

The quality control in a single purpose facility, where the product and the irradiation processing is uniform, is much simpler than in a multipurpose facility, where different products require different irradiation conditions.

In spite of the variations from one facility to another, the results of the following CASE STUDIES may serve as a guide for estimating the picowave processing costs.

The processing costs decrease significantly as the annual throughput increases. It is seen that the picowave processing plants should preferably have an annual throughput greater than 20000 tons per year. This characteristic is not specific for picowave processing plants, but for most food processing and food distribution plants. For example, distribution plants of frozen or refrigerated foods are usually larger than 20000 tons per year and are preferably around 100000 tons per year for the same reason. A picowave processing plant should preferably be located, therefore, as a part of or near the large distribution centers, for example in the outskirts of large cities.

In the Tables of CASE STUDY 1 are listed detailed cost analyses of a central picowave processing facility, including material handling as well as the estimates of the capital investment in sources, equipment and buildings, and the cost of operation.

In CASE STUDY 2, we give similar costs when the material handling is excluded.

The summaries of several other CASE STUDIES are listed in Figs. 9 through 12, where the costs per kg of products are given as functions of the annual throughput in tons per year.

CASE STUDY 1: IRRADIATION COSTS (US $)

PARAMETERS (ASSUMPTIONS):

Accelerator output in kw maximum	40.00
Cobalt-60 source strength in kw	40.00
Price pr. curie of cobalt-60	1.00
Encapsulation price pr. curie	0.06
Dose, minimum required in kGy	5.00
Acc.: Fraction of rad. absorbed in prod.	0.40
Co-60:Fraction of rad. absorbed in prod.	0.30
Density of the product, kg per cubic dm	0.50
Number of hrs per year accel is utilized	6000.00
Number of hrs per year Co-60 is utilized	8000.00
Cost of electricity per kwhr	0.06
Cost of cooling water per cubic meter	0.15
Cost of heating oil per liter	0.30
Annual interest rate on capital	0.15
Depreciation of equipment per year	0.20
Depreciation of sources per year	0.10
Depreciation of accelerator per year	0.20
Depreciation of buildings per year	0.10
Unforeseen expense factor	1.30

THROUGHPUTS:

Accelerator facility throughput, kg/hr	11520.00
Cobalt-60 facility throughput, kg/hr	8640.00
Accelerator facility throughput, tons/yr	69120.00
Cobalt-60 facility throughput, tons/yr	69120.00
2 weeks volume in cubic meters	7741.44
Req. warehouse for 2weeks storage, cu.m	23224.32

ANNUAL OPERATING COSTS (INCL.INT.AND DEPRECIATION):

Accelerator irradiation, $/yr	3220610.31
Cost per kwhr	13.42
Cost per 100 kg	4.66
Cobalt-60 irradiation, $/yr	3692051.71
Cost per kwhr	11.54
Cost per 100 kg	5.34
Difference in costs: (Co-60 - Accel)	471441.40

TABLE I. COSTS OF AN ACCELERATOR

INJECTOR AND BUNCHER	
Gun	10000.00
Gun mounting	5000.00
Gun modulator transformer	20000.00
Modulator mounting	5000.00
Gun focusing	10000.00
Buncher	10000.00
Buncher drive	5000.00
Labor	40000.00
Subtotal for injector and buncher:	105000.00

KLYSTRON, MODULATOR AND RF WAVEGUIDES	
Klystron	32000.00
Modulator for klystron	80000.00
Waveguides	5000.00
RF windows	5000.00
Focusing magnets for klystron	16000.00
Mounting structures	5000.00
Labor	30000.00
Subtot. for 20 kw unit of modul.& klys.:	173000.00
Subtot. for klys&mod for the act. accel:	346000.00
RF DRIVE	
Primary generator	20000.00
Klystron drive	20000.00
Phase controlers and attenuators	20000.00
Labor	30000.00
Subtotal for RF drive	90000.00
ACCELERATOR SECTIONS AND BEAM HANDLING	
Accelerator sectio-	90000.00
Supporting frame	5000.00
Beam focusing	10000.00
Vacuum systems	15000.00
Bending magnet, 90 degrees, beam chamber	10000.00
Bend. magn. powersupply, contr.&monitor.	5000.00
Scanner magnet and chamber	25000.00
Scanner powersupply, control&monitoring	10000.00
Beam collector and beam monitor.&record	15000.00
Controls and monitoring	40000.00
Labor	50000.00
Subtotal 20 kw accel.& beam handl.syst.:	275000.00
Subtotal for the actual accelerator:	357500.00

SUMMARY OF COSTS OF OF THE ACCELERATOR

10 MeV accelerator	898500.00
Transport of accelerator	16000.00
Installation	33000.00
Dosimetry and initial adjustment	33000.00
Total for accelerator:	980500.00

TABLE II. COSTS OF THE COBALT-60 SOURCES

Cobalt-60	2717000.00
Encapsulation	171520.00
Transport	63000.00
Installation	33000.00
Dosimetry and initial adjustment	33000.00
Subtotal for sources:	3017520.00

TABLE III. BUILDING Costs

Site and site development	100000.00
Shielding	230000.00
Modulator, transformer, or sources pool	80000.00
Control room	26000.00
Dosimetry laboratory	26000.00
Loading area	197794.56
Storage rooms (two weeks)	494486.40
Subtotal for building costs:	1154280.96

TABLE IV. ACCELERATOR EQUIPMENT, VENTILATION & WATER COOLING

Ventilation and filtering	60000.00
Water cooling and filtering beds	41000.00
Conveyor	149120.00
Instrumentation and tools	100000.00
Dosimetry	56912.00
Health physics instrumentation	15000.00
Spare parts	160000.00
Subtotal:	582032.00

TABLE V. COBALT-60 EQUIPMENT, VENTILATION & WATER COOLING

Ventilation	60000.00
Water cooling and filtering beds	20000.00
Conveyor	269120.00
Source elevator and source frame	65000.00
Instrumentation and tools	24000.00
Dosimetry	36912.00
Health physics and instrumentation	20000.00
Spare parts	10000.00
Subtotal:	505032.00

TABLE VI. ACCELERATOR FACILITY MISCELLANEOUS

Planning and overhead	140000.00
Architect fees	173142.14
Interest during construction	407521.94
Subtotal:	720664.09

TABLE VII. COBALT-60 FACILITY MISCELLANEOUS

Planning and overhead	140000.00
Architect fees	248896.94
Interest during construction	701524.94
Subtotal:	1090421.89

TABLE VIII. ACCELERATOR TOTAL INVESTMENTS

Accelerator	980500.00
Building	1154280.96
Equipment	582032.00
Planning, architecture, and interest	720664.09
Total:	3437477.05

TABLE IX. COBALT-60 TOTAL INVESTMENTS

Cobalt-60	3017520.00
Building	1154280.96
Equipment	505032.00
Planning, architecture, and interest	1090421.89
Total:	5767254.85

TABLE X. ACCELERATOR OPERATING COSTS

Manager, an electronic engineer	50000.00
Supervisor, an electronic techncian	38000.00
Operators of the accelerator	96000.00
Gun transf+Gun focus(20000 hr)/20 kwhr	1.50
Gun+buncher(10000hr)/20 kwhr	1.50
Mod+acc+wav+foc(80000hr)/20 kwhr	4.70
kly+RF wind+vac pump(10000 hr)/20 kwhr	3.70
Bend mag+scann mag (30000 hr)/20 kwhr	1.17
Bend+ scan controls (10000 hr)/20 kwhr	1.50
RF gen (30000 hr)/20 kwhr	0.67
RF drive+phase control(20000 hr)/20kwhr	2.00
Components for maintenance, a summation	200800.00
El:acc(w*2*3)+gun(5)+scan(5)+bend(1)	94320.00
El:Wat.pum(10)+airbl(10)+ctrl(5)+lig(10)	21600.00
El:aircond(20)	14400.00
Heating oil per year	5715.17
Water: =75 liters per kwhr	25110.00
Dosimetry material and record keeping	210360.00
Maintenance of facility buildings	9000.00
Travel	18400.00
Material handlers for loading conveyor	791200.00
Insurance	51562.16
Overhead, 40% of the sum of the above	650586.93
Subtotal:	2277054.26

TABLE XI. COBALT-60 OPERATING COSTS

Manager, a physicist	45000.00
Supervisor, a mechanical technician	36000.00
Operators of the cobalt facility	60000.00
Components for maintenance	28000.00
Cobalt-60 replenishment	397277.60
Power, water, and heat	29000.00
Dosimetry materials and record keeping	140240.00
Maintenance of facilities	19000.00
Travel	16900.00
Material handlers for loading conveyor	791200.00
Insurance	86508.82
Overhead (40% of the sum of the above)	659650.57
Subtotal:	2308776.99

CASE STUDY 2: IRRADIATION COSTS EXCLUSIVE OF MATERAL HANDLING

PARAMETERS (ASSUMPTIONS):

Accelerator output in kw maximum	40.00
Co-60 source strength in kw	40.00
Price pr. curie of Co-60	1.00
Encapsulation price pr. curie	0.06
Dose, minimum required in kGy	5.00
Acc.: Fraction of rad. absorbed in prod.	0.40
Co-60:Fraction of rad. absorbed in prod.	0.30
Density of the product, kg per cubic dm	0.50
Number of hrs per year accel is utilized	6000.00
Number of hrs per year Co-60 is utilized	8000.00
Cost of electricity per kwhr	0.06
Cost of cooling water per cubic meter	0.15
Cost of heating oil per liter	0.30
Annual interest rate on capital	0.15
Depreciation of equipment per year	0.20
Depreciation of sources per year	0.10
Depreciation of accelerator per year	0.20
Depreciation of buildings per year	0.10
Unforeseen expense factor	1.30

THROUGHPUTS:

Accelerator facility throughput, kg/hr	11520.00
Cobalt-60 facility throughput, kg/hr	8640.00
Accelerator facility throughput, tons/yr	69120.00
Cobalt-60 facility throughput, tons/yr	69120.00
2 weeks volume in cubic meters	7741.44
Warehouse for 2 weeks storage, cubic m	0.00

ANNUAL OPERATING COSTS (INCL.INT.AND DEPRECIATION):

Accelerator irradiation, $/yr	1993614.13
Cost per kwhr	8.31
Cost in cents per kg	2.88
Cobalt-60 irradiation, $/yr	2469743.38
Cost per kwhr	7.72
Cost in cents per kg	3.57
Difference in annual costs (Co-60-Accel)	476129.25

TABLE I. COSTS OF AN ACCELERATOR

INJECTOR AND BUNCHER	
Gun	10000.00
Gun mounting	5000.00
Gun modulator transformer	20000.00
Modulator mounting	5000.00
Gun focusing	10000.00
Buncher	10000.00
Buncher drive	5000.00
Labor	40000.00
Subtotal for injector and buncher:	105000.00
KLYSTRON, MODULATOR AND RF WAVEGUIDES	
Klystron	32000.00
Modulator for klystron	80000.00
Waveguides	5000.00
RF windows	5000.00
Focusing magnets for klystron	16000.00
Mounting structures	5000.00
Labor	30000.00
Subtotal for a 20 kw accelerator:	173000.00
Subtotal for the actual accelerator:	346000.00
RF DRIVE	
Primary generator	20000.00
Klystron drive	20000.00
Phase controlers and attenuators	20000.00
Labor	30000.00
Subtotal for RF drive:	90000.00
ACCELERATOR SECTIONS AND BEAM HANDLING	
Accelerator section	90000.00
Supporting frame	5000.00
Beam focusing	10000.00
Vacuum systems	15000.00
Bending magnet, 90 degrees, beam chamber	10000.00
Control and monitoring of bending magnet	5000.00
Scanner magnet and chamber	25000.00
Scanner powersupply, control&monitoring	10000.00
Beam collector and beam monitor.&record	15000.00
Controls and monitoring	40000.00
Labor	50000.00
Subtotal for a 20 kw accelerator:	275000.00
Subtotal for the actual accelerator:	357500.00

SUMMARY OF COSTS OF THE ACCELERATOR

10 MeV accelerator	898500.00
Transport of accelerator	16000.00
Installation	33000.00
Dosimetry and initial adjustment	33000.00
Total for accelerator:	980500.00

TABLE II. COSTS OF THE COBALT-60 SOURCES

Cobalt-60	2717000.00
Encapsulation	171520.00
Transport	63000.00
Installation	33000.00
Dosimetry and initial adjustment	33000.00
Subtotal for sources:	3017520.00

TABLE III. BUILDING Costs

Site and site development	100000.00
Shielding	230000.00
Modulator, transformer, or sources pool	80000.00
Controlroom	28000.00
Dosimetry laboratory	37000.00
Loading area	245400.00
Storage rooms (two weeks)	0.00
Subtotal for building costs:	720400.00

TABLE IV. ACCELERATOR EQUIPMENT, VENTILATION & WATER COOLING

Ventilation and filtering	60000.00
Water cooling and filtering beds	41000.00
Conveyor	149120.00
Instrumentation and tools	100000.00
Dosimetry	63824.00
Health physics instrumentation	20000.00
Spare parts	160000.00
Subtotal:	593944.00

TABLE V. COBALT-60 EQUIPMENT, VENTILATION & WATER COOLING

Ventilation	60000.00
Water cooling and filtering beds	20000.00
Conveyor	269120.00
Source elevator and source frame	65000.00
Instrumentation and tools	24000.00
Dosimetry	36912.00
Health physics and instrumentation	25000.00
Spare parts	10000.00
Subtotal:	510032.00

TABLE VI. ACCELERATOR FACILITY MISCELLANEOUS

Planning and overhead		140000.00
Architect fees		108060.00
Interest during construction		344226.60
	Subtotal:	592286.60

TABLE VII. COBALT-60 FACILITY MISCELLANEOUS

Planning and overhead		140000.00
Architect fees		184564.80
Interest during construction		637192.80
	Subtotal:	961757.60

TABLE VIII. ACCELERATOR TOTAL INVESTMENTS

Accelerator		980500.00
Building		720400.00
Equipment		593944.00
Planning, architecture, and interest		592286.60
	Total:	2887130.60

TABLE IX. COBALT-60 TOTAL INVESTMENTS

Cobalt-60		3017520.00
Building		720400.00
Equipment		510032.00
Planning, architecture, and interest		961757.60
	Total:	5209709.60

TABLE X. ACCELERATOR OPERATING COSTS

Manager, an electronic engineer	60000.00
Supervisor, an electronic technician	38000.00
Operators of the accelerator	96000.00
Gun transf+Gun focus(20000 hr)/20 kwhr	1.50
Gun+buncher(10000hr)/20 kwhr	1.50
Mod+acc+wav+foc(80000hr)/20 kwhr	4.70
kly+RF wind+vac pump(10000 hr)/20 kwhr	3.70
Bend mag+scann mag (30000 hr)/20 kwhr	1.17
Bend+ scan controls (10000 hr)/20 kwhr	1.50
RF gen (30000 hr)/20 kwhr	0.67
RF drive+phase control(20000 hr)/20kwhr	2.00
Components for maintenance, a summation	200800.00
El:acc(w*2*3)+gun(5)+scan(5)+bend(1)	94320.00
El:Wat.pum(10)+airbl(10)+ctrl(5)+lig(10)	21600.00
El:aircond(20)	14400.00
Heating oil per year	6000.00
Water: =75 liters per kwhr	25110.00
Dosimetry material and record keeping	210360.00
Maintenance of facility buildings	9000.00
Travel	19400.00
Material handlers for loading conveyor	0.00
Insurance	43306.96
Overhead, 40% of the sum of the above	335318.78
Subtotal:	1173615.74

TABLE XI. COBALT-60 OPERATING COSTS

Manager, a physicist	60000.00
Supervisor, a mechanical technician	36000.00
Operators of the cobalt facility	60000.00
Components for maintenance	28000.00
Cobalt-60 replenishment	397277.60
Power, water, and heat	29000.00
Dosimetry materials and record keeping	140240.00
Maintenance of facilities	19000.00
Travel	18400.00
Material handlers for loading conveyor	0.00
Insurance	78145.64
Overhead (40% of the sum of the above)	346425.30
Subtotal:	1212488.54

REFERENCES

1. LOAHARANU, P., "Benefits of radiation processing to food industries in developing countries", Radiat. Phys. Chem. 22 (1983) 225-232.

2. LOAHARANU, P., "Asian regional co-operative project on food irradiation (RPFI)", Food Irradiation Processing (Proceedings of a symposium, Washington D.C., 4-8 March 1985), (1985) 175-184.

3. CHINSMAN, B., "Food irradiation development in Africa", Food Irradiation Processing (Proceedings of a symposium, Washington D.C., 4-8 March 1985), (1985) 185-201.

4. RUBIO,T., "Food irradiation activities in Latin American countries", Food Irradiation Processing (Proceedings of a symposium, Washington D.C., 4-8 March 1985), (1985) 203-214.

5. MA ZUE-TEH, ZHOU LIANG-YI, "Goal, strategy and project selection for the radiation processing",Radiat. Phys. Chem., 25 (1985) 905-910.

6. FACTORS INFLUENCING THE ECONOMICAL APPLICATION OF FOOD IRRADIATION (Proceedings of a Panel organized by the Joint FAO/IAEA Division of Atomic Energy in Vienna, 14-18 June 1971). Published by IAEA, Vienna, 1973, STI/PUB/331.

7. KRISHNAMURTHY, K.,BONGIRWAR, D.R., "Design considerations for food irradiators in developing countries", Food Irradiation Processing, (Proceedings of a Symposium, Washington,D.C., 4-8 March 1985), IAEA, Vienna,STI/PUB/695, ISBN 92-0-010185-2, (1985) 353-363.

8. BANDITSING, C., PRINKSULKA, V., PIADANG, S., SUTANTAWONG, M., NOOCHAPRAMOOL, K., PRACHASITISAKDI,Y., "The multi-purpose food irradiation plant in Thailand", ibid. pp. 379-395.

9. MARTIN, V.J., MONTALBAN, A., CURBELO, S., "Evaluacion economica del proceso de irradiacion para una planta multiproposito", ibid., pp.379-395.

10. KÁLMÁN, B., KÉKESSI, E., SÁNTA, R., "Introduction of irradiation technology into the Hungarian food industry", ibid. 109-115.

11. MCKINNON, R.G., CHU, R.D.H., "Pallet Irradiators for food processing", Radiat. Phys. Chem. 25 (1985) 141-154.

12. TAMURA, N, "Gamma irradiation facilities", Proceedings of the International Meeting on Radiation Processing, Tokyo, Japan, October 26-31, 1980, (1980) 273-283.

13. STENGER,V., SIPOS, T., LÁSZLÓ, L., HARGITTAI, P., KOVÁCKS, A., and HARVÁTH, I., "Experiences with a high capacity industrial scale pilot onion irradiator", Radiat. Phys. Chem. 22 (1983) 717-732.

14. MASEFIELD, J., DIETZ, G.R., OWENS,W.M., "Major considerations governing the adaptation of cobalt-60 sterilization", Radiat. Phys. Chem. 14 (1979) 277-283.

15. LEEMHORST, J.G., "Industrial application of food irradiation", Food Irradiation Now (Proceedings of a symposium, held in Ede, the Netherlands, 21 October 1981, sponsord by GAMMASTER, Ede, The Netherlands), Martinus Nijhoff/Dr. W. Junk publishers, The Hague, (1982) 60-68.

16. O'SULLIVAN, E.T., HARVEY, R.W., GREENBORG, J., "Progress in cesium-137 irradiation sources for food processing", Chemical and Food Applications of Radiation, Chemical Engineering Progress Symposium Series, No 83, 64 (1968) 31-41.

17. MARKOVIC, V.M., EYMERY, R., YUAN, H.C., "A new approach of Co-60 plant design for introduction of radiation sterilization in developing countries", Radiat. Phys. Chem. 9 (1977) 651-631.

18. WILLIAMS, J. L., DUNN, T. S., "Radiation sources - gamma", Radiat. Phys. Chem. 14 (1979) 185-201.

19. MACHI, S., "Industrial application of radiation processing in Japan", Radiat. Phys. Chem. 14 (1979) 155-170.

20. HARROD, R.A., "AECL gamma sterilization facilities", Radiat. Phys. Chem., 9 (1977)91-117.

21. EYMERY, R., "The prospect of using cesium for radiosterilization", Technical Developments and Prospects of Sterilizationby Ionizing Radiation, (Proc. Int. Conf. in Vienna, April 1-4, 1974, E.R.L. Gaughran and A.J. Goudie, eds.) (1974) 173-184. Multiscience Publication Limited. Montreal, Canada.

22. SIVINSKI, J.S., "Efficacy testing and market research for pork industry", Radiat. Phys. Chem. 25 (1985) 263-269.

23. FERRELL, N.J., SLOAN, D.P., "Demonstration facilities for the byproducts utilization program", Radiat. Phys. Chem. 25 (1985) 251-261.

24. NABLO, S.V., TRIPP, E.P., "Low energy electron process applications", Radiat. Phys. Chem. 9 (1977) 325-352.

25. FARRELL, J.P., SELTZER, S.M., SILVERMAN, J., "Bremsstrahlung generators for radiation processing", Radiat. Phys. Chem. 22 (1983) 469-478.

26. BECKER, R.C., BLY, J.H., CLELAND, M.R., FARRELL, J.P., "Accelerator requirements for electron beam processing", Radiat. Phys. Chem. 14 (1979) 353-375.

27. HAIMSON, J., "Advances in electron beam linear accelerator technology", Sterilization by Ionizing Radiation, ISBN 0-919868-00-2 (Proceedings of an International Conference, Vienna, Austria, April 1-4, 1974, E.R.L. Gaughran and A.J. Goudie eds.) Multiscience Publication Limited, Montreal, Canada, (1974) 71-106.

28. LIU ANDONG, WANG BINGLIN, QIAN SIMIN, ZHANG YINFEN, HU HUADAN, GU YONGBAO, WANG PEIDE, "The multipurpose uses of a scanned linac", Radiat. Phys. Chem., 25 (1985) 653-664.

29. BRYNJOLFSSON, A., "Three-dimensional dose distribution in samples irradiated by electron beams", Radiation Research Proceedings of an International Conference, at U. S. Army Natick Laboratorie, Natick Massachusetts, January 14-16 1963, Published by U.S.Department of Commerce, Office of Technological Services, Washington D.C., (1963) 116-129.

30. CLELAND, M.R., PAGEAU, G.M., "Electrons versus gamma rays - alternative sources for irradiation processes", Food Irradiation Processing, (Proceedings of a Symposium, Washington,D.C., 4-8 March 1985), IAEA, Vienna,STI/PUB/695, ISBN 92-0-010185-2, (1985) 397-406.

31. MCKEOWN, J., SHERMAŃ, N.K., "Linac based irradiators", Radiat. Phys. Chem. 25 (1985) 103-109.

32. GALLIEN, C.L., PAQUIN,J., FERRADINI, C., ,SADAT, T., "Electron beam processing in food industry - technology and costs", Radiat. Phys. Chem. 25 (1985) 81-96.

33. LAGUNAS-SOLAR, M.C., MATHEWS, S.M., "Comparative economic factors on the use of radionuclide or electrical sources for food processing with ionizing radiation", Radiat. Phys. Chem. 25 (1985) 111-124.

IAEA-SR-129/31

TRADE IN IRRADIATED FOODS: AN APPROACH TO RETAILERS AND CONSUMERS

S.D. KERR
Grocery Products Manufacturers of Canada,
Don Mills, Ontario,
Canada

Abstract

Government and industry in Canada are moving quickly to provide the legislation, regulations and practical protocol necessary for the commercialization of food irradiation. Marketing, public relations and media expertise will be needed to successfully introduce this new processing choice to retailers and consumers.

Consumer research to date including studies conducted in the Netherlands, United States, South Africa and Canada will be explored for signposts to successful approaches to the introduction of irradiated foods to retailers and consumers.

Research has indicated that the terms used to describe irradiation and information designed to reduce consumer fears will be important marketing tools. Marketers will be challenged to promote old foods which look the same to consumers, in a new light. Simple like or dislike or intention to buy surveys will not be effective tools. Consumer fears must be identified and effectively handled to support a receptive climate for irradiated food products.

A cooperative government, industry, professional organization, consumer organization and retailer effort will be necessary for a successful introduction or irradiated foods into the marketplace.

IRRADIATED FOODS WILL NOT BE SUCCESSFUL ON THE RETAIL MARKET IF CONSUMER FEARS ARE NOT IDENTIFIED AND DEALT WITH EFFECTIVELY. THIS PAPER, TRADE ON IRRADIATED FOODS, AN APPROACH TO RETAILERS AND CONSUMERS WILL LOOK AT CONSUMER RESEARCH TO DATE. THESE STUDIES, CONDUCTED IN THE NETHERLANDS, SOUTH AFRICA, THE UNITED STATES AND CANADA, HAVE IDENTIFIED CONSUMER ATTITUDES TOWARDS IRRADIATION.

CONSUMER OPINION STUDIES ARE REPORTING LESS CONSUMER HESITATION TO BUY IRRADIATED FOODS THAN OFTEN ANTICIPATED. HOWEVER, MORE RESEARCH ON CONSUMER ATTITUDES TOWARD IRRADIATION NEEDS TO BE

CONDUCTED. THERE IS ALREADY AN ABUNDANCE OF RESEARCH CONDUCTED ON THE TECHNICAL AND SAFETY ASPECTS OF IRRADIATION. MARKET RESEARCH ON RETAILER AND CONSUMER PERCEPTIONS OF IRRADIATION IS VERY MEAGRE BY COMPARISON.

CONSUMER OPINION RESEARCH CAN BE DIVIDED INTO THREE AREAS: LABELLING, TO BUY OR NOT TO BUY DECISIONS AND SENSORY ACCEPTANCE.

LABELLING RESEARCH

A NUMBER OF STUDIES HAVE BEEN CONDUCTED TO DETERMINE WHETHER CONSUMERS WANT IRRADIATED FOODS LABELLED AND IF SO HOW. THE RESEARCH HOUSE OF YOUNG AND RUBICAM-KOSTER IN THE NETHERLANDS CONDUCTED A STUDY IN 1981, ON THE REACTIONS AND OPINIONS OF CONSUMERS TOWARDS IRRADIATED FOODS. (5) CONSUMERS WERE ASKED THEIR REACTIONS TO THE TERMS IRRADIATION, TRANS RADIATION AND SHORTWAVE ELECTRONIC TREATMENT ON FOOD LABELS. THESE TERMS RECEIVED UNFAVOURABLE RESPONSES. THEY WERE LINKED TO CANCER, DISEASE, X-RAYS AND UNNATURAL PROCESSES. THE RESEARCHERS CONCLUDED THAT TECHNICAL TERMS TO IDENTIFY THE PROCESS CONFUSED AND MISLEAD CONSUMERS. THEY RECOMMENDED A SYMBOL TO IDENTIFY AN IRRADIATED PRODUCT. THE SYMBOL CURRENTLY USED IN THE NETHERLANDS IS REGISTERED TO AN IRRADIATION PLANT OPERATED BY THE GOVERNMENT OF THE NETHERLANDS. THEY HAVE GRANTED PERMISSION FOR ITS USE TO SEVERAL COUNTRIES.

IN CANADA CONSUMERS WERE ASKED QUESTIONS ON THE LABELLING OF IRRADIATED FOOD BY THE CANADIAN GALLUP POLL IN 1984. (3) THE TERMS IRRADIATION, TRANS RADIATION, BACTERIA REDUCED AND GAMMA PROCESSED ALL RECEIVED A NEGATIVE RESPONSE. THE TERM

IONIZED RECEIVED POSITIVE COMMENTS FROM PARTICIPANTS IN THE STUDY. THE TERM FRESHNESS EXTENDED DID NOT RECEIVE A FAVOURABLE RESPONSE IN ENGLISH SPEAKING ONTARIO BUT DID RECEIVE A FAVOURABLE RESPONSE IN FRENCH SPEAKING QUEBEC. THE RESPONDENTS FAVOURED A SYMBOL ON THE LABEL. THE SYMBOL TESTED WAS A SUN SYMBOL, NOT THE INTERNATIONAL SYMBOL.

A STUDY CONDUCTED BY THE UNITED STATES DEPARTMENT OF ENERGY IN CONJUNCTION WITH THE NATIONAL PORK PRODUCERS COUNCIL ALSO FOUND CONSUMERS FEARFUL OF RADIATION SPECIFIC WORDS ON THE LABEL. (18)

THE NEW YORK RESEARCH DEPARTMENT OF THE INVESTMENT FIRM, KIDDER AND PEABODY, CONDUCTED A SURVEY OF CONSUMER ATTITUDES TOWARDS IRRADIATED FOOD IN WHICH THEY ASKED, "SHOULD IRRADIATED FOOD HAVE A SPECIAL LABEL ON IT?" 87% OF RESPONDENTS SAID YES. (11) THE RESPONDENTS WEREN'T ASKED TO CHOOSE BETWEEN A SYMBOL OR WORDS.

THE BRAND GROUP, A MARKET RESEARCH FIRM IN CHICAGO, CONDUCTED RESEARCH FOR THE NATIONAL MARINE FISHERIES SERVICE IN THE UNITED STATES. (1) SEVENTY TWO PER CENT OF THE CONSUMERS THEY SURVEYED WANTED TO BE ABLE TO IDENTIFY IRRADIATED FOODS.

LABELLING IS CRUCIAL TO THE ACCEPTANCE OF IRRADIATED FOODS. IRRADIATION SPECIFIC WORDS ON LABELS, WILL SLOW ACCEPTANCE BY BOTH THE TRADE AND CONSUMERS. IT WILL SLOW ACCEPTANCE BECAUSE PRODUCERS, DISTRIBUTORS AND RETAILERS ARE LIKELY TO BE SENSITIVE TO HAVING THEIR PRODUCTS SO VISIBLY ASSOCIATED WITH RADIATION. CONSUMERS, IN TURN, HAVE REGISTERED NEGATIVE REACTIONS TO IRRADIATION SPECIFIC TERMS. THIS SENSITIVITY WILL PERSIST UNTIL IRRADIATION IS A WIDELY ACCEPTED PROCESS.

IN CANADA, AS IN MANY COUNTRIES, INDUSTRY HAVE STATED THEIR LABEL PREFERENCE FOR A SYMBOL ONLY TO IDENTIFY THE IRRADIATION PROCESS. GOVERNMENTS MAKING LABELLING DECISIONS ARE ALSO BEING INFLUENCED BY VALID CONSUMER RESEARCH AND BY CONSUMERS DIRECTLY. IN CANADA, THE VAST MAJORITY OF CONSUMER COMMENT RECEIVED BY THE GOVERNMENT FAVOURS LABELLING. IN THE UNITED STATES, 90% OF COMMENTS RECEIVED BY THE FOOD AND DRUG ADMINISTRATION FAVOUR LABELLING. THE MESSAGE IS CLEAR, IN NORTH AMERICA AT LEAST, CONSUMERS WANT IRRADIATED FOODS LABELLED. A SYMBOL APPEARS TO BE THE MOST ACCEPTABLE FORM OF LABELLING. THE MOTIVATION FOR WANTING LABELLING IS LESS CLEAR. A 1985 GOOD HOUSEKEEPING STUDY CONDUCTED IN THE UNITED STATES INDICATES THAT 82% OF CONSUMERS TESTED DEPEND ON LABELLING TO EVALUATE NEW PRODUCTS, 75% USE LABELS TO JUDGE QUALITY, ONLY 4% USE LABELS TO AVOID FOODS. (7) THIS SUGGESTS THAT IRRADIATION LABELLING COULD HAVE A VERY POSITIVE EFFECT ON CONSUMER ACCEPTANCE OF THE PROCESS IF ASSOCIATED WITH PRODUCT QUALITY.

TO BUY OR NOT TO BUY RESEARCH

WHETHER LABELLED OR UNLABELLED WILL CONSUMERS BUY IRRADIATED FOODS? WHAT WILL ENCOURAGE THEM TO BUY?

A NINE MONTH SOUTH AFRICAN MARKETING TRIAL REVEALED THAT NOT ONLY WERE CONSUMERS WILLING TO BUY IRRADIATED PRODUCTS THEY DID BUY IRRADIATED POTATOES, MANGOES, PAPAYAS, AND STRAWBERRIES MARKED WITH THE INTERNATIONAL SYMBOL. THESE LABELLED PRODUCTS RECEIVED POSITIVE REACTIONS FROM 90% OF CONSUMERS. CONSUMER ACCEPTANCE WAS ENHANCED THROUGH EDUCATIONAL EFFORTS, SUCH AS DISTRIBUTION OF LEAFLETS IN SUPERMARKETS, IN-STORE INFORMATION DESKS, USE OF THE MEDIA AND SUPPORTIVE CONSUMER ORGANIZATIONS.

THESE EFFORTS ENCOURAGED CONSUMERS NOT ONLY TO ACCEPT, BUT TO PURCHASE IRRADIATED FOODS.

THE GOOD HOUSEKEEPING INSTITUTE IN THE UNITED STATES, CONDUCTS AN ANNUAL FOOD ATTITUDE SURVEY. (8) IN 1985 THEY ASKED THEIR PANEL, "WHICH METHODS WOULD YOU PREFER FOOD COMPANIES TO USE TO REDUCE SPOILAGE AND PRESERVE FOODS, IRRADIATING THE FOOD OR ADDING CHEMICAL PRESERVATIVES TO THE FOOD?" THE RESULTS: - 44% SAID THEY "DIDN'T KNOW ENOUGH TO JUDGE" (THIS GROUP CAN BE INFLUENCED). - 27% SAID "I DON'T WANT EITHER", 23% SAID "I PREFER IRRADIATION", 3% SAID "I PREFER PRESERVATIVES", 3% SAID "I HAVE NO PREFERENCE".

KIDDER AND PEABODY IN NEW YORK REPORT SIMILAR RESULTS TO THOSE OF THE GOOD HOUSEKEEPING INSTITUTE.(11) WHEN ASKED "WOULD YOU BUY FOODS THAT HAD BEEN IRRADIATED WITH GAMMA RAYS ASSUMING THEY COST NO MORE AND THEY DID NOT SPOIL AS FAST AS REGULAR FOODS"? "FORTY FOUR PERCENT OF RESPONDENTS DIDN'T KNOW, 28% WOULD BUY IRRADIATED FOODS, 28% WOULD NOT BUY IRRADIATED FOODS. AGAIN, A LARGE PERCENTAGE OF THIS GROUP COULD BE INFLUENCED.

THE UNITED STATES DEPARTMENT OF ENERGY STUDY FOUND CONSUMERS FELT THE USE OF CHEMICALS, PRESERVATIVES AND ADDITIVES WAS OF MORE CONCERN THAN IRRADIATION. (18) THE SAME REACTION WAS NOTED BY A UNIVERSITY OF CALIFORNIA AT DAVIS STUDY RELEASED IN 1986. (2) PARTICIPANTS IN THIS STUDY EXPRESSED MORE CONCERN ABOUT THE PRESENCE OF PRESERVATIVES IN FOOD THAN THEY DID ABOUT IRRADIATION. THIS STUDY ALSO EXAMINED THE EXTENT OF ATTITUDE CHANGE WHEN CONSUMERS WERE GIVEN AN OPPORTUNITY TO READ ABOUT AND DISCUSS FOOD IRRADIATION. RESPONDENTS WERE CATEGORIZED AS

CONVENTIONAL CONSUMERS OR ALTERNATIVE CONSUMERS. THE ALTERNATIVE CONSUMERS REPRESENT A VOCAL ANTINUCLEAR, ANTI-IRRADIATION GROUP. THE CONVENTIONAL CONSUMERS IN THE STUDY SHOWED A LOWER LEVEL OF CONCERN TOWARDS THE SAFETY OF IRRADIATED FOODS THAN DID THE ALTERNATIVE CONSUMERS AS YOU WOULD EXPECT. BOTH CONVENTIONAL AND ALTERNATIVE CONSUMERS EXPRESSED MORE CONCERN ABOUT THE PRESENCE OF PRESERVATIVES IN FOODS AND THE USE OF CHEMICAL SPRAYS ON FOODS THAN FOOD IRRADIATION. AFTER LEARNING MORE ABOUT THE PROCESS OF IRRADIATION THE ALTERNATIVE CONSUMERS SIGNIFICANTLY INCREASED THEIR CONCERN ABOUT IRRADIATION. MORE ALTERNATIVE THAN CONVENTIONAL CONSUMERS SHOWED A HIGHER LEVEL OF CONCERN INITIALLY TOWARDS IRRADIATION AND INTERESTINGLY ENOUGH THEIR CONCERN INCREASED AFTER EDUCATIONAL EFFORTS. ON THE OTHER HAND CONVENTIONAL CONSUMERS EXPERIENCED A REDUCED CONCERN LEVEL TOWARDS IRRADIATION AFTER EDUCATION. THE RESEARCHERS ALSO FOUND THAT HAVING A DISCUSSION LEADER KNOWLEDGEABLE ON THE SUBJECT OF FOOD IRRADIATION REDUCED THE CONCERNS OF THE CONVENTIONAL CONSUMERS MUCH MORE THAN DID A NON EXPERT LEADER. THE STUDY CONCLUDED THAT THE CONVENTIONAL CONSUMERS ATTITUDES TOWARDS IRRADIATION COULD BE INFLUENCED POSITIVELY BY EDUCATION. THEY FOUND THAT THIS POSITIVE INFLUENCE WAS MOST EFFECTIVE WHEN THE CONSUMER WAS ABLE TO TALK TO SOMEONE WHO WAS KNOWLEDGEABLE ABOUT IRRADIATION. APPROXIMATELY 10% OF CONSUMERS IN THE U.S.A. ARE ALTERNATIVE CONSUMERS. THIS GROUP WILL BE ALMOST IMPOSSIBLE TO INFLUENCE .

WILLINGNESS TO BUY IRRADIATED FOODS ON THE PART OF THE CONSUMERS IN THESE ATTITUDE STUDIES WAS BASED ON THE SAFETY OF THE PROCESS RATHER THAN ON ANY ADVANTAGES OF SPECIFIC IRRADIATED FOOD

PRODUCTS. AS THE CONSUMER'S PERCEPTION OF THE SAFETY OF IRRADIATION INCREASED THEIR WILLINGNESS TO BUY INCREASED. IT SHOULD BE NOTED THAT IN ALL THE STUDIES CITED, EXCEPT THE SOUTH AFRICAN STUDY, WILLINGNESS TO BUY IS ONLY STATED WE DON'T KNOW IF IT WILL RESULT IN A PURCHASE.

A MARKET RESEARCH STUDY COMMISSIONED BY THE U.S. NATIONAL MARINE FISHERIES SERVICE FURTHER VERIFIES CONSUMERS STATED WILLINGNESS TO BUY IRRADIATED PRODUCTS. SEVENTY THREE PERCENT OF CONSUMERS TESTED WOULD TRY THE IRRADIATED FOOD DESCRIBED TO THEM. (1) RESPONDENTS WERE CONCERNED ABOUT IRRADIATION BUT WHEN THEY RECEIVED INFORMATION ABOUT THE SAFETY OF THE PROCESS THE MAJORITY STATED THEY WOULD PROBABLY USE IRRADIATED FOOD. THIS STUDY SEPARATED CONSUMERS INTO THREE GROUPS ACCORDING TO THEIR ATTITUDES TOWARD IRRADIATION. THE FIRST GROUP CALLED REJECTORS, CURRENTLY ESTIMATED AT 5-10% OF AMERICAN CONSUMERS, REJECT IRRADIATED FOODS ON THE BASIS OF CONFLICTING VALUES. EDUCATION WILL HAVE NO EFFECT ON THIS GROUP. THE NEXT GROUP CALLED UNDECIDED, COMPRISE 55-65% OF CONSUMERS. THIS GROUP IS CONFUSED BY IRRADIATION TECHNOLOGY. THEY HAVE CONCERNS BUT THEY ARE UNCERTAIN AS TO WHAT THEIR ATTITUDE SHOULD BE TOWARDS IRRADIATION. THIS GROUP CAN BE INFLUENCED BY EDUCATION AND PROMOTION. THE THIRD GROUP CALLED ACCEPTORS, COMPRISE 25-30% OF CONSUMERS. THEY BELIEVE THEY UNDERSTAND THE TECHNOLOGY, GENERALLY TRUST THE SAFETY OF IRRADIATION, BUT THEIR POSITIVE ATTITUDES CAN BE SHAKEN BY EXPOSURE TO OTHERS CONCERNS. EDUCATION WILL BE IMPORTANT TO MAINTAIN THIS GROUP AS ACCEPTORS OF THE PROCESS.

THE U.S. MARINE FISHERIES STUDY FOUND THAT FEW CONSUMERS EXPRESSED FEAR IN REACTION TO GENERAL IRRADIATION DESCRIPTIONS. CONSUMER CONCERNS AND UNCERTAINTIES ABOUT IRRADIATED FOOD WERE RELATED TO MISCONCEPTIONS ABOUT THE UNFAMILIAR TECHNOLOGY. THE MARKET SUCCESS OF IRRADIATED FOODS, THE RESEARCHERS FELT, WAS MORE DEPENDENT UPON PROMOTION AND ACCEPTANCE OF THE PRODUCT THAN UPON PROMOTION AND ACCEPTANCE OF THE TECHNOLOGY. CONSUMER ACCEPTANCE OF IRRADIATED FOOD BASED ON A PROCESS DESCRIPTION WAS 25-35% VERSUS AN ACCEPTANCE LEVEL OF 72% WHEN BASED ON A PRODUCT DESCRIPTION ONLY. THE RESEARCHERS RECOMMENDED THAT CONSUMER INFORMATION ABOUT IRRADIATION FOCUS ON THE PRODUCT RATHER THAN THE PROCESS. THE BRAND GROUP RECOMMENDS SUPPORT OF COOPERATIVE EFFORTS TO DEVELOP INDUSTRY WIDE CONSUMER EDUCATION PROGRAMS (1). THEY RECOMMENDED THAT GUIDELINES FOR COMMUNICATING ABOUT IRRADIATION BE DEVELOPED TO ENSURE EFFECTIVE AND CONSISTENT INFORMATION FOR THE CONSUMER. INFORMATION ABOUT IRRADIATED PRODUCTS THEY FELT, SHOULD BE PROVIDED THROUGH ALL AVAILABLE CHANNELS OF TRADITIONAL PROMOTION. LAY ORIENTED INFORMATION ABOUT THE PROCESS SHOULD BE PROVIDED AT SOURCES EASILY ACCESSIBLE TO MOST CONSUMERS. DETAILED AND TECHNICAL MATERIALS TO BE MADE AVAILABLE ONLY TO CONSUMERS WHO REQUEST THEM. MAJOR EDUCATIONAL EFFORTS, THEY FELT, SHOULD COINCIDE WITH IRRADIATED PRODUCT INTRODUCTIONS. THIS WAS WHEN CONSUMER INTEREST AND CURIOSITY WOULD BE AT A PEAK. THEY CAUTIONED THE FOOD INDUSTRY TO BE AWARE OF THE STRATEGIES OF VOCAL OPPONENTS TO FOOD IRRADIATION. THEY STRESSED THAT INDUSTRY SHOULD BE PREPARED TO EFFECTIVELY CHALLENGE MISLEADING ARGUMENTS.

CONSUMER CONCERNS

WHAT ARE CONSUMERS CONCERNED ABOUT? WHAT WOULD AFFECT THEIR DECISION TO BUY? CONCERNS INCLUDE THE FEAR OF EXPOSURE TO RADIATION THROUGH FOOD CONSUMPTION; FEAR THAT TOXIC PRODUCTS ARE CREATED BY THE PROCESS AND CONCERNS THAT NUTRIENTS ARE DESTROYED. QUESTIONS THAT FOOD MANUFACTURERS CAN EXPECT FROM RETAILERS AND CONSUMERS INCLUDE ARE IRRADIATED FOODS SAFE?, ARE THEY RADIOACTIVE?, WILL I GLOW IN THE DARK?, ARE THEY NECESSARY?, WILL THEY COST MORE?, WHAT FOODS WILL BE TREATED IN THIS WAY?, ARE IRRADIATED FOODS AS NUTRITIOUS AS FRESH?. OTHER QUESTIONS THAT CAN BE EXPECTED ARE: HOW WILL IRRADIATED FOODS LOOK?, FEEL?, TASTE AND SMELL?; WILL STORAGE, COOKING AND REHEATING TIMES CHANGE?; WILL FOODS TREATED WITH IRRADIATION BE SO COMMON THAT CHOICE IS ELIMINATED?; ARE THERE OTHER SOURCES OF IONIZING ENERGY BESIDES NUCLEAR?; WHO WILL INSPECT AND CONTROL IRRADIATION FACILITIES?; HOW WILL SPENT RODS OF COBALT 60 BE DISPOSED OF?; COULD IRRADIATION RESISTANT MICROORGANISMS BE FORMED?; HOW ARE APPROPRIATE DOSE RATES DERIVED?; COULD THEY BE LOWER?; WILL IRRADIATION BE USED IN COMBINATION WITH OTHER PROCESSING METHODS SUCH AS CANNING OR FREEZING?; IS THERE A POTENTIAL FOR MUTED GENES OVER A LONG PERIOD OF IRRADIATED FOOD CONSUMPTION?; HOW CAN IRRADIATION KILL BACTERIA AND NOT DESTROY NUTRIENTS?; IS IRRADIATION CARCINOGENIC?; CAN YOU EAT TOO MUCH IRRADIATED FOOD?; WHAT ABOUT NUCLEAR COMPOUNDS FORMED DURING THE IRRADIATION PROCESS?; WHAT ARE THEY?; ARE THEY TOXIC, MUTOGENIC? TO CONSUMERS IRRADIATION MEANS RADIOACTIVE, AND HAZARDOUS. IT IS ASSOCIATED WITH RADIOACTIVE WASTE, WORKER SAFETY PROBLEMS AND THE NUCLEAR ARMS BUILD UP. ALL OF THESE QUESTIONS WILL HAVE TO BE ANSWERED TO THE SATISFACTION OF THE CONSUMER, BEFORE IRRADIATION CAN HOPE TO OVERCOME ITS NEGATIVE ASSOCIATIONS.

RESEARCH DOES TELL US THERE ARE WAYS TO REDUCE CONSUMER CONCERNS (5, 11, 18) FOR EXAMPLE, USING A SYMBOL RATHER THAN WORDS ON A LABEL. AN EDUCATION/INFORMATION PROGRAM IS ESSENTIAL. ASSURANCES OF THE SAFETY OF IRRADIATION FROM THE FOOD AND AGRICULTURE ORGANIZATION AND WORLD HEALTH ORGANIZATION OF THE UNITED NATIONS AND MEDICAL ASSOCIATIONS ARE WELL RECEIVED. CONCEPTS OF FRESH, SAFE, DURABLE, NO CHEMICALS, NO PRESERVATIVES ARE ALL WELL RECEIVED, AS ARE EXPLANATIONS THAT THE PROCESS IS USED BY CONSUMERS IN OTHER COUNTRIES. STATEMENTS SUCH AS, LEAVES NO RESIDUE OR RADIATION IN FOODS, REDUCES WORLD HUNGER, REDUCES USE OF CHEMICALS IN FOODS, HAS THE ABILITY TO REDUCE FOOD SPOILAGE, ARE ALL WELL RECEIVED. STATEMENTS THAT ARE NOT VERY POWERFUL IN REDUCING CONSUMER CONCERN ARE: USED FOR FOOD CONSUMED BY PEOPLE WITH CRITICAL IMMUNITY PROBLEMS, USED TO STERILIZE MEDICAL AND SURGICAL PRODUCTS, USED BY ASTRONAUTS, ENERGY USE IS SIMILAR TO THAT OF ULTRAVIOLET LIGHT. EXPLANATIONS USING COBALT 60 CREATE FEAR. EXPLANATIONS USING PARTICLE ACCELERATORS HAVE BEEN CRITICIZED FOR BEING TOO SCIENTIFIC. A CLEAR INDICATION OF SAFETY TESTING TO ELIMINATE HEALTH CONCERNS; A SIMPLE EXPLANATION TO DEAL WITH RADIATION CONCERNS; AND A STATEMENT TO STRESS THE MINIMUM EFFECTS OF THE PROCESS ON THE FOOD ITSELF ARE MOST EFFECTIVE IN REDUCING CONSUMER CONCERNS. THE U.S. DEPARTMENT OF ENERGY STUDY FOUND THAT OVER A THIRD OF THE PEOPLE TESTED WITH INITIAL CONCERNS, REDUCED THEIR CONCERN LEVELS AS ATTRIBUTES OF THE PROCESS WERE PRESENTED. (18)

THE NATIONAL MARINE FISHERIES STUDY PROVIDES SOME ADVICE FOR THOSE PLANNING EDUCATIONAL PROGRAMS. (1) LITTLE INTEREST EXISTS AMONG THE GENERAL PUBLIC TOWARDS IRRADIATION DESPITE MEDIA

ATTENTION WHICH OCCURS EVERY TIME THERE IS SOME NEWS ON IRRADIATION. (A REGULATORY PROPOSAL, A SPOKESMAN FOR OR AGAINST IRRADIATION MAKING A STATEMENT.) CONSUMER AWARENESS OF IRRADIATION IS ONLY SLIGHTLY GREATER TEN MONTHS AFTER MEDIA COVERAGE THAN BEFORE . IN FACT, OVER A SEVENTEEN YEAR PERIOD IN THE UNITED STATES CONSUMER AWARENESS, DESPITE MEDIA COVERAGE, HAS REMAINED RELATIVELY STEADY WITH 24-32% OF CONSUMERS CLAIMING TO BE FAMILIAR WITH IRRADIATION. THE PUBLIC ARE LIKELY, ACCORDING TO THE STUDY RESEARCHERS, TO BECOME INTERESTED IN IRRADIATION AND RECEPTIVE TO INFORMATION WHEN THEY NEED TO MAKE PURCHASING DECISIONS. ASSURANCES OF THE SAFETY OF IRRADIATED FOODS WILL BE VITAL AT THIS POINT. THE GOOD HOUSEKEEPING INSTITUTE, IN THEIR 1985 FOOD ATTITUDE STUDY POINT OUT THAT THE SAFETY OF FOOD IS OF PRIMARY IMPORTANCE TO FOOD SHOPPERS. (8) NINETY SIX PERCENT OF FOOD SHOPPERS STATED THAT HAVING THE FOOD SAFE WAS THE MOST IMPORTANT CHARACTERISTIC THEY LOOKED FOR WHEN SHOPPING. THE SOURCES OF INFORMATION THEY LOOKED TO BEFORE DECIDING AN ITEM WAS SAFE INCLUDED THE AMERICAN MEDICAL ASSOCIATION, THEIR PHYSICIAN, A NUTRITION EXPERT, THE SURGEON GENERAL OF THE U.S., A PROGRAM ON EDUCATIONAL T.V., THE T.V. PROGRAM 60 MINUTES, THE NATIONAL INSTITUTE OF HEALTH, THE U.S. DEPARTMENT OF AGRICULTURE, THEIR OWN INSTITUTE'S SEAL OF APPROVAL AND THE FOOD AND DRUG ADMINISTRATION. IT CAN BE SEEN HOW IMPORTANT PROFESSIONAL ASSOCIATIONS, THE MEDIA AND GOVERNMENT WILL BE TO HAVING IRRADIATION ACCEPTED.

ATTITUDE OF RETAILERS

RETAILERS HAVEN'T BEEN SUBJECTED TO AS MANY ATTITUDE STUDIES AS CONSUMERS. IT IS EQUALLY IMPORTANT HOWEVER, FOR MANUFACTURERS

TO DETERMINE IF RETAILERS WILL BUY IRRADIATED FOODS GIVEN THE CHOICE.

THE RETAIL COUNCIL OF CANADA INFORMALLY CANVASSED THEIR MEMBERS AND REPORT THAT THEY ARE NOT OPPOSED TO IRRADIATION. THE RETAILERS SAW REAL BENEFITS TO INDUSTRY AND TO CONSUMERS. THEY SAW THEMSELVES BECOMING INVOLVED IN COORDINATED INFORMATION PROGRAMS ALONG WITH THE MANUFACTURERS AND GOVERNMENT. IT IS REASONABLE TO EXPECT RETAILERS TO ACCEPT THE IRRADIATION PROCESS BECAUSE THEY WILL RECEIVE THE SAME TANGIBLE BENEFITS OF EXTENDED SHELF LIFE WHICH APPEAL TO MANUFACTURERS.

A CANADIAN GALLUP POLL SURVEY ASKED RETAILERS OF FRESH FISH THE PROBLEMS THEY CURRENTLY FACED IN MARKETING THEIR PRODUCT. (3) THIS WAS AN EFFORT TO DETERMINE IF AND HOW IRRADIATION COULD BE HELPFUL TO FISH RETAILERS. INCONSISTENCY OF SUPPLY, AND QUALITY AND LACK OF CONSUMER FAMILIARITY WITH FRESH FISH WERE THE MAIN PROBLEMS THE RETAILERS FACED. REACTION TO IRRADIATION AS A MEANS TO SOLVE THEIR PROBLEMS WAS CAUTIOUS, BECAUSE OF CONSUMER CONCERNS.

RETAILERS, WHOLESALERS, BROKERS, INSTITUTIONS, RESTAURANTS, AND OTHER VOLUME FEEDING OPERATIONS HAVE TO BE SOLD ON THE PROCESS OF IRRADIATION. MARKET RESEARCH IN THIS AREA WILL BE IMPORTANT TO PRODUCERS OF IRRADIATED FOODS.

SENSORY PERCEPTION RESEARCH

RETAILERS AND CONSUMERS HAVE EXPRESSED INTEREST IN SEEING AND TASTING IRRADIATED PRODUCTS. PURCHASING DECISIONS WOULD BE BASED

ON IRRADIATED FOODS LOOKING AND TASTING LIKE THEIR NON-IRRADIATED COUNTERPARTS. PRODUCTS SUCH AS POULTRY, TEA, FRUITS AND VEGETABLES HAVE BEEN SHOWN TO IRRADIATE WELL, WITH NEGLIGIBLE ORGANOLEPTIC CHANGE. PRODUCTS SUCH AS MILK, AND FATTY FISH, ON THE OTHER HAND, UNDERGO FLAVOUR CHANGES. SENSORY EVALUATION OF IRRADIATED FOODS TO ENSURE ACCEPTABILITY IS A VITAL AREA OF RESEARCH.

CONCLUSION

FOOD MANUFACTURERS KNOW THERE IS A MARKET FOR CANNED, FROZEN AND MICROWAVABLE FOODS. ALL THESE PROCESSES TOOK TIME TO BECOME AS WELL ACCEPTED AS THEY ARE TODAY. IRRADIATION IS A NEW PROCESS TO CONSUMERS. IT WILL TAKE TIME BEFORE IRRADIATED FOODS ARE ACCEPTED. THE TIME CAN BE KEPT TO A MINIMUM IF SETBACKS ARE MINIMIZED. SETBACKS COULD BE CAUSED BY LACK OF CONSUMER KNOWLEDGE AND LACK OF PROPER PREPARATION AND PLANNING ON THE PART OF MARKETERS. RESEARCH DESIGNED TO INVESTIGATE WAYS TO REDUCE CONSUMER FEARS WILL BE AN IMPORTANT MARKETING TOOL. IT IS VITALLY IMPORTANT THAT THIS RESEARCH BE CONDUCTED AND EDUCATION PROGRAMS THEN BE DEVELOPED, AND TESTED BASED ON THIS RESEARCH.

INTRODUCING IRRADIATED FOODS WILL PRESENT UNIQUE CHALLENGES TO MARKETERS. NEW FOODS ARE NOT BEING INTRODUCED INSTEAD OLD FOODS WHICH LOOK THE SAME TO THE CONSUMER ARE BEING PRESENTED IN A NEW LIGHT. SIMPLE LIKE OR DISLIKE OR INTENTION TO BUY RESEARCH WILL NOT BE SUFFICIENT. CONSUMER FEARS MUST BE IDENTIFIED AND EFFECTIVELY HANDLED TO SUPPORT A RECEPTIVE CLIMATE FOR IRRADIATED FOODS. COOPERATIVE EFFORT BY GOVERNMENT, INDUSTRY AND PROFESSIONAL ORGANIZATIONS ARE ALSO NECESSARY TO

EASE THE PROCESS INTO THE MARKETPLACE. (9) THESE COORDINATED EFFORTS HAVE BEEN SHOWN TO BE SUCCESSFUL IN COUNTRIES SUCH AS SOUTH AFRICA. (17, 19) THE USE OF IN DEPTH EDUCATIONAL PROGRAMS HAS ALSO BEEN SHOWN TO BE EFFECTIVE IN REDUCING FEAR OF THE IRRADIATION PROCESS. (2)

THE HURDLE OF GOVERNMENT ACCEPTANCE OF FOOD IRRADIATION HAS BEEN SUCCESSFULLY CLEARED IN MANY COUNTRIES. THE RESEARCH PRESENTED IN THIS PAPER, THE ADDITIONAL RESEARCH MANUFACTURERS WILL NEED TO CONDUCT, AND THE PROMOTIONS MARKETERS WILL CREATE, SHOULD ENABLE TRADE AND CONSUMER ACCEPTANCE TO BE THE NEXT SUCCESSFUL HURDLE.

References:

1. Brand Group Irradiated seafood Products. A position paper for the seafood industry. Prepared for National Marine Fisheries, Washington, D.C. 1986.

2. Bruhn, C.M., Schutz HG, Sommer, R. Attitude Change toward Food Irradiation among conventional and Alternative Consumers. To what extent can consumers' fears of food irradiation be allayed through education. FOOD TECHNOLOGY, JANUARY 1986.

3. Canadian Gallup Poll Qualitative research on the Marketing of Irradiated Fish Prepared for: The Department of Fisheries and Oceans; Canada. 1984.

4. Coalition for Food Irradiation Prospectus 1401 New York Ave. N.W., Suite 400, Washington D.C., Dec., 1984.

5. Defesche, F, Van Asperen de Boer. Consumer Attitudes towards Irradiation of Food (A Pilot Study in the Netherlands) Young & Rubicam - Koster, B.U., 1982. IAEA - Tech Doc. 290.

6. Doyle, M. Irradiated Foods may pose credibility and liability challenges to retailers Progressive Grocer, May, 1984.

7. Good Housekeeping Institute Consumer Research Department Report Women's attitudes toward new food technologies Feb. 1985.

8. Good Housekeeping Institute Food Attitude Study, Report, The Consumer Research Department, April, 1985.

9. I.A.E.A. Marketing and Consumer Acceptance of Irradiated Foods Report of Consultants: Marketing, Market Testing and Consumer Acceptance of Irradiated Foods., Vienna, 1982. IAEA Tech Do. -290.

10. I.A.E.A. Report of the Task Force Meeting on Trade Promotion of Irradiated Food Vienna 1985.

11. Kidder, Peabody & Co. Survey on Consumer Attitude Toward Irradiation, New York ,1984.

12. Science Council of Canada Workshop on Food Irradiation Proceedings June, 1985.

13. Sigurbjornsson, B., van Kooij, J.G., Loaharanu, P. International Cooperation on Food Irradiation Joint FAO IAEA Division of Isotope and Radiation Applications IAEA, 1985.

14. Spielmann, H., Demand characteristics for Fresh and potentially gamma irradiated papaya on selected U.S. Mainland Markets - an attitudinal approach Research Bull. 149, Hawaii Agr. Exp. Station, U. of Hawaii, Feb. 1971.

15. Titlebaum, L.F., Dubin, E.Z., Doyle M. Will Consumers accept Irradiated foods, J. Food Safety, May, 1983.

16. Van der Linde, H.J.; Brodrick, H.T.; Commercial Experience in Introducing Radurized Foods to the South African Market. Nuclear Development Corporation, Pretoria, South Africa, I.A.E.A. SM-271/42, 1985.

17. Webb, C.P.N. Experience in Marketing Irradiated Food in South Africa O.K. Bazaars Ltd., Johannesburg, South Africa. 1982, I.A.E.A. - Tech. Doc. - 290.

18. Weise Research Associated Consumer Reaction to the Irradiation Concept Prepared for Pork Producers/U.S. Dept. of Energy March 1984.

19. de Wet, W.J. The South African Food Irradiation Programme: Role of Government Institutions. Nuclear Development Corporation, 1985, Pretoria, South Africa I.A.E.A. - SM - 271/41.

20. Young, M. Consumer Acceptance of Irradiated Food Consumers Association of Canada. 1983, I.A.E.A. Tech Paper GPS 334.

COMMERCIALIZATION OF IRRADIATED POTATOES IN JAPAN AND FUTURE PROSPECTS

T. HAYASHI
National Food Research Institute,
Ministry of Agriculture, Forestry
and Fisheries,
Tsukuba-gun, Ibaraki-ken,
Japan

Abstract

The studies on food irradiation have been conducted for three decades and the National Food Irradiation Research Project was started in 1967 and completed in 1981. The Japanese Government cleared potato irradiation in 1972 based on the results of the work in the Project, and commercial potato irradiation was commenced by Shihoro Agricutural Co-operative Association in 1973. Since then the potato irradiation has been conducted at an annual production of 15,000 to 30,000 tons. Although we encountered unexpected obstacles such as protest activity against potato irradiation carried out by some radical consumer groups, the commercial potato irradiation is successful owing to scientific countermeasures to the activity. The Agricultural Co-operative developed a technique to irradiate potatoes at half doses (4 to 10 krad) and to utilize the irradiated potatoes for potato processing. Potatoes irradiated at half doses will be widely used in potato processing plants in the future when there is no fear of consumers' reaction against irradiated foods.

The consumers' activity hindered the development of food irradiation in Japan. The Government is afraid of stimulating radical consumers again and no food irradiation other than potato irradiation has been approved in our country. However the commercialization of some food irradiation is an urgent problem, especially as an alternative technique to fumigation.

National Food Irradiation Research Project

The Atomic Energy Commission specified the study of food irradiation for the purpose of extending the shelf-life of food, as part of its Special Research on the Designated Uses of Atomic Energy, and the National Food Irradiation Research Project started in 1967. Seven food items such as potato, onion, rice, wheat, Mandarin orange, Vienna sausage and kamaboko (boiled fish paste) were subjected to the project. Although the project was scheduled to end in 1976, it was completed in 1981, because we performed some experiments other than those planned to do at the time of the start of the project owning to the development of new methods to evaluate the safety of irradiated foods.

The wholesomeness of the irradiated foods was proven and the results on the items except Mandarin orange was reported to the Government (Table 1). Although the results on irradiated

Table 1 SUMMARY OF MAJOR RESULTS OF RESEARCH AND DEVELOPMENT ON FOOD IRRADIATION IN JAPAN (REPORTS ALREADY RELEASED)

Item	Effect of irradiation		Identification method	Wholesomeness				Remarks
Produce name (purpose of irradiation)	Effect	Problem points		Nutritional test	Chronic toxicity test	Reproduction test	Mutagenicity test	
Potatoes (sprout inhibition)	Sprouting at room temperature can be prevented for 8 months, by an irradiation dose of 70 to 150 GY.	No particular problem.	No practical method could be found.	No effect	No effect	No effect	No effect	Permitted by Food Sanitation Law (1972). Has actually been used.
Onions (sprout inhibition)	Sprouting at room temperature can be prevented for 8 months, by an irradiation dose of 20 to 150 GY.	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Results of research have been reported. (1980) (Application has not yet been presented.)
Rice (insect dis-infestation)	Irradiation dose of 200 to 500 GY is enough for controlling insect.	Some varieties of rice of show a deterioriation of flavor and taste after being irradiated.	Ditto	Ditto	Ditto	Ditto	Ditto	Results of research have been reported. (1985) (Application has not yet been presented.)
Wheat (insect dis-infestation)	Ditto	The amylographic vis-cosity of flour has been decreased.	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto
Wiener sausage (decontami-nation)	Shelf-life can be extended to 3-5 times the usual length of time, at a storage temperature of 10°C, by irradiation at 3 to 5 KGY.	Nitrogen gas packaging with a material which has low oxygen perme-ability is necessary.	Ditto	Ditto	Ditto	Ditto	Ditto	Results of research have been reported. (1983) (Application has not yet been presented.)
Boiled fish paste (decontamina-tion)	Shelf-life can be extended to 2-3 times the usual length, at a storage temperature of 10°C, by irradiation at 3 KGY.	No particular problem.	There is a possibility of using change of the fluores-cent spectrum, for identifi-cation	Ditto	Ditto	Ditto	Ditto	Ditto
Mandarin oranges (surface decon-tamination)	Not released							

Mandarin oranges have not been reported, their wholesomeness has been confirmed and the same results as the others will be reported soon.

Legislation of Food Irradiation in Japan

Food irradiation is regulated according to Food Sanitation Law in Japan and the law prohibits food irradiation generally. However potato irradiation was cleared in 1972 based on the wholesomeness data in the National Food Irradiation Research Project. The law restricts food irradiation in "Specifications and Standards of Foods and Food Additives" as follows :

1) Irradiation shall not be used in the manufacturing and processing of food. However, in the case of control of manufacturing and processing of food, when the absorbed dose is less than 10 rad, and also in case 3) there is no restriction.
2) Irradiation shall not be done for the purpose of the preservation of food.
3) Irradiation of potatoes, for the purpose of sprout inhibition, must follow the procedure below.
   a) Gamma rays from Co-60 must be used.
   b) The absorbed dose for potatoes should be less than 15 krad.
   c) Irradiated potatoes must not be re-irradiated.
4) The regulations for the execution of this law also specify that the packaging and containers of irradiated foods must indicate that irradiation has been done.

Background of Potato Irradiation in Shihoro

Potato seanson begins in April when potatoes are harvested in southern part of Japan and the harvesting area is shifted to the north and then the season ends in October in Hokkaidoh, northern Japan (Fig. 1). The potatoes harvested in Hokkaidoh in autumn are stored and marketed up to the following spring.

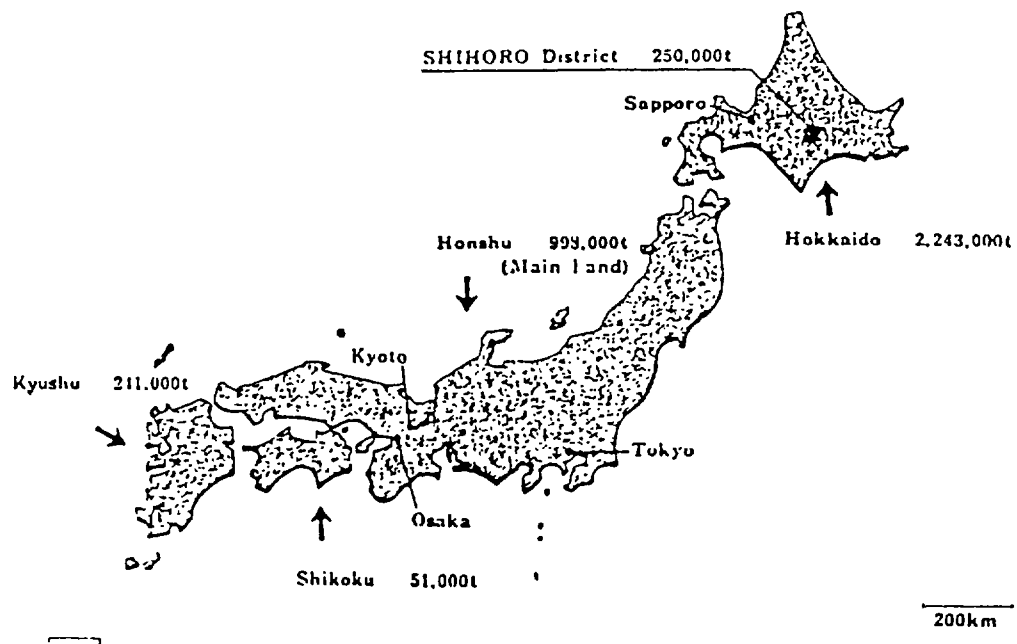


Fig.1 Potato Yield in Japan (Total 3,200,000t)

However they sprout in the off-season, February to April, and the price of potatoes is prone to increase due to the lack of sound potatoes. Before the commercialization of potato irradiation the Vegetable Price Stabilization Fund and Tokyo Metropolitan Government used to buy several thousand tons of potatoes harvested in Hokkaidoh in autumn for the purpose of preventing price fluctuation. Although they were successful in overcoming the price fluctuation up to February, these potatoes started sprouting in March and April, when the purpose of price stabilization could not be attained. It was required to keep potatoes which never sprout in the off-season, which meant a necessity to irradiate potatoes in Japan because the usage of chemicals for sprout inhibition was prohibited.

The Shihoro Agricultural Co-operative is one of the most active and progressive farmers' co-operative unit in our country. Production of potatoes in Shihoro, central Hokkaidoh, is 250,000 t/year. Before the establishment of the Shihoro Potato Irradiator, Shihoro Agricultural Co-operative had its own potato processing plants ; starch manufacturing plants with a capacity of 180,000 t/year and a marshed potato plant with a capacity of 17,000 t/year etc. The irradiated potatoes which were not sold at fresh market could be efficiently utilized at these plants as material and the cost of irradiation could be absorbed by the several plants. Further it was expected that the operation period of the potato processing plants could be extended.

Shihoro Potato Irradiator

The potato irradiation plant was designed to hold a Co-60 source of 300 kCi and to irradiate approximately 350 tons of potatoes per day for a period of 3 months in a year, thus irradiating over 30,000 tons of potatoes per year (Table 2). The

Table 2 General Description of Shihoro Irradiator

Gamma source	
	Co-60 300kCi, maximum capacity;800－1,000kCi
	AECL type Co-60 pellet 7500Ci x 36pcs.
Container of potatoes	
	Internal dimension;0.98 x 1.6 x 1.3m----1.5 t of potatoes
	0.98 x 1.6 x 0.65m---0.75 t of potatoes
Absorbed dose	
	Max;15krad, Min;6krad, Max/min=2.5
Irradiating capacity	
	15 t/hr, 10,000 t/month
Irradiating time	
	2 hours (irradiating both sides)
Source efficiency	
	9.5%

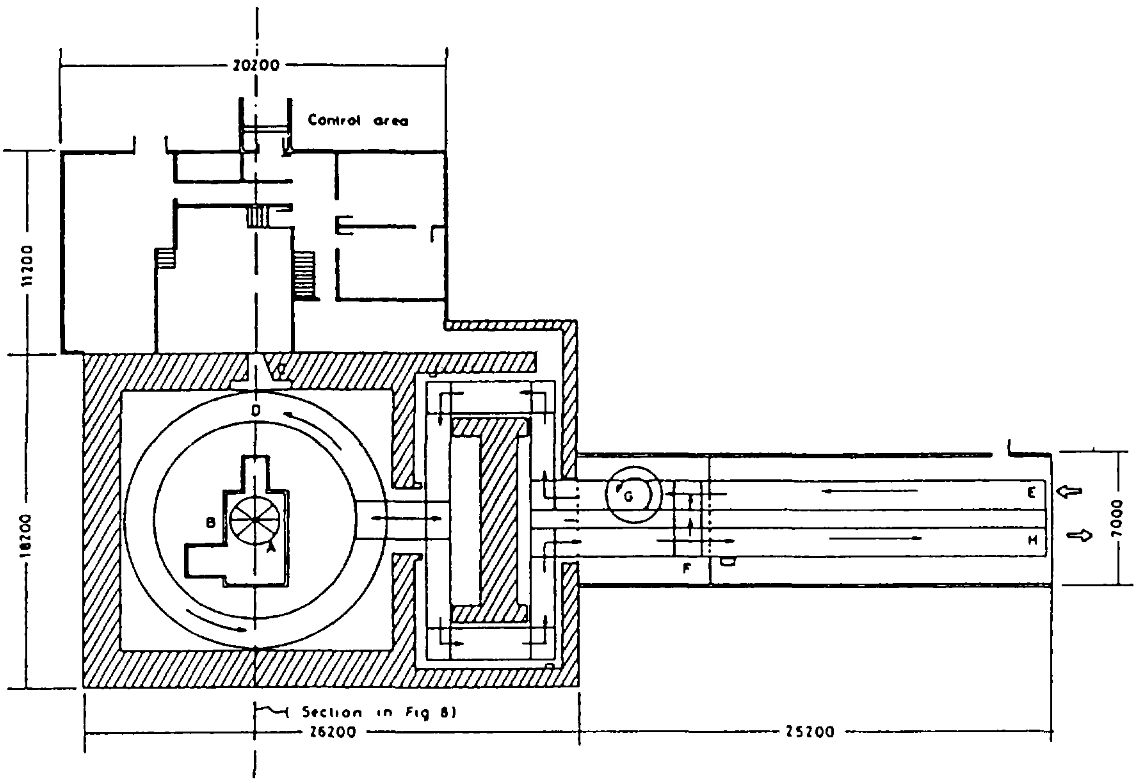


Fig.2 Shihoro Agricultural Co-operative Association potato irradiator (plane view): A. source; B. water pool; C. window; D. irradiation conveyor; E. entrance line; F. line transfer; G. turntable; H. exit line.

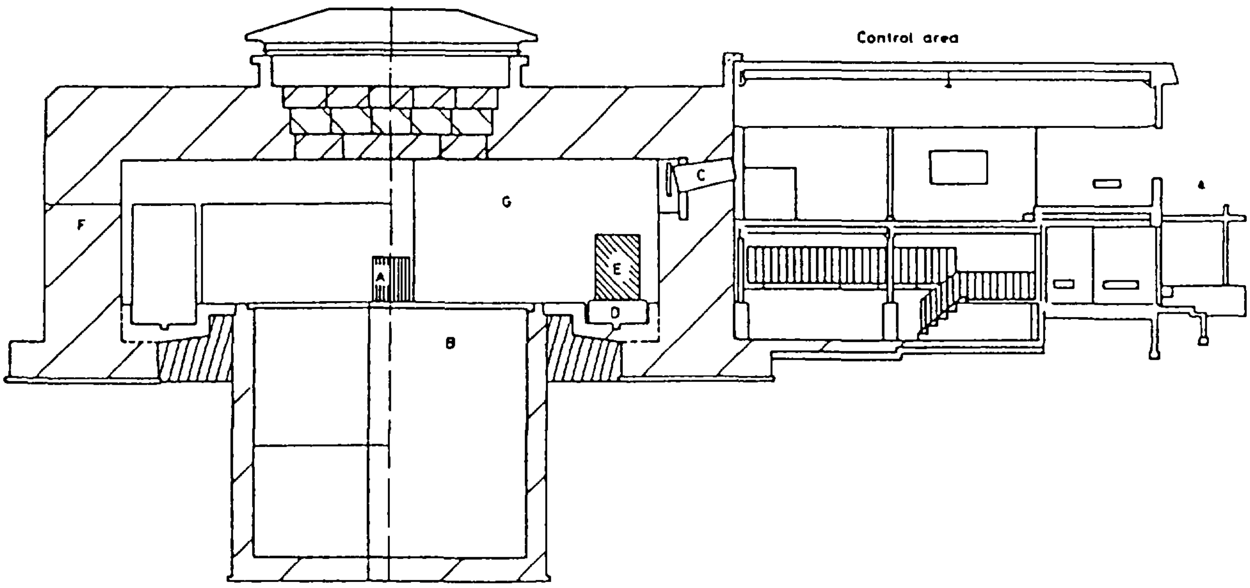


Fig.3 Shihoro Agricultural Co-operative Association potato irradiator (section): A. source; B. water pool; C. window; D. irradiation conveyor; E. potato container. F. shield. G. irradiation chamber.

potato irradiating plant was constructed at Shihoro Agricultural Co-operative in Hokkaidoh as illustrated in Figs. 2 and 3 and its construction cost a total sum of 389 million yen (US$ 1.30 million, 300 yen= 1 dollar, Table 3), of which 230 million yen (US$ 0.77m) was financed by the Japanese Government, 23 million yen (US$ 0.07m) by the Hokkaidoh Prefectural Government and the rest by the Shihoro Agricultural Co-operative Association.

Table 3 Construction Cost of Shihoro Irradiator

Item	Cost (US dollar)
Building	
Irradiation area ($449m^2$)	257,400
Control area ($303m^2$)	38,200
Working area ($981m^2$)	66,700
Conveyor area ($179m^2$)	17,600
Equipment	
Conveyor system	170,000
Source control system	
Safety control system	450,000
Associated facilities	
Source	
Co-60 (300,000 Ci)	170,000
Others	
Fork-lift	7,800
Containers (2,000boxes)	120,000
Total	1,297,700

300yen = 1dollar

Several other plants for potato processing and warehouses were constructed in the same site, forming a potato processing center (Fig. 4 and Table 4), with a finantial assistance by the Japanese Government.

The irradiation plant is operated by two operators, one liftman and one assistant in the day-time and by two oparators and two liftmen at night. During the period when the irradiation plant is closed all of them except one management staff are transferred to other sections or plants of the Agricultural Co-operative. The replenishment of Co-60 source was performed 5 times since the construction (37.5kCi in 1974, 37.5kCi in 1976, 38.0kCi in 1981, 45.0kCi in 1983, 35.0kCi in 1985), and the irradiator holds ca. 160 kCi of Co-60 at present. The irradiation cost is influenced by various factors such as replenishment of Co-60, tonnage of irradiated potatoes,

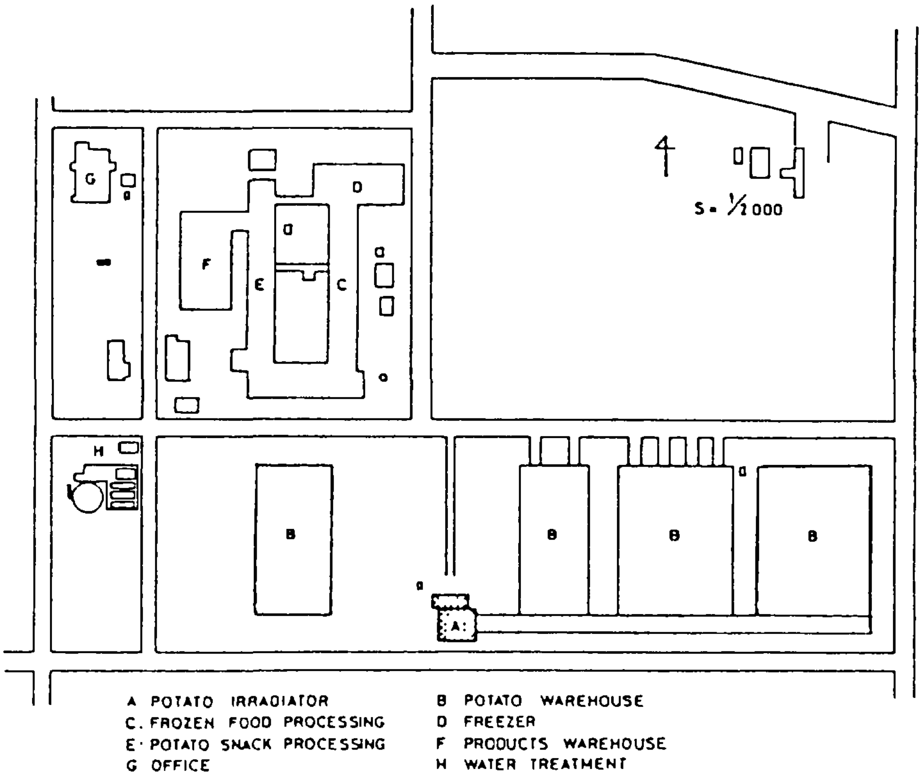


Fig.4 Layout of Shihoro potato processing center

Table 4 Potato Processing Center in Shihoro

Item		Capacity	Year	Cost($)
Potato chips plant	3,501m²	40t/day	1973	1,557,000
Frozen food plant	2,782m²	24t/day	1973	1,480,000
Frozen food warehouse	2,563m²	1,475t	1973	1,350,000
Frozen food processing machine		40t/day	1976	2,657,600
Waste water treatment	3,855m²	70t/day	1973	330,000
		total		7,374,600

300yen = 1dollar

repairment of the facility etc. and is in the range of 10-20 $/ton (Table 5). When the plant is operated at its full capacity (30,000 t/y) the cost of potato irradiation is estimated at $ 5-10/ton.

Commercialization of Potato Irradiation and Protest Activity against Irradiated Potatoes

The irradiated potatoes were first marketed in 1974 with the label shown in Fig. 5 on a carton or a container and contributed to the stabilization of potato price in the off-season of potatoes in Japan (February to April). Vegetable Price

Table 5 Cost of Irradiating Potatoes

Item	73/74[1]	74/75[1]	82/83[2]	83/84[2]	84/85[2]
Interest	35,854	34,107	15,355	13,246	11,800
Tax	1,140	18,413	0	0	0
Depreciation	113,557	66,660	19,396	14,450	11,811
Replenishment	0	55,000	0	98,180	0
Repair & maintenance	8,370	8,334	8,464	72,464	6,668
Energy	8,474	11,947	33,702	27,806	24,660
Labour	32,140	35,047	92,000	88,000	104,200
Others	31,702	15,827	13,537	21,159	12,197
Total	231,237	245,335	182,454	335,305	171,336
Irradiated potatoes(t)	15,033	19,033	20,511	17,668	20,913
Cost of irradiation($/t)	15.38	12.89	8.90	18.98	8.19

[1] 300yen=1dollar

[2] 250yen=1dollar

(Example of Japanese certification for irradiated potatoes. (Irradiation by gamma rays, date of irradiation, and "potatoes" are indicated here.))

Fig.5 Label for Irradiated Potatoes

Stabilization Fund bought 5,500 and 3,700 tons of irradiated potatoes in a season of February to April in 1974/1975 and 1975/1976 respectively, while the tonnages of irradiated potatoes were 19,033 and 21,675 tons in 1974/1975 and 1975/1976 respectively. The rest of the irradiated potatoes were used for potato processing and starch production.

In May, 1976 a protest activity against irradiated potatoes was opened by sending a questionnaire to Shihoro Agricutural Co-operative Association inquiring the irradiation dose, the buyers of irradiated potatoes and the safety of irradiated potatoes.

Another questionnaire was forwarded to potato processing companies inquiring the source of raw potatoes, whether they used the irradiated potatoes or not and, if so, the amount of irradiated potatoes they utilized. The central body of this protesting activity was Japanese Federation of Consumers, extremely radical consumer group. They started teach-ins for the members of the Japanese Federation of Consumers and tried to emphasize danger of radiation, genetic toxicity of irradiated foods and destruction of nutrients by irradiation. A newsletter "Consumers' Report" dealt with food irradiation in its 8 successive issues between August, 1976 and February, 1977. In the articles they questioned the safety of irradiated foods with intentionally collected information such as listed in Table 6.

Table 6 Comments on the Wholesomeness of Irradiated Foods by the Radical Consumers' Group

1) Withdrawal of approval of irradiated bacon in USA based on such observations as adverse effects on reproduction, increase in mortality and decreased body weight of experimental animals
2) Extraction of Radiotoxin from irradiated potatoes and its genetic toxicity
3) Decrease in weight and ovarian size of rats fed on irradiated potatoes (Japanese National Project)
4) The changes in nutrients and substances in potatoes caused by gamma-radiation are not clear
5) Japan is the only country where irradiated food is widely consumed

They demanded the Japanese Government to withdraw the approval of potato irradiation and several local governments such as Tokyo Metropolitan one to ban selling irradiated potatoes in each area. The movements against irradiated potatoes were introduced to the whole country by major newspapers. The activities mentioned above made it impossible for Vegetable Price Stabilization Fund to sell irradiated potatoes, although the fund had bought 3,700 tons of irradiated potatoes. And the irradiated potatoes were used for processing.

The Japanese Research Association for Food Irradiation (JRAFI) organized all available information to oppose the position of the consumers' groups and coped with the press by providing interpretation of the safety of irradiated potatoes. However department stores and supermarkets announced the cancellation of irradiated potatoes and the School Lunch Program Association banned usage of irradiated potatoes in March, 1977. Socialist Party's Member of the House of Representatives Mrs. Takako Doi submitted to the Speaker of the House of Representatives 15 item-questionnaire entitled "Questions on Irradiated Foods" in March, and Ministry of Health and Welfare, Ministry of Agriculture and Forestry, and Science and Technology Agency jointly prepared an official reply to the questionnaire in April. The governmental agencies started to take efficient measures to the press to tranquilize the irrational consumers' movement, and the movement ceased in May. A large amount of irradiated potato stock, however, lost their buyers and ultimately was directed to potato starch mills.

Table 7 Contents of Food Irradiation, Japan, Vol.12 No.2
Special feature issue;Boycott Movement Against Irradiated Potatoes

1. Preface for the special feature issue
2. Present status of food irradiation and its feasibility
   1) Present status of food irradiation in Japan
   2) Wholesomeness of irradiated foods---Especially on irradiated potatoes
   3) Economical effects of irradiated foods and future aspect in food distribution
   4) Present status of food irradiation in various countries
   5) Irradiated food commodities recognized as safe for human consumption
   6) List of the members of the Joint FAO/IAEA/WHO Expert Committee on the Wholesomeness of Irradiated Food
3. Background of the disapproval of irradiated bacon in USA in 1968
4. Toxicity of sprouted potatoes and the mechanisms of sprout inhibition of potatoes by irradiation
5. The development of boycott movement and the countermeasures to the movement
   1) 1st stage: Questionnaire and Consumers' Report
   2) 2nd stage: Report on the newspaper and boycott meeting
   3) 3rd stage: Countermeasure by JRAFI and administrative organs
   4) Present status
6. Reference materials
   1) Outline of food irradiation and Japanese policy on food
   2) Regulations related to irradiated potatoes
   3) List of domestic reports concerning food irradiation
7. Others
   1) Publication list by JRAFI
   2) Member list of JRAFI
   3) Record of JRAFI's activities
8. Editor's comments

In September, 1977, JRAFI published a special issue of its journal "Food Irradiation, Japan" in which all the documents related to the boycott movement were cited and available literatures on the wholesomeness of irradiated foods were introduced in order to scientifically cope with the radical groups (Table 7). The special issue was circulated among the governmental agencies, local governments, consumers' associations, food industry and agricultural co-operatives with 1,500 copies. The publication was highly effective in overcoming the general misunderstanding and in promoting better understanding of the wholesomeness of irradiated foods. No protest movement against irradiated potatoes happened thereafter and we observed a recovery of the sale of irradiated potatoes in the spring of 1978. The commercial potato irradiation has been successful since then.

An illegal food irradiation activity was revealed in September, 1978. A food processing company had been irradiating dehydrated vegetables for baby-food more than 10 years and was prosecuted for the illegal irradiation. This scandal, however, did not leave a slightest influence on the sale of irradiated potatoes. The attitude of the press was quite neutral about this sensation based on their better understanding of the safety of irradiated foods.

Irradiation of potatoes is advantageous at potato processing plant as well as fresh market. If Shihoro Agricultural Co-operative preserves irradiated potatoes up to the autumn in the year following the harvest and uses them for processing, the Co-operative can utilize its own potatoes and does not have to transport potatoes from the Mainland of Japan. A large amount of irradiated potatoes is necessary at the time of self-sufficiency of potatoes for processing, and the tonnage of irradiated potatoes has to be increased. They experimentally irradiated potatoes at a dose of 4 to 10 krad (half dose irradiation) in order to increase the tonnage. The potatoes treated with half-dose irradiation sprout slightly and show a filamentous sprout, which is easily removed during washing before processing. Another advantage of half-dose irradiation is that the contents of reducing sugars are not so high as those irradiated at a normal dose. These observations indicate that the potatoes for only processing do not have to be irradiated at a dose of 6 to 15 krad.

Current Situation of Food Irradiation in Japan

The protest movements against irradiated potatoes left a serious influence on the development of food irradiation in Japan. The Government does not want to stimulate radical consumers any more and food processing companies pretend as if they were not interested in food irradiation. Therefore no petition for the approval of food irradiation has been done and the Government has not taken an action toward the permission of food irradiation.

The Joint FAO/IAEA/WHO Expert Committee concluded that the food irradiated at an overall average dose up to 1,000 krad is wholesome for human consumption in 1980, and Codex Alimetarius Committee distributed the Recommended Codes related to food irradiation in 1983. Around that time WHO recomended the ban of usage of EDB because of its carcinogenic activity and food irradiation was considered to be promising as an alternative method to fumigation. The number of countries which clear and/or commercialize food irradiation is increasing in the world.

We are importing a large amount of citrus fruits from USA and her banning EDB is expected to cause several problems. Although at present USA is fumigating the fruits to be exported to Japan, the Japanese importers are afraid of ceasing their fumigating treatment. They are investigating into establishing an alternative technique to fumigation other than irradiation, which is not successful so far. The usage of ehtylene oxide for decontamination of foods such as spices and dehydrated vegetables is prohibited in Japan, and the microbial level of spices for food processing should be lower than 10,000/g according to the Food Sanitation Law. It is almost impossible to attain this microbial level without fumigation or irradiation. We reject around 50 tons of frozen shrimps and lobsters imported to Japan, because of the contamination with pathogenic microorganisms, every year.

In considering the international trend and the current problems related with food sanitation, we have to re-consider food irradiation. However it is difficult to re-introduce food irradiation to our country because of the emotional reaction to food irradiation by radical consumers. We believe that we have to continue a scientific effort to convince consumers that the foods irradiated at a certain level are wholesome for human consumpsion. As a first step, we started collecting information on the current status of food irradiation in various countries.

Appendix History of Food Irradiation in Japan

1967	National Project was started
1972	Irradiation of potatoes was authorized
1973	Potato irradiation was started at Shihoro
1974 (March)	Irradiated potatoes were sold
1976 (May)	Questionnaire was sent to Shihoro Agricultural Co-operative and to food processing companies
	Teach-in was started by a consumers' group
1976 (Aug) — 1977 (Feb)	Consumer's Report placed a series of feature articles on danger of irradiated foods
1977 (Feb)	Radical groups informed the press that they will launch a boycott movement against irradiated potatoes
1977 (March)	JRAFI started to cope with the movement
1977 (March)	The School Lunch Program Association banned the usage of irradiated potatoes
1977 (March)	Mrs.Doi submitted a Questionnaire to the Speaker of H.R.
1977 (April)	The Government prepared an official reply to the Questionnaire
1977 (May)	The Government started to take efficient measures to the press to tranquilize the irrational consumers' movement
1977 (Sept)	JRAFI edited a special feature issue of its journal, Food Irradiation, Vol 12 No 2
1978 (Sept)	Illegal food irradiation was revealed
1982	JRAFI published Q&A on food irradiation in Food Irradiation Vol 17
1985	Japan Atomic Energy Relations Organization published a Press Release on Food Irradiation

IAEA-SR-129/91

AUSTRALIA'S CO-OPERATION UNDER THE FRAMEWORK OF THE ASIAN REGIONAL CO-OPERATIVE PROJECT ON FOOD IRRADIATION

P.A. WILLS
Lucas Heights Research Laboratories,
Australian Atomic Energy Commission,
Sutherland, New South Wales,
Australia

Abstract

The second phase of the Asian Regional Project on Food Irradiation (RPFI) became effective on 11 April 1985, and will last for three years, with Australia as the funding country. The first major activity was a two-week Workshop on the Commercialisation of Ionising Energy Treatments of Food, held at the Australian School of Nuclear Technology from 29 April to 10 May, 1985, attended by representatives from eight RPFI countries and two observers from New Zealand. Studies of the transportation irradiated foods under commercial conditions are an integral part of the Project. Results of shipping/airfreight trials between Thailand and Australia of Nan Klang Won mangoes and frozen shrimps are presented. These trials were successful as irradiated produce shipped under commercial conditions reached its destination in good, marketable condition.

INTRODUCTION

The first phase of the Asian Regional Project on Food Irradiation (RPFI) operated from 18 August, 1980 to 27 August, 1984 and was funded by Japan. In 1983, a mission of experts visited several of the Project countries to evaluate the progress an achievements of the Project. It concluded that "food irradiation technology in most RPFI countries had reached the stage where it can be effectively transferred to the relevant industries". With this encouraging report, the RPFI project Committee at its fourth meeting held in Seoul, April 1984 agreed to a three year cooperative programme for technology transfer of food irradiation, subject to the availability of funds.

As Japan did not wish to continue its sponsorship of the RPFI, the International Atomic Energy Agency (IAEA) suggested that Australia should become the funding country, even though Australia had not participated in Phase I. This proposal was eventually accepted, some of the reasons being that food irradiation technology in Australia was at the stage where it could be transferred to local industries, there was a common trade interest in a number of the food items being studied under RPFI, and there were close political and economic ties between Australia and many of the participants in RPFI. The Australian government accordingly allocated US$ 260,000 to fund the Project for three years from 11 April 1988.

WORKSHOP

The first major activity of the Project was to hold a two-week Workshop on Commercialisation of Ionising Energy Treatment of Food. The Workshop was held at the Australian School of Nuclear Technology (ASNT), Lucas Heights, Australia from 29 April to 10 May 1985. Its main objective was to demonstrate pilot-scale applications of food irradiation to scientists and interested industrialists from RPFI countries in order to enable them to plan transfer of the technology to appropriate applications in their own countries.

RPFI countries participating in the Workshop included Australia, Bangladesh, Indonesia, Republic of Korea, Malaysia, Pakistan, the Philippines and Thailand. Two participants from New Zealand also attended the Workshop. Unfortunately, with the exception of Australia and the Philippines, representatives from food industries in the RPFI countries did not attend the Workshop.

The Workshop programme included lectures on the basic principles of food irradiation and applications for different foods, batch plant irradiation of seafoods, fruits, spices, onions, and other foods, dosimetric techniques, quality assurance tests, organoleptic assessment, and field visits. After a panel discussion on strategies for marketing irradiated foods, participants agreed unanimously on two recommedations for forwarding to their relevant national authorities:

"(1 This Workshop recommends that those in attendance should seek to initiate and stimulate interest in food irradiation among food manufacturers and the community in general, and to this end should work towards forming a steering group/committee involving representative of food industry, consumer organisations, etc. to prepare and disseminate educational material and if necessary to urge the adoption of the Codex Alimentarius Commission's General Standard of Irradiated Foods and its Recommended Code of Practice for the Operation of Radiation Facilities used for the Treatment of Foods.

(2) It is further recommended that the steering group should operate through the central organisation representing food manufacturers, and/or food producers."

FIRST PROJECT COMMITTEE MEETING

This meeting was hosted by the Australian Atomic Energy Commission (AAEC) and held at the Lucas Heights Research Laboratories on 13-15 May, 1985. A work schedule involving each participating country was drawn up.

IAEA/AAEC Research Agreement

An AAEC proposal for a research project for RPFI, Phase II on technology transfer for commercialisation of food irradiation was accepted by the IAEA, effective from 1 November 1985. Part of this project involves evaluation of food items shipped from RPFI countries after irradiation.

TRANSPORT STUDIES

A study of the possible effects of irradiation, on the quality of foods after commercial transportation to importing countries is an integral part of evaluating the technological feasibility of a radiation process for export foods. Products irradiated as part of the RPFI Project can be shipped by the participating country to Australia for assessment by the Australian Atomic Energy Commission in collaboration with quarantine control and other Commonwealth importing authorities.

The two food items tested so far are mangoes and frozen, headless shrimps. Mangoes are already being exported from some RPFI countries. Radiation disinfestation treatment against fruit flies and the mango seed weevil can provide a quarantine control method that is an alternative to the chemical fumigant ethylene dibromide, the use of which is banned in some countries because of potential carcinogenicity. Under specific conditions, radiation treatment may extend shelf-life of mangoes, which could lead to market expansion. Frozen shrimps from Asian countries are sometimes decontaminated in European radiation facilities. As radiation plants become available, treatment in the country of origin will be an alternative which could bring economic benefits to the region [1]. A shipping trial for onions irradiated to inhibit sprouting is planned for later this year.

Mangoes

Two trials were carried out on the Nan Klang Won variety harvested from the same orchard located near Chiang Mai, Thailand, in collaboration with D. Buangsuwon and other officers from the Division of Plant Pathology and Microbiology, Thailand Department of Agriculture and Cooperatives and visiting IAEA Technical Consultant in Thailand, Dr. A.M. Dollar.

In the first trial, conducted as part of the Phase II Project Workshop held in Sydney, mangoes harvested at Chiang Mai, on 25 April 1985, were transported to Bangkok then wrapped in tissue paper and placed in single-layer cartons (11-12 fruit per carton, about 78 kg). They were airfreighted from Bangkok on 29 April and reached Sydney on 30 April at 08.00 hours (local time). A quarantine officer transported the mangoes by car to Lucas Heights (10.30 hours), where they were transferred to the laboratory for storage at ambient temperature (about 18^{o}C).

At 14.00 hours the mangoes were unpacked and sorted according to colour on a 1 (green) to 5 (3/4 to full colour) scale. The mangoes were then divided into three groups: Grade 1 (28%) Grade 3(46%) and Grade 4 (26%). Each group was divided into four sub-groups for separate treatments. Grade 3 mangoes were further sub-divided into two replicates per treatment. Replicates consisted of 10 to 14 fruits. The four treatments were as follows:-

(1) no treatment,
(2) hot water dip (55^{o} for 5 minutes),
(3) radiation only (750 Gy minimum),
(4) combination treatment of hot water followed by irradiation.

For each treatment about 45 mangoes were used.

For the hot water dip treatment, mangoes in open mesh plastic bags were transferred to laboratory water baths operating at $55^{o}C + 0.5^{o}C$ for 5 minutes. The temperature dropped initially to 54^{o} but returned to $55^{o}C$ within two minutes. Immediately after dipping, the mangoes were removed from the mesh bags and placed on paper towelling (sterilised at 25 kGy) to dry and cool. The delay between completion of hot water treatment and commencement of irradiation was one to three hours.

For irradiation, the mangoes were placed one layer deep in heavy cardboard trays such as used by the Australian mango industry. Paper towelling was packed around the mangoes to prevent their movement within the tray during handling. Two trays were placed vertically and parallel to the source in each drawer of a Cobalt-60 facility (2). Tray depth was about 10 cm. Dose rate was 1.80 $kGyh^{-1}$. Trays were irradiated to give a minimum dose of 0.75 kGy; this dose exceeds the dose needed as a quarantine control treatment to disinfest mangoes of fruit flies and the mango seed weevil, and also may provide extension of shelf life. (Only oriental melon flies are expected in fruit from Thailand).

All fruits were stored in a laboratory at Lucas Heights until 2 May and then returned by airfreight to Bangkok, arriving there the same day. After about 18 hours storage at the airfreight office ($27 \pm 2^{o}C$), the mangoes were transferred on 3 May to a laboratory for immediate inspection of colour and condition.

Colour and condition grades (5-point scale) are summarised in Table 1. Analysis of variance showed no significant differences ($P < 0.05$) in either quality for mangoes given different treatments. The colour of the mangoes increased approximately by one unit between arrival in Sydney and inspection in Bangkok (data not shown). Eight days post-harvest, and having been airfreighted a distance of about 14,000 km, 91.5% of the fruit were regarded as being of marketable quality (condition grade 1 to 3).

The experimental design of the second trial involved six replicated for untreated mangoes and three replicates for each treatment, hot water dip, radiation, and a combination treatment of hot water and radiation. Each replicate used 12 mangoes.

Mangoes (72 kg) harvested on 26 May were airfreighted the same day to Bangkok and stored at $24 \pm 0.5^{o}C$ until 28 May when a portion of the crop was dipped in hot water (51.8 ± 0.3^{o}) for 15 min. After cooling in moving air for about 35 min, the mangoes were individually wrapped in tissue paper and packed stem-end down and one layer deep into 47 x 31 x 10 cm deep fibreboard cartons. The cartons were sealed with tape to prevent reinfestation, transferred to a cool room ($3 + 1^{o}C$) for 4 h to reduce the internal pulp temperature to $20 + 1^{o}C$, before overnight storage at $24 + 1^{o}C$.

On 29 May (day 3), the cartons were transported to the Office of Atomic Energy for Peace, Bangkok for irradiation treatment using an AECL Gammabeam 650 facility. Six cartons, three of which contained hot-water dipped mangoes, were irradiated, with rotation half-way through the irradiation, to an average minimum absorbed dose of 0.22 ± 0.03 kGy (range 0.206 to 0.26 kGy), at a dose rate of 0.077 $kGyh^{-1}$. The maximum: minimum dose ratio was 1.5.

The mangoes were airfreighted from Bangkok to Sydney on 30 May, arriving on 31 May (day 5). They were transported to Lucas Heights under quarantine supervision and transferred to an air-conditioned container for storage at about 14°C (range 10-19°C) with a relative humidity (RH) of about 70% (range 60-95) for the first 5 days (day 10) and 20° (range 20 to 20.5°C), with and RH of about 60% (range 48-75) until day 16.

Mangoes were inspected and graded on a 1 to 5 scale for colour and condition on 5, 8, 10, 12, 14 and 16 days after harvest. Mean values for colour and condition ratings at each inspection are given in Table 2. Significant differences in colour development after different treatment were apparent (Student - Newman - Keuls Procedure). In general, ripening was accelerated in the mangoes dipped in hot water both with an without radiation treatment. Radiation treatment alone neither accelerated or retarded ripening. The condition of the mangoes was not affected by any of the treatments until day 16, when the condition of the mangoes indicated a marketability percentage of 43, 83, 67 and 83 for untreated, hot water dipped, irradiated and a combination of hot water/irradiation treated mangoes, respectively.

Organoleptic assessment of mangoes was carried out on days 12 and 16 post-harvest using triangle taste tests and rating on a 1 (like very much) to 5 (dislike very much) scale. About half the panelists detected differences between the untreated and treated samples, irrespective of the kind of treatment, and either preferred the untreated mangoes or rated them equally with treated fruit. One problem encountered with this assessment was the difficulty of selecting fruit of comparable ripeness for taste tests.

The percentage of untreated, hot water dipped, irradiated and combination treated mangoes with skin punctures from insect infestation were 12.5, 13.9, 8.3 and 0% respectively. One larva was seen crawling on the outside of one mango. A low rate of insect infestation was confirmed by Australian plant quarantine inspectors who check only the exterior of the fruit in search of points of insect entry. Mangoes given radiation disinfestation treatment by an exporting country would therefore need to be accompanied by certification that appropriate treatment has been carried out. Inspectors do not normally cut fruit to inspect for the presence of insects, although, where the fruit are intended for research this could be arrange by officers of another department, if necessary. To comply with quarantine conditions permitting importation of mangoes for research, all fruit were autoclaved at 121°C for 30 minutes and cartons were gamma sterilised at 25 kGy before disposal.

Frozen Shrimp

This study is being carried out in collaboration with P. Rattagool and other officers of the Fisheries Technology Development Division, Department of Fisheries, Thailand Ministry of Agriculture and Cooperatives. Dr. A.M. Dollar is also associated with this project.

In the first trial, uncooked, unpeeled, headless marine shrimps and pond-raised shrimps were processed separately, frozen and packaged in 1 kg lots under standard commercial export conditions by a leading seafood exported in Bangkok, Thailand.

Samples were transported to a nearby 150,000 Ci Cobalt-60 commercial radiation facility, Gammatron, and treated in plastic foam boxes containing dry ice at a dose rate of 3.4 $kGyh^{-1}$. The boxes received average absorbed doses of 0.94, 2.25 or 3.08 kGy as measured by Perspex dosimetry carried out by the Office of Atomic Energy for Peace, Thailand. The samples were transported in a container by sea from Bangkok to Fremantle, Western Australia, with a commercial shipmen of other frozen seafoods. They were then airfreighted under dry ice to Sydney, arriving on 6 August 1985. On arrival at Lucas heights, the outside temperature of individual packs was -15°C. All packs arrived in good condition. Samples were stored at -20° until testing began in September, 1985.

Microbiological testing of all packs was carried out according to the Australian Standard Methods for the Microbiological Examination of Food (As 1766) for total plate count, coliforms (MPN and triplicate tube methods). Escherichia coli (MPN), Staphylococcus aureus (coagulase positive) and Salmonella sp. A modified MPN method was used for Vibrio parahaemolyticus assesment[3].

Table 3 shows that doses of 2 to 3 kGy reduced the number of colony-forming units per gram of frozen shrimps by about 97%. Coliforms, E. coli, and Salmonella or coagulase positive Staphylococcus aureus (less than 100 per gram) were not detected, before or after irradiation, nor Vibrio parahaemolyticus after irradiation (3.6 per gram before irradiation). All the samples therefore met the Australian microbiological standard for imported frozen seafoods. There are no official chemical standards for imported frozen seafoods.

After cooking, an irradiation odour, but not flavour, was detected in some in the marine prawns treated at 3 kGy, but not in the corresponding pond-raised prawns.

A second trial is in progress using frozen shrimps obtained from different sources and processed in Bangkok under various conditions as well as other frozen seafood products sea-freighted to Sydney. These samples will probably be assessed by the Australian Government Analytical Laboratory, the organisation responsible for testing imported foods.

CONCLUSION

The Australian Government's decision to sponsor the second phase of the Asian Regional Project on Food Irradiation recognises the considerable interest being shown by RPFI participatory countries in the commercialisation of a technology which has the capacity to reduce crop losses, improve food safety, provide an alternative to chemical quarantine control treatments, and increase overseas markets.

Trade in irradiated foods depends not only on the technical efficacy of the process, but also on the ability of the irradiated produce to reach its destination in good condition after shipment under commercial conditions and to meet the standards and specifications set by the importing country. These requirements were met by commercial shipments of Nan Klang Won variety mangoes and frozen shrimps irradiated in Thailand before their transport by air and sea respectively to Australia.

ACKNOWLEDGEMENTS

I wish to thank my collaboration in Thailand, Mrs. D. Buangsuwon and Mrs. P. Rattagool and their colleagues, Federal and State Officers of the Australian Plant Quarantine Service and Mrs. C. Banos (AAEC) for their involvement and assistance with the transport studies.

REFERENCES

(1) Banditsing, C., Prinksulka, V., Piadang, S., Sutantawong, M., Nouchapramool, K. and Prachasitisakdi, Y. (1985). The multi-purpose food irradiation plant in Thailand. In "Food Irradiation Processing", Proc. FAO/IAEA Symp. Washington, 4-8 March, IAEA, Vienna, 365-377.

(2) Wills, P.A. (1981). Commercial application of freezing-irradiation combination process for pasteurization of two specific batches of cooked, peeled shrimps. In "Combination Processes in Food Irradiation", Proc. FAO/IAEA Symp., Colombo, 24-28 Nov. (1980), IAEA, Vienna, 291-304.

(3) Eyles, M.J. et al. (1985). Evaluation of methods for enumeration and identificatin of Vibrio parahaemolyticus in oysters, Food Technol. Austral. 37 (7) 302-304.

RESULTS OF FEEDING TRIALS OF IRRADIATED DIETS IN HUMAN VOLUNTEERS: SUMMARY OF THE CHINESE STUDIES*

A. BRYNJOLFSSON
Department of Applied Biological Sciences,
Massachusetts Institute of Technology,
Cambridge, Massachusetts,
United States of America

Abstract

Following extensive chemical analyses and animal experimentation, which have shown that irradiated foods are safe, the Chinese researchers have carried out 8 well controlled experiments involving human volunteers consuming irradiated foods for 7 to 15 weeks periods. There were 17 to 70 test subjects in each experiment, and the total number of subjects was 439. Each clinical test in all the experiments failed to discern any significant difference between the control groups and the test groups consuming irradiated foods. Seven of the eight experiments involved investigations of chromosomal aberrations in a total of 382 individuals. Some of these experiments included freshly irradiated wheat in the diet. No significant difference between the number of chromosomal aberrations in the control groups and the test groups could be discerned in any of the seven experiments, either when evaluated individually or when all seven were pooled together. When all the experiments were pooled together, the average number of polyploidy at the beginning of the tests, before the exposure to irradiated foods, was 0.22% and 0.36% for the control and experimental groups respectively and after the exposure to the irradiated foods the polyploidy was 0.29% and 0.26% in the control and in the experimental groups respectively. The standard deviation of the mean value, 0.28%, was 0.23%. The relative increase in polyploidy in the control group, 0.29%-0.22%=+0.07%, and the relative decrease in the polyploidy in the experimental group, 0.26%-0.36%=-0.10% is statistically insignificant.

In separate experiments it was shown that irradiation significantly reduces carcinogenic nitrosamines found in many foods confirming similar observation at U.S. Army Natick Laboratories in the 70's.

INTRODUCTION

Chinese scientists are doing excellent work in radiation chemistry, food irradiation technology, and wholesomeness testing of foods, and have initiated practical applications of this method. Of the 72 papers presented at the meeting 33 were from China. The first pilot-plant in the Shanghai area for

* In view of the interest of Member States in voluntary consumption of irradiated food, this paper which refers to studies carried out in China has been included.

irradiation of food has been operational since the end of 1985 (20 metric tons/hour of potatoes, onions fruits and vegetables, initial load 200 kCi to be increased to 500kCi by 1988; 20% efficiency; Dmax/Dmin=1.7, 1.3, and 1.2 depending on the density, semi-automatic). The irradiated foods have been well accepted by the general public. The Chinese have built their own modern irradiation plants and are able to produce the cobalt-60 sources as well as the electron accelerators for irradiating the food.

Rather than summarize the meeting, which included many papers from other countries, I will focus on the results of the wholesomeness studies in China and in particular on the results of the feeding trials of irradiated diets to human volunteers.

The extensive analyses by FASEB [1-3] as well as by FDA [4] and JECFI [5] of the radiolytic products [6-20] have failed to find any grounds to suspect that the radiolytic compounds formed in foods when irradiated up to an average doses of 58 kGy would constitute any hazard to health of persons consuming reasonable quantities [1]. Further, the many long-term multigeneration studies on irradiated foods fed to mammals such as dogs, rats, and mice have failed to find any toxic, carcinogenic, mutagenic, or teratogenic effects as a result from eating irradiated foods [4,5,21-26]. The Chinese researchers have come to the same conclusion.

In spite of the fact that the health authorities and scientist familiar with the subject recognize that irradiated foods are safe, some people have remained skeptical. They erroneously think that irradiation must make food unwholesome because radiation is dangerous for living organisms. In other cases these skeptics have pointed at results of experiments which may indicate an harmful effect, such as the studies at National Institute of Nutrition (NIN) in Hyderabad, India by Bhaskaram and Sadasivan [27] of the polyploidy in 15 (5 in the test group) kwashiorkor children, and studies by Vijayalaxmi of 21 (7 in the test group) Macaca monkeys [28] and in studies by Vijayalaxmi and Sadasivan and Vijyalaxmi in rats [29-30]. The effects of increased polyploidy could not be reproduced by several other researchers in subsequent, more thorough experiments, usually using rats and mice as test subjects [30-35]. The experts in the field have pointed out that the observed numbers of polyploidy in the control groups in all the NIN experiments are abnormally low and that this fact is the main cause of the apparent effect. Reviewers of the subject have concluded [4,5,37] that in the NIN experiments the number of test subjects was too small to allow any conclusion and that the apparent effect could be explained as due to statistical fluctuation. While most concerns raised by the NIN studies have been refuted, it is nevertheless of great interest to review the many Chinese studies of chromosomal aberration in humans consuming irradiated foods.

THE CHINESE STUDIES

At the IAEA/FAO International Symposium in Washington in March of 1985, it was reported that the Chinese had carried out feeding studies on humans. These human studies were initiated after the animal feeding studies, which started in early 70's, had shown that irradiated foods were safe and wholesome [38,39]. At the Washington meeting, however, we received very few details of the testing results. At the FAO/IAEA Seminar in Shanghai in April of 1986, we received many more details on the results of these studies, although the thrust of the seminar was on the practical application of food irradiation. Four of the papers [40- 43] reported on the results of these studies.

From Dr. Dai Yin's overview paper[40] I have extracted the data shown in Table 1. I have made statisical analysis of the data which clearly confirms the

Table 1. Summary of Experiments on Polyploidy in Humans Consuming Nonirradiated and Irradiated Foods.[40]

Foods	Dose in kGy	No. of subj.	Age in yrs.	consumed food gram/day	Duration wks	Polyploid cells in % of cells examined: control groups before	control groups aft.	control groups diff.	Irr. Food groups before	Irr. Food groups aft.	Irr. Food groups diff.
Rice	0.37	59	18-48	500	13	0.480	0.430	-0.050	0.820	0.160	-0.660
Sausage	5-8	70	18-28	125-250	13	0.160	0.060	-0.100	0.440	0.000	-0.440
Peanut	0.2-1	61	18-53	50	13	0.080	0.170	0.090	0.000	0.090	0.090
Potato	0.2	60	17-40	250	14	0.660	0.600	-0.060	1.030	0.520	-0.510
Mushroom	1.0	19	21-40	250	7	0.000	0.000	0.000	0.200	0.600	0.400
Whole diet	0.1-8	70	18-46	60% irr.	13	0.090	0.290	0.200	0.070	0.350	0.280
Whole diet	0.1-8	43	21-47	66% irr.	15	0.090	0.180	0.090	0.000	0.090	0.090
Unweight. aver. of each col.:						0.223	0.247	0.024	0.366	0.259	-0.107
Std. dev. of average values:						0.093	0.080	0.040	0.157	0.088	0.159

Overall average value of polyploid cells in the human subjects:	0.274
Overall std. dev. of group averages from the overall average:	0.125
Overall std. dev. for the values in each group in each test:	0.277

These data are from: Prof. Dai Yin
Institute of Food Safety Control and Inspection
Ministry of Public Health
Beijing
Peoples Republic of China

---

conclusion by the Chinese researchers that the consumption of irradiated food has no effect on the polyploidy in the cells studied.

These chromosomal studies are based on 7 separate tests and involve altogether 382 human subjects, usually medical students. The overall average incidences of polyploidy was found to be 0.27%. During the feeding tests, the unweighted average of the poliploidity in the control groups, fed nonirradiated food, increased from 0.223% to 0.247%, an increase of 0.024%, and in the groups fed irradiated food it decreased from 0.366% to 0.259%, a decrease of 0.107%. These differences are well within the statistical uncertainty in the measurements, with the standard deviation for the differences on the order of 0.16%.(See table 1)

In the paper by Jin Wei Qiao and Yuan Jia Kuan [41], it is reported that after the studies of the five individual foods: rice, sausage, peanut, potato, mushroom, (five of the items shown in table 1.) were completed and no adverse effects were found, the Department of Nutrition of the School of Public Health of Shanghai Medical University performed experiments on rats fed irradiated (up to 10 kGy) food constituting 80% of the diet for three months. No adverse effects could be discerned in the nutrition, development, fertility, reproduction, hepatic and renal functions, nor in the histological and cytogenetic examinations of the various organs.

Thereafter, 70 volunteers (36 male and 34 females) with no smoking habits were selected out of a group of 120. The 70 were randomly selected into two groups, 35 in each, one fed nonirradiated foods and the other fed irradiated foods for a 90 days period, after both groups were fed one week on control diet to have a similar nutritional level before starting the irradiated foods tests, followed by a complete check-up of the parameters to be studied.

The parameters studied were: (1) body weight; (2) blood pressure; (3) blood picture(hemoglobin, hematocrit, platelet and leucocyte counts); (4) serum protein and lipid indices; (5) liver function indices; (6) blood urea nitrogen; (7) serum cortisol and cholinesterase; (8) T- and B-lymphocyte contents; (9) lymphocyte chromosomae polyploidy counts (see table 1); (10) lymphocyte chromosome structural aberrations; (11) sister chromotid exchange (SCE) (12) examination of micronuclei in the lymphocytes; and (13) Ames test of urine (see table 2); (14) EKG and sonography of liver and spleen.

No adverse effects from consuming irradiated foods could be discerned in any of the tests.

Table 2. Ames test of urine from humans consuming irradiated foods.[41]

Test	$TA_{98} + S_9$		$TA_{98} - S_9$		$TA_{100} + S_9$		$TA_{100} - S_9$	
	ctrl. fd	irr. fd	ctrl. fd	irr. fd	ctrl. fd	irr. fd	ctrl. fd	irr. fd
Before M + SD	31.1+7.8	36.1+6.5	27.1+2.6	29.4+8.9	144+17.5	143+20.8	139+14.0	146+26.9
After M+SD	23.4+4.6	24.2+6.4	25.3+8.4	23.7+8.4	169+14.2	167+8.3	167+24.8	148+9.6

The number: 31.7 + 7.8 in the first column means that the average count was 31.7 and the sta.dev. 7.8. For the other numbers, the meaning is analogous.

The ratio: Rt/Rc=(induced revertants)/(spontaneous revertants) was less than 2.5 in all cases.

For comparison, the same researchers obtained for a heavy smoker the Rt value for $TA_{98} + S_9$ of 195.6 and for the Rt/Rc=195.6/24.9=7.9.

In the paper by Han chi et al. [42], it is reported that after the human testing of the five individual foods, (5 of the foods shown in table 1.) which were carried out by a number of medical colleges and research institutes in 1982 to 1984, showed no adverse effects to the subjects exposed to the irradiated foods, it was decided to carry out studies where the diet was composed mainly of irradiated foods (see the two last items in table 1.).

43 medical students, 21 in the control group fed nonirradiated food and 22 in the test group fed irradiated food were used in the test. The diet consisted of: rice (0.37 kGy, stored at 0^{o} C for three months); wheat (0.4kGy, stored at room temperature for two weeks); meat products, including pork sausage and pork chops (up to 8 kGy, stored at room temperature for 2 weeks); mustard tuber preserved with chili (1 kGy, stored at room temperature for two weeks); 14 different varieties of vegetables, including tomato, potato, garlic sprouts, cucumber, cauliflower, cabbage, carrot, Chinese cabbage, rape, Chinese chive, hyacinth bean, celery, sweetbells, red peppers, lettuce, and peanut (up to 3

kGy, stored at room temperature for three days). The control group consumed the same varieties and amounts of nonirradiated foods (same batch, stored at same condition)

The major groups of parameters studied were: (1) acceptability; (2) anthropometric measurements; (3) hematological indices; (4) liver and kidney functions indices; (5) blood lipids; (6) blood sugars; (7) endocrine system indices; and (8) chromosomal aberrations. Each of these major groups included several parameters.

No adverse effects from consuming irradiated foods could be discerned in any of the tests.

In the paper by Wang Ruishu et al. on the human feeding studies on rice (see also table 1), it was concluded that there was no adverse effect was discerned in any of the many tests.

In the one of the paper [42], references are made to several more detailed articles on the human studies of individual food items [44-48].

In this context, we should recall that the Office of the Surgeon General of the Army conducted seven separate feeding studies on human volunteers fed irradiated foods in the late 50's [49]. No adverse effect from consuming irradiated foods could be discerned in any of these seven studies.

At the Shanghai conference a paper related to wholesomeness, but not involving human studies, was reported by Hu Jifan and Song Puju [50]. Their experiments showed that in such foods as shrimp, fish meal, and salted eel, the nitrosodimethylamine are significantly reduced in the dose range of 5 to 20 kGy. Their findings are similar to the findings at Natick Laboratories and USDA Philadelphia Laboratories [51] which showed that any nitrosoamines in bacon are significantly reduced or eliminated in the same dose range.

REFERENCES

[1] F.A.S.E.B. 1977. Report prepared for U.S. Army Medical Research and Development Command: "Evaluation of the Health Aspects of Certain Compounds Found in Irradiated Beef", by Life Sciences Research Office, Federation of American Societies for Experimental Biology, 9650 Rockville Pike, Bethesda Md. 20014. Contract Number: DAMD-17-76-C-6055. Final Report.

[2] F.A.S.E.B. 1979. "Further Toxicological Considerations of Volatile Compounds". Ibid., Supplement I.

[3] F.A.S.E.B. 1979. "Possible Radiolytic Compounds". Ibid., Supplement II.

[4] FDA. 1986. 21 CFR Part 179. Irradiation in the Production, Processing, and Handling of Food; Final Rule. Department of Health and Human Services; Food and Drug Administration. Federal Register, 51, No. 75, Friday, April 18, 1986.

[5] JECFI. 1981. "Wholesomeness of Irradiated Food"; Report of a Joint FAO/IAEA/WHO Expert Committee. Technical Report Series: 659. World Health Organization, Geneva, 1981

[6] MERRITT, C.,Jr., ANGELINI, P., VADJI, M., HALLIDAY, J.,W., ROBERTSON, D.,H., STANLEY, G., K., and SWIFT, S., M., Radiolysis compound in bacon

and chicken. Final Report (for the period September 18, 1981- September 20, 1982 under Agreement No. 58-3244-0-169) submitted, by the principal investigator Dr. C. Merritt, Jr. at the Science and Advanced Technology Laboratory, U.S. Army Natick Research and Development Laboratories Natick, Ma 01760 to U.S.D.A. Eastern Regional Research Center Food Safety Laboratory.

[7] MERRITT, C., Jr. and Taub, I.A. 1983. Commonality and predictability of radiolytic products in irradiated meats. In "Recent Advances in Food Irradiation". (P.S. Elias and A.J. Cohen, eds.), pp. 27-57. Elsevier Biomedical Press, Amsterdam, The Netherlands.

[8] MERRITT, C., Jr., VADJI, M., BAZINET, M.L. and ANGELINI, P. 1983. A Quantitative study of the pathways involved in the formation of radiolysis poducts in ethyl palmitate. JAOCS, 60, pp. 1509-1516.

[9] MERRITT, C., Jr., ANGELINI, P. and GRAHM, R.A. 1978. Effect of radiation parameters on the formation of radiolysis products in meat and meat substances. J. of Agricultural and Food Chemistry, 26, pp. 29-35.

[10] TAUB, I.A. 1983. Reaction mechanisms, irradiation parameters, and product formation. In "Preservation of Food by Ionizing Radiation". (E.S. Josephson and M.S. Peterson, eds.). Vol. II, Ch. 3, pp. 125-166. CRC Press Inc.; Boca Raton, Florida.

[11] TAUB, I.A., ANGELINI, P. and MERRITT, C., Jr. 1976. Irradiated food: Validity of extrapolating wholesomeness data. J. Food Sci. 41, pp. 942-944.

[12] TAUB, I. A., HALLIDAY, J. W., WALKER, J.E.,ANGELINI, P., VAJDI, M. and MERRITT, C., Jr. 1980. Chemiclearance: Principle and application to irradiated meats. Proceedings of the 26th European Meeting of Meat Research Workers; Vol.I, pp. 233-236.

[13] NAWAR, W.W. 1983. Radiolysis of nonaqueous components of food. In "Preservation of Food by Ionizing Radiation". (E.S. Josephson and M.S. Peterson, eds.). Vol. II, Ch. 2, pp. 75-124. CRC Press Inc.; Boca Raton, Florida.

[14] NAWAR, W.W. 1978. Reaction mechanisms in the radiolysis of fats: A review. J. of Agricultural and Food Chemistry, 26, pp. 21-25.

[15] DIEHL, J.F., ADAM, S., DELINCEE, H. and JAKUBICK, V. 1978. Radiolysis of carbohydrates and of carbohydrate-containing foodstuffs. J. of Agricultural and Food Chemistry, 26, pp. 15-20.

[16] SIMIC, M.G. 1978. Radiation chemistry of amino acids and peptides in aqueous solutions. J. of Agricultural and Food Chemistry, 26, pp. 6-14.

[17] SIMIC, M.G. 1983. Radiation chemistry of water-soluble food components. In "Preservation of Food by Ionizing Radiation". (E.S. Josephson and M.S. Peterson, eds.). Vol. II, Ch. 1, pp. 1-73. CRC Press Inc.; Boca Raton, Florida.

[18] WARD, J.F. 1978. Chemical consequences of irradiating nucleic acids. J. of Agricultural and Food Chemistry, 26, pp. 25-28.

[19] BRYNJOLFSSON, A. 1981. Chemiclearance of food irradiation process: Its scientific basis. In "Combination Processes in Food Irradiation". Proceedings of a Symposium, Colombo, 24-28 November, 1980; Jointly

organized by IAEA and FAO. Pp. 367-373. Published by IAEA, Vienna, STI/PUB/568; ISBN 92-0-110081-7.

[20] BASSON, R.A. 1983. Advances in radiation chemistry of food and food components - an overview. In "Recent Advances in Food Irradiation". (P.S. Elias and A.J. Cohen, eds.), pp. 7-25. Elsevier Biomedical Press, Amsterdam, The Netherlands.

[21] ANON. 1980. "Wholesomeness of Irradiated Food"; Summaries of data considered by the Joint FAO/IAEA/WHO Expert Committee on the Wholesomeness of Irradiated Food, Geneva, 27 October- 3 November 1980. EHE/81.24. This document can be obtained from the Division of Environmental Health, World Health Organization, Avenue Appia, 1211 Geneva 27, Switzerland.

[22] The Surgeon General of the Army. 1965. Statement on the Wholesomeness of Irradiated Foods. In "Radiation Processing of Foods", Hearings before the Subcommittee on Research, Development and Radiation of the Joint Committee on Atomic Energy, Congress of the United States, eighty-ninth Congress; June 9 and 10, 1965; pp. 105-106. U.S. Government Printing Office, Washington D.C.

[23] Tracor Jitco, Inc. 1983. Report prepared under contract No. 53-3K06-2-143 for USDA Eastern Regional Research Center, including: "Irradiated Chicken Meat, Toxicological Evaluation", Final Report, June 30, 1983. Also Report by Raltech Scientific Services, Inc. prepared under contract DAMD 17-76-C-6047 for US Army Medical R&D Command: "Evaluation of Mutagenicity of Irradiated Sterilized Chicken by the Sex-linked Recessive Lethal Test in Drosophila melanogaster "; Final Report, June 15 1979. This report and many of the reports on the irradiated chicken toxicological studies (PB84-186980; PB84-186998; PB84-187004; PB84-187012;PB84-187020; PB84-187038; PB84-187046; PB84-187053; PB84-187061; PB84-187079; PB-187087; and PB84-187095) are available from Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

[24] ANON. 1980. "Wholesomeness of Irradiated Food"; Summaries of data considered by the Joint FAO/IAEA/WHO Expert Committee on the Wholesomeness of Irradiated Food, Geneva, 27 October- 3 November 1980. EHE/81.24. This document can be obtained from the Division of Environmental Health, World Health Organization, Avenue Appia, 1211 Geneva 27, Switzerland.

[25] BRYNJOLFSSON, A. 1986. Wholesomeness of irradiated Foods: A Review. J. Food Safety, 7, pp. 107-126, 1985.

[26] CAST. 1986. Ionizing Energy in Food Processing and Pest Control: Part I, Wholesomeness of Food Treated With Ionizing Energy. A Report prepared as a consequence of a Congressional request by a Task Force of specialists for the COUNCIL FOR AGRICULTURAL SCIENCE AND TECHNOLOGY (CAST) , Headquarter Office: 137 Lynn Ave., Ames, Iowa 50010-7120. Report No. 109, July 1986.

[27] BHASKARAM, C. and SADASIVAN, G. 1975. Effects of feeding irradiated wheat to malnourished children. Int. J. Radiat. Biol., 27, p. 93, 1976; and Am. J. of Clin. Nutr., 28, pp. 130-135, 1975.

[28] VIJAYALAXMI, C. 1978. Cytogenetic studies in monkeys fed irradiated wheat. Toxicology, 9, p. 181-184.

[29] VIJAYALAXMI, C. and SADASIVAN, G. 1975. Chromosomal aberrations in rats fed irradiated wheat. Int. J. Radiat. Biol., 27, pp.135-142.

[30] VIJAYALAXMI, C. 1975. Cytogenetic studies in rats fed irradiated wheat. Int. J. Radiat. Biol., 27, pp. 283.

[31] GEORGE, K.P., CHAUBEY, R.C., SUNDARAM, K. and GOPAL-AYENGAR, A.R. 1976. Frequency of polyploid cells in the bone marrow of rats fed irradiated wheat. Food Cosmet. Toxicol., 14, pp. 289-291.

[32] TESH, J.M., DAVIDSON, E.S., WALKER, S., PALMER, A.K., COZENS, D.D. and RICHARDSON, A.K. 1977. Studies in Rats Fed a Diet Incorporating Irradiated Wheat: Part 1. "Incidence of polyploid configuration in bone marrow cells". Part 2. "Incidence of micronucleated polychromatic erythrocytes in bone marrow cells". Part 3. "Dominant lethal assay". Technical Report Series: IFIP-45. International Project in the Field of Food Irradiation. Institut für Strahlentechnologie, Karlsruhe, Federal Republic of Germany.

[33] REDDI, O.S., REDDY, P.P., EBENEZER, D.N. and NAIDU, N.V. 1977. Lack of genetic and cytogenetic effects in mice fed on irradiated wheat. Int. J. Rad. Biol., 31, pp. 589-601.

[34] MURTHY, P.B.K. 1981. SCE in monkeys fed irradiated wheat [Letter]; Food. Cosmet. Toxicol., 19, p. 523.

[35] MURTHY, P.B.K. 1981. Sister-chromatid exchanges in mice given irradiated wheat. Toxicology, 20, pp. 247-249.

[36] CHAUHAN, P.S., ARAVINDAKSHAN, M., KUMAR, N.S., SUBBA RAO, V., AIYAR, A.S. and SUNDARAM, K. 1977. Evaluation of freshly irradiated wheat for dominant lethal mutations in wistar rats. Toxicology, 7, pp. 85-97.

[37] KESAVAN, P., C. 1978. Indirect effects of radiation in relation to food preservation: Facts and fallacies. J. Nucl. Agric. Biol., 7, pp. 93-97.

[38] DAY Yin. 1985. Safety evaluation of irradiated food in China. Food Irradiation Processing, (Proceedings of a Symposium in Washington, D.C.,4-8 March, 1985; Jointly organized by IAEA and FAO) pp. 234, 1985.

[39] XU Zhicheng. 1985. Research and development of food irradiation in Shanghai, China. Ibid. pp. 475-477, 1985.

[40] DAI Yin. 1986. An introduction to safety evaluation of irradiated foods in China. To be published in the proceedings of the FAO/IAEA Seminar for Asia and the Pacific on the Practical Application of Food Irradiation held in Shanghai 7-11 April, 1986.

[41] JIN Wei Qiao, and YUAN Jia Kuan. 1986. Safety evaluation of human eating 35 irradiated foods. Ibid.

[42] HAN Chi, GUO Shiping, WANG Maogi, LIU Zegin, CUI Wemming, and DAI Yin. 1986. A feeding trial of diet mainly composed of irradiated food in human volunteers. Ibid.

[43] WANG Ruishu, WU Zihua, ZENG Lingfu, HOU Yanhua, PENG Shusheng, and LI Zhaiquan. 1986. Wholesomeness evaluation of gamma ray irradiated rice toxicological studies and human trial. Ibid.

[44] HOU Yun Hua et al. 1984. Feeding trial of irradiated rice in human. The Proceedings of Food Hygiene Research, 2(2), 18-24, 1984.

[45] LI Hao et al. 1984. Feeding trial of gamma-ray irradiated potato in human volunteers. Ibid., 2(2), 32-37, 1984.

[46] HE Zhiqian et al. 1984. Study on safety of irradiated mushroom to human body. Ibid., 2(2), 43-49, 1984.

[47] LI Juesen et al. 1984. Feeding trial of gamma-ray irradiated peanut in human volunteers. Ibid., 2(2), 56-61, 1984.

[48] ZHANG Yan et al. 1984. Feeding trial of gamma-ray irradiated meat products in human. The Proceedings of Food Hygiene Research, 2(2), 69-74, 1984.

[49] Plough, I. C., Bierman, E., L., LEVY, L. M. and WITT N., F. 1960. Human feeding studies with irradiated foods. Federation Proceedings, 19, pp. 1052-1054, 1960.

[50] HU Jifan and SONG Puju. 1986. Elimination of nitrosoamines and their precursors in some marine foods by cobalt-60 irradiation. To be published in the Proceedings of the Shanghai Seminar.

[51] FIDDLER, W., GATES, R.A., PENSABENE, J.W., PHILLIPS, J.G., and WIERBICKI, E. 1981. Investigations on nitrosamines in irradiation sterilized bacon. J. Agric. Food Chem. 29, 551-553, 1981.

SUMMARIES OF CONTRIBUTED PAPERS

IAEA-SR-129/1

PROPOSED FOOD IRRADIATION PROGRAMS IN QUEENSLAND, AUSTRALIA

N.W. HEATHER
Department of Primary Industries,
Indooroopilly, Queensland

G.E. MITCHELL
Department of Primary Industries,
Hamilton, Queensland

Australia

Irradiation is virtually essential to Queensland as an insect disinfestation treatment to enable exports of tropical fruits, especially mangoes. The two insect pests most important in this way are Australian native species of fruit flies, Dacus spp., and the exotic mango seed weevil Sternochaetus mangiferae (Fabricius). Also important are the native macadamia nut borer Cryptophlebia ambrodelta (Lower) and a number of other native and exotic pests. All are the subject of quarantine prohibitions in countries to which we wish to export our fresh fruit and vegetables. Many of these were the subject of treatment with ethylene dibromide (EDB), now banned in the USA and currently being phased out elsewhere. Irradiation is judged to be the best replacement for EDB for Queensland and this adds a further dimension to its importance.

Provision of facilities for disinfestation purposes will make an opportunity for a commercial irradiation industry based on foods generally. Although poultry, seafoods and other fresh and prepared meats are currently marketed at very safe levels of tolerance for Salmonella and other similar organisms, irradiation is expected to prove more economical than existing processes for at least a portion of production. For fresh fruits and vegetables, irradiation has the additional advantages of improvement of shelf life and control of postharvest diseases. When dosages are optimised these two benefits can be combined with disinfestation for a number of commodities. Grain is another commodity likely to be treated with irradiation for control of insect pests. However this will be dependent on the acquisition of an electron beam facility and it is not yet clear how important irradiation will become as a method of pest control in the grain industry in Queensland.

Proposals for food irradiation in Queensland and elsewhere in Australia are dependent on legislative approvals. It is anticipated that these will be enacted during 1986 or earlier and that they will closely parallel the recommendations of Codex Alimentarius.

Examples of commodities produced in Queensland and for which irradiation is expected to be utilised will be discussed. Some consideration will also be given to alternative measures available for these commodities and how irradiation might be expected to compare in a competitive sense.

DISTRIBUTION OF MICROFLORAS IN SPICES AND THEIR DECONTAMINATION BY GAMMA IRRADIATION

M. LEBAI JURI, H. ITO
Nuclear Energy Unit,
Puspati Complex,
Bangi, Selangor,
Malaysia

Spices have been recognised as potential source of spoilage organisms in manufactured food products. Molds growth was known to accelerate quality change of spices during transportation and storage, and occassionally toxigenic.

Fourteen samples consisting of 4 kinds of spices were used in the investigation. The total aerobic bacterial counts ranged from 2.8×10^3 to 4.8×10^7 /g in whole spices and 4.9×10^3 to 5.3×10^7 /g in powder spices. The most highly contaminated spices were whole and powder Black pepper, and powder Turmeric with counts more than 10^7/g. The main spoilage organisms incriminated were aerobic sporeformers of B. pumilus, B. subtillis, B.megaterium and B. licheniformis; and nonsporeformers of Pseudomonas radiora and Micrococcus sp.

The coliforms counts ranged from non-detectable level up to 10^6/g in one sample of whole White pepper. The coliform species identified were Klebsiella, Enterobacter and Citrobacter. No Salmonella or pathogenic E. Coli were isolated.

Osmophilic molds and Fungi counts in spices were between 75 to 6.5×10^4/g consisting of A. restrictus group, A glaucus group, A. fumigatus group, A. flavus group and penicillium. Some samples contained undetectable amount of the microorganisms.

Inactivation curves using three selected samples revealed in order to reduce total aerobic bacteria, Coliforms, and molds and Fungi below detectable levels required 1.2-1.4Mrad, 0.8-1.2Mrad and 0.4-0.5Mrad respectively.

The storage study of 8 spice samples packed in PE pouches, and stored at temperature of 35°C, and RH, 90-93% showed, the Osmophilic molds counts increased up to 10^6/g during 56-70 days storage. In powder samples, 0.2-0.4Mrad were sufficient to surpress mold growth below detectable levels. However, in some samples of whole spices, 0.2Mrad was required to reduce growth to similar level throughout storage. In whole Black pepper, molds were still able to increase to 10^5 - 10^6/g even at 0.4Mrad irradiation. The water activity of the spices increased during storage. Generally, the water activity attained during storage was more than sufficient i.e. $a_w \geq 0.65$ to support mold growth.

STUDY OF IRRADIATION HOT PEPPER PRESERVATION TECHNOLOGY

Qixun CHEN
Institute of Applied Nuclear Technology,
Chengdu, Sichuan, China

This paper has introduced the preliminary study on he application of ^{60}Co gamma irradiation for preservation of hot pepper.

The problems are. the temperature during the harvesting of hot pepper is very high. Therefore, bacterial contamination is also very high. Besides insects breed fast, and product gets mouldy during the storage. It is very difficult to store pepper in powder form. As soon as Aspergillus contaminates and subsequently affloxin B_1 is produced, the pepper is prohibited to be sold. Irradiation of pepper at 5 kGy drops the total of bacterial count by four log cycles and the number of bacillus to 30. If the packaging quality is good, the colour, flavour and taste of the product can be maintained for one year. When pepper is irradiated at 8kGy, practically no bacterium remains. Such quality product retains its colour and is highly accepted by the consumers. The Sichuan broas beam food which is prepared with irradiated hot pepper also has less bacterial load. Besided, the colour, flavour and taste of the food is not affected by the incorporation of irradiated pepper.

SAFETY EVALUATION OF IRRADIATED FOODS IN CHINA

Yin DAI
Institute of Food Safety Control
and Inspection,
Ministry of Public Health,
Beijing, China

The works about this in China could be divided into three phases.

1st Phase: That was 1950's to 1960's Phase. In this period we started to irradiate foods, especially potatoes, and we carried out some animal toxicity tests. In the end of 1960's a human experiment consuming irradiated potato was performed.

2nd. Phase: That was 1970's Phase. In this phase under the organization of National Scientific Committee of China a nation-wide Program of animal toxicity tests for irradiated foods was conducted.

3rd. Phase: That is 1980's Phase. In this period we pay more attention to the direct human consumption tests and to the establishments of a series of food hygienic standards and regulation for irradiated foods

After comparison with unirradiated foods we found the irradiated foods can meet the safety standards of unirradiated foods. This is the first stage of establishing food hygienic standards for irradiated foods.

During the 2nd. stage specific hygienic standards for irradiated foods will be studied. For example, radiation could induce the change of microbes in/on foods, so it is obvious that from regulatory toxicological point of view irradiated foods should have their own hygienic standards in microbiology.

In other hand we plan to carry out quite a few human consumption tests. It was considered only in this way we can get the direct evidences to show the safety of irradiated foods for human consumption. 1st. step: 2-3 months human consumption trials. From 1982 up to now we have already got five results of human consumption tests, they were rice, potato, peanut, mushroom, and pork sausage. In addition, human feeding studies of irradiated staple and nonstaple foods for 3 months have been finished. There were no significant differences between experimental and control groups.

Based on these above studies China has approved the hygienic standards of following irradiated foods for domestic trial, i.e. rice, potato, mushroom, peanut, onion, garlic and sausage.

2nd. step: Long-term human consumption observation and setting up specific hygienic standards for irradiated foods.

At last we do hope under the organization of IAEA it will be able to have an international cooperation in the field to promote the application and commercialization of irradiated foods.

SAFETY EVALUATION OF 35 KINDS OF IRRADIATED FOOD FOR HUMAN CONSUMPTION

Weiqiao JIN
Shanghai Institute of Radiation Medicine,
Shanghai Medical University

Jiakuan YUAN
Shanghai Institute of Nuclear Research,
Academia Sinica

Shanghai, China

This paper reported the observations of the volunteer subjects who took 35 irradiated foods as main diet during 90 days. The subjects consisting of 70 medical students and 8 staff members of Shanghai Medical University, were random divided into two groups. one group was supplied irradiated foods. Another was the control eating the same food non-irradiated

The 35 irradiated foods are listed as follows:

grain: rice, flour, red bean, soybean, peanut;
meat product: sausage, dried beef;
vegetables: potato, cabbage, leaves, taro, wild rice stem, carrot, mushroom, bamboo shoot, lettuce, arrowhead, cauliflower, sword bean, radish, pepper, hyacinth bean, white gourd, tomato, young soyabean, water chestnut, lotus root, ginger;
fruits: orange, apple;
dried fruits: date, longen, lotus seed;
and others: day lily, dried bean mike cream in tight rolls.

The absorbed doses of the irradiated foods varied from 0.1 to 8.0 kGy. The irradiated foods made up 60.3% of total intake weight. The double blind method was adopted in this experiment. It was unknown to the subjects and the researcher which foods were irradiated.

The observations during 90 days indicated that the subjects were all pleased with the diet of irradiated foods and there were no adverse effects on their health. A series of clinical and laboratory examination had failed to reveal any significant changes. These examinations included routine blood and urine tests, blood biochemical examinations, liver and kidney function tests, endocrinological examination, cellular immunity tests, several mutagenecity studies (The incidence of polyploid cells and structural aberrations of chromosome in peripheral lymphocytes, sister chromatic-exchange, micronuclear test, urine Ames test) and serum trace elements. Therefore this experiment showed that eating irradiated foods was safe for the human body

IAEA-SR-129/7

PROSPECT OF FOOD IRRADIATION IN THE PEOPLE'S REPUBLIC OF CHINA

Jiaxiang WU
Department of High Technology,
State Science and Technology
Commission of China

Jiang ZHU
Bureau of Foreign Affairs,
Ministry of Nuclear Industry

Jilan WU
Department of Technical Physics,
Peking University,
Peking

China

In this paper the needs of food irradiation in P.R.C have been described. A research programme of food irradiation has been worked out by The State Science and Technology Commission of China. Enthusiatic and prudent policy for development of irradiated food has been adopted.

The programme consists of four main fields:

1) Investigation of food irradiation technology

2) To set up the Expert Committee for enacting hygienic Standard of Irradiation Food,

3) Quality control and dosimetry,

4) Construction of Co facility.

Expecting that after 1 or 2 years possibly small amount of irradiation food will be placed on trial sale. After summarizing the experience, the further commercialization plan will be made.

PRESERVATION OF VACUUM-PACKED SLICED CORNED BEEF BY IRRADIATION

A.F. EGAN
CSIRO, Meat Research Laboratory,
Cannon Hill, Queensland

P.A. WILLS
Lucas Heights Research Laboratories,
Australian Atomic Energy Commission,
Sutherland, New South Wales

Australia

Luncheon meats, which are commonly sold sliced and vacuum-packaged, are cooked, but recontamination during slicing and packing may result in a starting count as high as 10^4 - 10^5 bacteria per g. Since the surface-to-volume ratio is comparatively high, bacterial spoilage may occur after only 2-3 weeks at 5°C. Treatment of vacuum-packaged sliced corned beef with doses of irradiation of about 1, 2.5 and 4 kGy reduced the initial microbial count by 1, 3 and 5 $\log_{10}$ units respectively. The treatments caused changes in the aroma, flavour and colour of the meat and these were evaluated using a trained analytical taste panel. Changes in aroma and flavour caused by a 1 kGy treatment were not statistically significant. Following doses of 2.5 and 4 kGy, the changes were significant but were rated by the panel as only slight and slight-moderate respectively. Meat treated with a dose of 2.5 kGy was stored at 5°C and compared with other irradiated samples which were stored at - 20°C and with untreated control samples also stored frozen. The acceptability of the irradiated meat stored at 5°C showed little change for four weeks but then declined. After six weeks storage its acceptability was significantly lower than those of both sets of control samples ($P<0.001$). Treatment with a 4 kGy dose further delayed the onset of spoilage caused by bacterial growth. These experiments have shown that the storage life of this product can be doubled by a low-dose treatment and that irradiation is an effective means of preservation.

ECONOMICS AND ACCEPTANCE OF FOOD IRRADIATION

Fuli XING, Qiurong LU
Beijing Institute of Nuclear Engineering,
Beijing, China

During the preservation period of different foods, the phenomena of sprouting, mould or deterioration are very serious. It is generally acknowledged that the irradiation preservation of food is a promising method in the world. According to 30 years research of basic science, it is recognized that under a certain level of irradiation the irradiated foods do not cause any health safety problems in nutrition, microbiology and toxicity. And some standards for irradiation foods have already been established. But why the development speed of food irradiation in industry is so slow and why it lags behind the irradiation disinfection of medical products and the chemicals in industry. In this paper, some answer to this question has been given.

The public acceptance of irradiated foods has been predicted through the economic analysis of food irradiation in a 60 Co food irradiation facility. The following contents are included:

1. Practical standard of acceptance.

2. Economic Analysis of irradiation foods.

3. Cost comparison jof irradiation and other processes.

4. Conclusions and sugestions.

IAEA-SR-129/12

MARKETING TRIALS AND CONSUMER ACCEPTANCE STUDIES OF IRRADIATED ONIONS AND POTATOES

M.A. MATIN, M.R. AMIN, M.A. HOSSAIN,
A.K. SIDDIQUI, S. RAHMAN, M.A. MALEK,
SHAH MD. IKRAMUL HUQ, J. HOSSAIN
Institute of Food and Radiation Biology,
Atomic Energy Research Establishment,
Dacca, Bangladesh

Marketing studies of onions preserved by irradiation and stored for 8-10 months at ambient condition and at cooler temperature (15°C) were conducted during 1981-1985. In irradiated onions effective inhibition of sprouting and significant reduction of storage losses (dehydration and rottage) were obtained and most consumers who were supplied with both control and irradiated onions reported superior quality of irradiated samples in 1981-1982 storage trial. In the storage trial of 1982-1983 with about 8 tons of freshly harvested onions, irradiated and control onions, during storage for 8 months, were sold to a restricted segment of consumers. Marketing trial was up scaled and irradiated onions were made available to the general public in 1984 1985 following the adoption of the Codex Standard by the Bangladesh Government. The irradiated onions were sold to retail markets, shopping centres and departmental stores in different localities of Dhaka City and suberbs with indicator labels "Onion preserved by irradiation: Govt. approved". In 1984-1985 promotional marketing was undertaken by putting about 10 tons of irradiated onions (2 varieties) at normal marketing net-work during 6-10 months storage period. Superior quality of the irradiated bulbs stimulated market demand but this could not be met because of limited stock. The consumers and shop owners appeared to have widely accepted irradiated bulbs. Similar market testing covering wider areas for distribution at competitive prices has been undertaken during August January lean period (1985-1986). No adverse comments regarding quality of the irradiated onion were received from either consumers or the retailers. The shops and centres which have retailed the product were made aware of the toxicological safety and wholesomeness of the treated bulbs. Increased quantity of irradiated onions are planned to be marketed in the next season (1986-1987). A separate warehouse with mechanical facility to harness natural air and blow in upwards through storage racks and sacks is planned to be made available by end 1986, to allow effective dessipation of heat of respiration in order to reduce storage losses.

Storage trials of irradiated (80-100 Gy) potatoes was conducted at semi-commercial scale. irradiated potatoes stored at 12–15°C in wooden crates or gunny bags containing 40 Kg in each were judged to be excellent in qualities with inhibition of sprouting and storage loss of about 2 percent in a storage period of 8 months. In Bangladesh, potatoes are usually stored in cold storage (2–4°C) where potatoes become sweetened because of accumulation of sugars. Moreover, cold stored potatoes become sprouted within a week on taking out of the storage. Contrastingly, irradiated potatoes stored at 12–15°C for more than 8 months and marketed during the lean period (July-December) were found to be very appealing among the consumers because it retained normal fresh quality, especially in respect of sugar concentration. Consumers were found to buy the irradiated tubers at even higher price than that prevailing at the market.

CONTROL OF IRRADIATED FOOD IN THAILAND

P. POTHISIRI
Food and Drug Administration,
Ministry of Public Health,
Bangkok, Thailand

Current food law and regulation

In Thailand, control over the manufacture, importation and distribution of food is the responsibility of Food and Drug Administration (FDA), Ministry of Public Health. FDA enforces the Food Act B.E. 2522 to protect the health and welfare of the consumers and to protect the honest manufacturers from their unscrupulous competitors. According to the Food Act B.E. 2522, those who determine to import food product into the kingdom must apply for import licence and those who determine to manufacture foods must apply for manufacturing licence.

In control of food, the law empowers the Minister of Public Health to specify the quality or standard of food, containers and the use of food additives etc., in order to prohibit the production, importation and distribution of harmful food. According to the Food Act B.E. 2522, foods are classified into three categories:

(1) Specific-controlled food: The food falling into this category is the one required to be registered. Food notified as specific-controlled food must have the quality complying with the established legal provisions which regard to the qualities, specifications, labelling requirements and other aspects of good manufacturing practice. There are now 37 kinds of food notified as specific-controlled foods Irradiated foods is also included into this category.

(2) Standardized food: Standardized food does not need registration but its quality has to comply with standard as notified by the Ministry of Public Health.

(3) General food: The foods which are not listed under the category (1) and (2) will be classified as general food or ordinary food. General food can be produced and distributed provided that it is not harmful to the consumer.

Legislative aspects of food irradiation

Irradiated food is one of the specific-controlled foods. Those who determine import such food into the kingdom must apply for import licence and registration number, those who determine to manufacture irradiated foods are also required to have manufacturing licence and product registration number. When requesting for a permission, the applicant have to state or propose the data concerning the wholesomeness of the irradiated food applied. If the evaluation results show that the food is wholesome, then the permission to irradiate the foodstuff concerned with a certain dose is usually granted.

At present, there is no irradiated food factories in Thailand. One who wants to preserve food by irradiation should ask for an assistance from Department of Atomic Energy for Peace. Dose of irradiation applied for each kind of food are considered by this department. The notification on irradiated food does not prescribe dose of irradiation in each food except for onion which prescribe that maximum dose required for sprout inhibition is 10 kilorad. However the regulation is being revised to form a basis for the correct application of irradiation.

Situation of irradiated food

Commercialization of irradiated food have not been done so far. However food manufacturers and exporters are taking a great interest in this area. There is a tendency that food irradiation industry will increasingly grow and become important industry in the future.

IAEA-SR-129/15

DOSIMETRY FOR AN AUSTRALIAN-DESIGNED RESEARCH/PILOT SCALE FOOD IRRADIATOR

M.E. IZARD
Isotope Division,
Australian Atomic Energy Commission,
Sutherland, New South Wales,
Australia

The gamma technology research irradiator (GATRI) at the Australian Atomic Energy Commission was designed as a research and small scale commercial irradiator to be available to government agencies and industry for technical and economic evaluation of irradiation processing. The source contains cobalt rods in a symmetrical array comprising 20 columns and 5 rows. The peripherally augmented plaque was loaded with 3.7 PBq (100 000 ci) of cobalt-60 and produces parabolical isodose curves at source to target distances greater than 300 mm.

For the theoretical estimation of dose rates, in order to project the expected operating efficiency of the irradiator, each of the twenty columns was considered to be a point source of 185 TBq (5000 ci) rather than a line source. Dose rates measured at points 1.0 m, 1.5 m and 2.0 m from the source, along horizontal lines subtended from the centre of the plaque at angles of 90, 45 and 22.5 degrees to the plane of the plaque, were within 10% of calculated values.

Irradiation parameters invetigated include the effect of source to target distance on relative dose rates within targets of the same density, the effect of density on dose rate distribution within targets irradiated at the same distance from the source and the contribution of transient dose to low absorbed doses as the source is raised and lowered. Various operating geometries have been evaluated including static irradiation with 180 degree rotation half-way through the irradiation period and irradiation on turntables. Frozen and chilled products have been irradiated in controlled environment cabinets. The efficiency of the irradiator was determined for various target densities and overdose ratios.

IAEA-SR-129/16

RADIATION DOSE DISTRIBUTION IN PARTICULATE FOODS

D.A.E. EHLERMANN, M. RUDOLF,
T. GRÜNEWALD
Federal Research Centre for Nutrition,
Karlsruhe, Federal Republic of Germany

Radiation processing of particulate foods in bulk may offer advantages in cases where packaging of the processed goods is not needed or renders further processing more difficult. A typical example from practical applications is the radiation disinfestation of grains during the unloading operation in the harbour. To ensure that pests are reliably eliminated, a certain dose level throughout the treated product must be guaranteed. At the same time, in many countries the health authorities demand that a certain maximum dose level is not exceeded. It is also in the interest of the operator of an irradiation facility to avoid excessive overtreatment, as additional exposure implies higher treatment costs.

The solution to the problem is in product dosimetry. For this purpose a dose meter is needed which can be easily mixed with the particulate foods to be processed and which can be easily recovered after processing. Furthermore, during the handling procedure of the goods the suspended dose meters must remain evenly distributed and must not segregate. Only in rare cases can the product itself serve as a dose meter; in all other cases a foreign material must be suspended in the stream of processed goods in such a way that its behaviour corresponds as closely as possible to that of processed particulate solids. Solutions of the problems, especially if the particles of the foods are about the size as grains, are mini-ampules filled with a dose meter material /1/ or miniature semiconductors /2/.

In some special cases the produce itself may serve as a dose meter if its particles exhibit an effect which is proportional to dose. For example, the chemi-, thermo-, and lyoluminescence of crushed crystals can serve for this purpose if the individual particles are still large enough to produce an amount of light emission which can be reliably measured. The luminescent properties of table salt and sugar are well known. For practical applications, however, biological materials are of much greater importance. For a bulk material consisting of relatively large particles, the chemiluminescence using an appropriate enhancer may be the method of choice. The chemiluminescence of spices is used to detect and identify the radiation processing of spices and dry condiments /3.. If the dose-light output response curve can be established for a broad enough interval, all prerequisites are met. For pepper kernels the chemiluminescence might be proportional to radiation dose applied and to surface of the particles /4/.

To estimate the possibilities and the reliability of such an approach, the dose-response curve for pepper kernels is established. The "calibrated" pepper can then be used to determine dose distributions in bulk pepper irradiated in an open vibrating trough conveyor.

References

/1/. E.W. Tilton, J.H. Brower and R.R. Cogburn, A method for dosimetry for a bulk-grain irradiator, Int. J. Applied Radiation and Isotopes 22 (1971), 577-580.

/2/. Th. Grünewald and M. Rudolf, Verwendung von Halbleiterdioden zur Dosimetrie bei der Bestrahlung von Schüttgut, Atomkernenergie-Kerntechnik 43 (1983), 284-286.

/3/. W. Bögl and L. Heide, Nachweis der Gewürzbestrahlung. Identifizierung gamma-bestrahlter Gewürze durch Messung der Chemilumineszenz, Fleischwirtschaft 64 (1984), 1120-1126.

/4/. W. Bögl, private communication.

RECENT ADVANCES IN DOSIMETRY STANDARDIZATION FOR RADIATION PROCESSING IN CHINA

Wenxia YANG, Fangpu ZHANG, Juncheng GAO,
Ruicao PANG, Chenghua LI
National Institute of Metrology,
Beijing, China

The quality of irradiated products is related to the reputation of radiation technology and social influence. For this reason, national authority requires establishing complete and reliable means of dose control and measurement for every radiation facility. The methods of dose measurement must be unified and the dosimeters applied in practice should be calibrated by national agency of metrology. In this paper the recent advance in dosimetry standardization for radiation processing, including the constructure of organization, the development of dose standards and routine dosimeters as well as the dissemination of dosimetric value, is introduced. In China the metrological regulation of ionizing radiation is performed by the National Institute of Metrology, the local and departmental institutes of metrology and radiation processing institutes. The high-dose measurement systems of gamma-ray from cabalt-60 are being established. The water-calorimeter and ferrous-sulfate dosimeter are to be accepted as national standards. The transfer dosimeter systems selected are: L-alanine/electron spin resonance (ESR); ceric-cerious sulfate solution and potassium dichromate solution/optical absorption and the radiochromic dye films, perspex and opti-chromic dosimeters would be recommended as routine dosimeters. The complete high-dose measurement systems will be accomplished in 1987. The traceability for absorbed dose value used in radiation processing is also described. In order to unify the high-dose value for radiation processing throughout the country and transit to legal regulation, it is necessary to realize the standardization of dosimeters, read-out devices, procedures, related parameters and so on.

IAEA-SR-129/18

INVESTIGATION OF ROUTINE DOSIMETRY FOR FOOD PRESERVATION BY IONIZING RADIATION

Zhili WU, Xinwei CHEN, Jiashan ZHANG
Shanghai Institute of Nuclear Research,
Academia Sinica,
Shanghai, China

This paper is the sum of the investigation of routine dosimetry in our laboratory. Liquid chemical dosimeter, plastic film dosimeter and visual colour indicator label used as quality control of food irradiation were studied. (1) The ferrous sulfate dosimeter and the ceric sulfate dosimeter were used as the reference dosimeter systems for calibration purpose. (2) The ferrous sulfate-benzoic acid-xylenol orange dosimeter, the liquid radiochromic dye-cyaride dosimeter and aqueous sulfuric acid solution of bromocresol purple were used as routine dose measure in the dose range from 1 Gy to 10 kGy. The dose measure range of aqueous sulfuric acid solution of bromocresol purple was 10 Gy to 3 kGy. The loss of colour with dose increase was detected by spectrophotometric analysis due to radiolytic bleaching. Experiment results showed that using the plastic ampules as irradiation cells and absorption cells were possible (3) The dose response characteristics of polymethyl methacryate piece, cellulose triacetate film, polycarbonate film, polystyrene film, polyethylene terephthalate film, which have been commercially supplied in Chinese market, for ^{60}Co gamma rays were searched, and dyed polymethyl methacrylate pieces were particularly made in order to measuring routine dose over 1 kGy. (4) The visual colour indicator labels of ionizing radiation dose were prepared in our laboratory. This indicator label can be applied in the dose range of 0.2 kGy to 80 kGy.

LOW COST FLEXIBLE IRRADIATORS

F.M. FRASER
Radiochemical Company,
Atomic Energy of Canada Limited,
Kanata, Ontario,
Canada

Gamma Radiation Processing is the preferred method for sterilizing medical disposables. It will, in the near future, emerge as a major process in the preservation of foods. Atomic Energy of Canada Limited, Radiochemical Company the world's leading supplier of radiation processing equipment and cobalt 60 sources, is reacting to the market demand for low cost flexible irradiators.

Two design concepts are examined. The first is an automatic portable irradiator sized to handle small but commercial volumes of food or medical disposables. The mechanism can be removed from a simple irradiator building and reinstalled in a second building location in less than a week. With strategically located irradiator buildings, this concept is an ideal method for increasing efficiencies when radiation processing seasonal crops.

The second design approach is a non-portable batch irradiator which has the capability of being readily upgraded to a fully automatic unit. This design minimizes the initial capital cost which permits the user to economically radiation process small volumes of product. At the same time it allows the user to put in place an irradiator building capable of housing automated equipment with high capacity to accommodate future growth.

IAEA-SR-129/20

EQUIPMENT SELECTION CRITERIA FOR FOOD IRRADIATION

A CHIN
Radiation Sterilizers Incorporated,
Menlo Park, California,
United States of America

With the growing worldwide interest in food irradiation, it is becoming increasingly more important for potential users to be able to evaluate how a specific equipment design will function in their application. Most of the radiation equipment in use today is based upon the technology developed for medical product sterilization during the last 25-30 years.

Certain components of the medical equipment designs are directly applicable to food irradiation. These include the licensing process, shielding designs, and radiation safety systems.

The major differences between the medical and food irradiation industries are, density of the product, radiation sensitivity, radiation dosages, quantity of product, and product mix.

The density of the product will affect the dose uniformity, the package size and load carrying capacity of the equipment. Typically food densities fall in the range of 0.3 to 0.7 gm/cm^3. In comparison medical products have densities in the range of 0.05 to 0.3 gm/cm^3.

The radiation sensitivity of food products will be a very important consideration. The dosage value at which the organoleptic properties are affected will establish the maximum allowable dosage. The minimum value is defined by the amount of dosage required to produce a desired result such as sprout inhibition or shelf life extension. These maximum and minimum values will greatly influence whether the product can be treated in carton or pallet quantities.

The radiation dosage requirements will define the basic equipment design philosophy. For dosages above 5kGy, the cost of the isotope is a significant cost. Since the product overlap systems are 25% more isotope efficient than the source overlap systems, they should be considered for higher dosages.

The quantity of product to be processed will determine whether a batch or continuous system should be selected. It will also greatly influence the type of material handling system which is required.

If the proposed system will be required to process a number of varying density and dosage products, an extremely versatile system will be required. Consideration should be given to whether these products may be run concurrently or sequentially.

This paper will discuss each of these factors and their effect on the equipment selection process.

IAEA-SR-129/21

A NEW GENERATION OF $^{60}Co/^{137}Cs$ TREATMENT PLANTS: M4p MULTIPURPOSE PICOWAVE PROCESSING PLANTS

J.N.G. GOEBEL
NUKEM GmbH,
Hanau, Federal Republic of Germany

The industrial irradiation market has an increasing requirement for multipurpose plants. These plants should be highly efficient, flexible and reasonable priced. NUKEM has with the M4p-system a new generation of gamma-irradiation plants, which offer outstanding advantages compared to most existing installations. The goods will be treated in their original packaging, stacked on pallets. Four to eight pallet-carriers rotate around a central source. A specially defined attenuation system avoids high overdosing of any part of the pallets. Depending on customers requirements, the M4p-system can be designed as simple batch multipurpose-plant or as fully automated high-throughput-installation. The system allows efficiencies of up to 60%. Special arranged attenuation systems, consisting of single extra items or by the goods itself, allow overdosing factors of 1,2 for a density of 0,15 g/cm^3 and an efficiency of 55% or 1,35 for a density of 0,5 g/cm^3 and an efficiency above 60%.

Due to the compact construction, only 30% of the surface-area of a traditional plant is necessary. Good with four to eight different densities and subjected to different doses can be processed simultaneously, depending on the size of the plant.

IAEA-SR-129/22

DESIGN OF FOOD IRRADIATION FACILITIES IN CHINA

Junren GU, Chuanzhen WANG
Beijing Institute of Nuclear Engineering,
Beijing, China

The history of the development of food irradiators in China is reviewed in this paper. Description of the present situation of food irradiation and the characteristics of those demonstration irradiators under construction for food irradiation is made. Focal point is to the introduction of the design and the construction programme, the design bases and principles for commercial food irradiation facilities, in combination with the experience in cosntruction of the facilities. The three stages for construction of the facilities are also practically described. They are - investment stage, investment --preforming stage, and production - operation stage. Taking the primary facilities buildt in Shanghai, Zhenzhou, Nanjing, Lanzhou and Chnedu for example which have been built or are under construction, and can be used in China as commercial or pilot food irradiation facilities, of which the main componenet systems and experience in designing work are presented. Fianlly, foreseeing the tendency of development of facilities used in China for food irradiation in the coming years is envolved in this paper.

IAEA-SR-129/23

INDUSTRIAL MULTIPURPOSE RADIATION CENTRE DESIGNED PRINCIPALLY FOR FOOD IRRADIATION

Chuanzhen WANG, Hehu ZHANG
Beijing Institute of Nuclear Engineering,
Beijing, China

This paper introduced the first industrial multipurpose radiation facility in our country----- Zheng zhou Radiation Centre briefly, including its nature, assignment, component, general arrangement, characteristics of the main process and equipment, dose monitor and quality control, radiation shield and safety installations, etc. Using the single slab source, the design source activities of the Centre is 500 Kci. Initially, it is 200 Kci. It mainly treats potatoes, onions, garlic, peanut kernels, fur, etc. Also, the Centre is equiped with more completed test means. In addition to radiation processing, it can be used for research and development of the new products. The Centre is in the progress of building. It is expected to complete construction and come to use before the end of June 1986.

^{60}Co SOURCE IRRADIATION FACILITY OF THE INSTITUTE OF ATOMIC ENERGY

Ziyan XU, Jiajiu WANG
Institute of Atomic Energy,
Beijing, China

A ^{60}Co source irradiation facility with the designed capacity of 300 K Ci was put into operation in Institute of atomic energy at the end 1984.This facility is designed for the researches of radiation chemistry and irradiation processing . It is also a pilot-plant for trial production.

This facility consists of a shielded structure,an operational mechanism for raising and lowering the source ,a product convayor systim,a viewer systim,a controlling systim and other auxiliary equipments.

The circular irradiation room covers an area of 37 m^2. A water pool is centrally located in the irradiation room for shielding the source when it does not work.

Sixty source slugs (Φ28x90 for each) are loaded in 20 tubes and the tubes are arranged cylindrically.

The product to be irradiated is transferred by an electromotive vehicle which draws five carts. Each cart contains three boxes(680x380x500for each). for the purpose of small scall research,irradiation of the samples are commonly performed on the rack or at the center of the cylinder.

Instead of TV,a shielding window is used for direct observation.This may give an explicit view of the irradiation process for chemists.

The raising and lowering of the source is automatically controlled. Safety of operation is ensured by diffrent kind of locks,protection and alarms, and adequate dose of monitoring systems.

This facility has been used in the research and trial production for the preservation of food, fruits and vegetables, the modification of macro molecular materials, the sterilization of medical appliances and research of radiation chemistry.

SHANGHAI IRRADIATION TECHNIQUES DEVELOPMENT CENTRE (SIC), SHANGHAI INSTITUTE OF NUCLEAR RESEARCH (SINR)

Jinxin ZHU
Shanghai Institute of Nuclear Research,
Academia Sinica,
Shanghai, China

Introduction

The purpose of SIC to develop commercial application of nuclear irradiation techniques. Shanghai is one of the largest cities in China. The supply of vegetables and fruits are big problems. In order to solve this problem, it is necessary to improve the preservation of vegetables and fruits by suitable techniques, and as well known, Co-60-ray irradiation is one of the best. So foods irradiation processing is the main aim of SIC. Besides, it will exploit the application of irradiation techniques in the area of sterilization of medical devices and instruments, preventing goods from mould and rot, modifying polymers and other materials etc.

Irradiator. The irradiator is of doubleflat model containing 200 kCi Co-60 with efficiency about 20%. The unhomogeneity designed of dose rate (D_{max} D_{min}) about 1.6 or somewhat better. It is capable of treating tens thousands ton of products per year. The thickness of water in the source well and wall of the "maze" are heavy enough to shield 500kCi Co-60's γ-ray.

The installation of equipments will be completed by the end of 1985.

R&D. In order to irradiate the foods and other objects in commercial scale successfully, since 1983, a number of lab. researches have been engaged, such as irradiation of vegetables, potatoes, garlic, onion, apples, longan, lichi, dried vegetables and fruits, medical devices.

Economics. Acording to the approximate estimate, the investment in establishing SIC could be recovered in 3-5 years or a little longer.

Prospect. In the second period, 500 kCi Co-60 will be equipped. At that time, high dose irradiation will be engaged, and the irradiated food programme will be enlarged to cover pork, beef, chicken, poultry, etc.

TRANSFER OF FOOD IRRADIATION TECHNOLOGY IN PAKISTAN

I. KHAN
Nuclear Institute for Food and Agriculture,
Tarnab, Peshawar,
Pakistan

We have been working on the radiation preservation of food for the last more than 16 years in the PAEC. We have conducted some trials on semi-commercial scale on potatoes. The similar trials on dry fruits and onions are in progress. We expect also quite encouraging results in the last two projects. The good results obtained in potato project have cleared the way for going commercial on the radiation preservation of food in Pakistan. The consumers acceptability and market testing performed during the last three years are also conducive to the commercialization of the technology in this country.

The plans are already underway to establish commercial irradiator for food preservation in Pakistan. At the same time, the industry and trade have also got interested in this new technology as they have been involved in our projects on dry fruits and onions. All the necessary requirements for the commercializing of food irradiation in this country are being finalized for the quick transfer of technology so that the huge postharvest losses occuring in various food commodities are avoided and the country is made not only self-sufficient in food but will also become an exporter of many food products. Gamma radiation is considered as the future potential alternate treatment of foods for quarantine purpose. This aspect of the technology is also being investigated to further promote the export of fruits and vegetables by using gamma radiation as a quarantine treatment. This is very much in line with the international trade on food irradiation being promoted with the help of IAEA.

IAEA-SR-129/32

COMMERCIALIZATION OF FOOD IRRADIATION FOR STORAGE IN SHANGHAI AREA

Xuexin CAO
Shanghai Municipality Science
and Technology Commission,
Shanghai

Zhiren XU
Shanghai Institute of Nuclear Research,
Academia Sinica,
Shanghai

China

This article is mainly intended to introduce the concerted efforts made by Shanghai Municipality Science and Technology Commission and Chinese Academy of Science in promotion of preservation technique of food irradiation.

The article consists of three major parts.

The first part attempts to describe how these two institutions made a correct decision on the orientation of its development; and how specific objectives have been clarified and priorities set up so that the technique is developed in a planned, organized way. This part, meanwhile, expounds with emphasis the principles in supporting and aiding preparations for the setting up of a Cobalt-60 source device (500 thousand curie; the initial stage 200 thousand curie), which is to be used in the irradiation to store vegetables and fruits fresh. While putting primary stresses on themulti-purpose of the irradiation device and low-dose irradiation in food preservation, the priciples also emphasize that preliminary development research should is conducted systematica;in product selection attention had been paid to economic profits and social effects such as selection of location, envoironment protection, transportation,trialsale and savor of the products and so on; and an arrangementis made so that research institutes, both local and under the Academy, supervisory institutions and commercial departments are involved in the such activities.

The secOnd part focuses on six key tasks totalling 25 projects the commission and the Academy have orgarized more than a dozen institution as Shanghai to tackle in collaboration. In accordance with the key projects characteristics an overall arrangement and plan was made concerning the areas such as product selection irradiation technical process, dosage, quality control, standards for safety and health, irradiation device, batch production process, packing and etc. During the course "three combinations" have been accomplished, that is, to integrate basic and mechanism research, with applied research and development; applied R & D with laws and rules stipulation; and applied development with small-scale production.

The final part contains the writers main conclusions and the prospective outlook, which are based on the factual effects brought about by the key projects accomplished since the setting up of the device and analysis of market acceptability. And the future plan.

IAEA-SR-129/33

ESSENTIAL CONSIDERATIONS FOR THE APPLICATION OF FOOD IRRADIATION TECHNOLOGY

G.B. NADKARNI
Bhabha Atomic Research Centre,
Bombay, India

Research and development work in food irradiation over the past several years was essentially directed towards answering all possible questions in respect of the suitability of the process, quality of materials and safety for human use. A major effort was indeed, around the toxicological evaluation, till it was recognised internationally that irradiated items of food do not present any health hazards. This recognition along with the awareness of the hazards in the use of chemicals has resulted in a renewed interest in the use of radiations for preservation of food. The national regulatory agencies are now looking at the process with more understanding, which should help in creating confidence in the traders and consumers alike.

Some questions are still to be answered. Radiation preservation of food would reach the stage of practical application with additional information on design and functional aspects of radiation sources, appropriate for specific commodities. Each item has a particular dose requirement depending on the purpose of irradiation and the type of handling. For example considerations for onions/potatoes are not workable for grains or fish. It is therefore essential to develop different types of irradiation facilities for optimal utilization. The radiation process will be acceptable for large scale operation, only if the costs are favourable from the user's angle. This is particularly relevant to the countries in the tropics which suffer from lack of organised food industry and inadequate facilities for storage and distribution. Some of the past experiences and the current efforts towards the transfer of the technology will be presented.

IAEA-SR-129/34

PROSPECTS OF THE FOOD IRRADIATION COMMERCIALIZATION PROGRAMME IN BANGLADESH

M.M. HOSSAIN
Atomic Energy Commission,
Dacca, Bangladesh

Bangladesh Atomic Energy Commission (BAEC) has been engaged for many years in research and development in the field of food preservation by radiation and is actively participating in research projects under the Regional Project in Food Irradiation (RPFI) of the RCA countries since its inception. Its Institute of Food and Radiation Biology (IFRB) has been using since 1979 a 50,000 Curie Gamma source for R & D and pilot-scale studies on many important food items. Based on these and other techno-economic feasibility studies, the National Expert Committee formed by the Government formally adopted in 1984 the Codex General Standards for Irradiated Foods and the Code of Practice for Operation of Irradiation Facilities for Bangladesh. The irradiated foods which are now ready for commercial introduction include potatoes, onions, dried fish, fresh fish, frozen shrimps and frog legs, grains, pulses, spices and some fruits and vegetable.

It has been proposed to the Government for the establishment of several Commercial irradiation plants both in the private and public sectors in the next Third Five Year Plan Period (1985-90). A Commercial plant of the size of about 200 K curie to be supplied by the Soviet Union has already been offered by IAEA under its technical assistance programme to BAEC which will be operational by early 1988. Some commercial and industrial entrepreneurs have also approached BAEC showing interest in setting up commercial irradiation plants. BAEC has already signed a Memorandum of understanding with a private entrepreneur to set up a commercial irradiator near the capital city of Dhaka. The factors considered for the siting of irradiation plants in different parts of the country have been explained. Bangladesh's experience and strategy for shaping public opinion in favour of accepting irradiated foods on commercial scale in the country and their export potentials have been described.

IAEA-SR-129/37

TRADE IN IRRADIATED FOOD

P.F. LEWIS
United States Department of Commerce,
Washington, D.C.,
United States of America

Current world production of irradiated foods is very small, despite the intense interest in this technology in many countries and regulations permitting its application for selected foods. Many potential applications likely to be commercialized in the near future involve foods frequently entering world trade. Barriers to international trade in irradiated foods include different regulations between countries, lack of systems to determine whether, and the extent to which, foods have been irradiated, differing labeling requirements, record keeping, and others.

This paper reviews the above, the efforts of international organizations to resolve these problems, and future problems which will have to be addressed. Also covered are the most promising applications for trade in irradiated foods with particular attention to trade opportunities for developing countries. The paper will include a brief summary of the latest reports on economic and technical feasibility for irradiating various foods plus a status report covering all food irradiation developments in the United States likely to be of interest to the audience. It is expected that the U.S. Food and Drug Administration will have made its long awaited decision on its irradiated foods proposal by the date of the meeting If this is the case, some time will be spent on the expected impact of this decision and future developments next to be considered by FDA because of the obvious effects they will have on future developments in food irradiation throughout the world.

SUMMARIES OF POSTER PRESENTATIONS

IRRADIATION STERILIZATION FOR POULTRY FEED

Shujian ZHANG, Xinhua OU,
Wei LI, Cairuan WU, Jibing ZHEN,
Aiyun MA
South China Agricultural University,
Guanzhou, China

We started the research on irradiation sterilization of poultry feed in 1982.

The results of our research are summarized as follows:

1. Irradiation technology.
   Food was divided into a number of groups, 0.25 kg each. Each group was packed in a small bag with double layers, the inner plastic one in polythene and the outer one woven by polythene filament. After bein sealed, the bags were put into a well-typed ^{60}Co- ray resource unit in the South China Agricultural University to be irradiated by the doses starting from 2 kGy to 4, 6 and 8 kGy. A dose of 1 kGy was used for the contrasted group. By analyzing the results of the experiments, we found that 6 and 8 kGy were the effective doses for sterilization.

2. Effect of irradiation sterilization.
   By checking the amount of germs in the samples on the 14th day after irradiation with 2,4,6 and 8 kGy respectively, it was found that the sterilizating effects to the different extents depended upon the different doses used. The total amount of germs in each tested group, especially in the groups processed with 6 and 8 kGy, was remarkably less than that in the contrasted group. When checking the amounts of germs on the 28th, 40th and 50th day respectively, though germs were found in every group, the difference of the amounts of germs between the tested groups and contrasted group was still evident. Through Chi-square (x^2) and Ridit analyses, we obtained $P<0.01$, that means the larger the dose is used the greater sterilizing effect will be achieved.

3. The Variation of nutrient contents of the irradiated feed.
   By analyzing the nutrient contents of the irradiated feed, ile., crude protein, crude fat, coarse fibre, non-nitrogene abstraction, calcium, phosphorus, salt and amino acid, etc. preserved for 50 days after irradiation, there was little loss of them to be found. By means of mean-square deviation analysis, we had $P>0.05$. Compared with the contrasted group, the differences between the two contrasting groups in various nutrient contents were unremarkable.

4. Hygienic safety study.
   By comparing the growth condition and physico-chemical indices (such as RBC and WBC numbers, WBC classification and hemoglobin content, etc.) and viscera coefficient of the chickens fed by irradiated feed of 6kGy dose with that fed by unirradiated food, ther was no evident difference between the two contrasting groups, and no poisonous substance, no toxicity reaction and detrimental affection on the chickens were found.

STUDIES ON RADIATION PRESERVATION OF FRESH PRAWNS

Mengqin ZHANG, Kaiping DENG,
Shufeng HOU, Lianfang DONG
Institute of Atomic Energy,
Beijing, China

In order to prevent the head of prawn from darkening during the process of preservation, the radiation preservation technology of fresh whole-prawn has been studied.

The initial experimental results show that after the prawn was irradiated with radiation dose 1.5×10^5 -6×10^5 rad of Co^{60} r-ray and stored at -4°c for a period of 40-50 days, the exterior of irradiated fresh whole-prawn looks like fresh prawn, and its meat possesses good resilience. And the results of examination of microbe show that it meets the first or second class freshness of national standard of PRC. There aren't any pathogenic bacteria. The colour of irradiated fresh prawn looks a little bit red and there isn't any monstrous taste.

Owing to the fact, that the head of non-irradiated fresh prawn darkens after a 15-20 days storage at deep freezing condition, or it darkens in 24 hours at 35°c, aquatic breed farms have to take off the head of prawn before putting it into deep freezing storehouse. But it causes a loss of the output of fresh prawn for about 40%.

IAEA-SR-129/P-I-3

ACCEPTANCE EVALUATION OF IRRADIATED AND FROZEN HAKE

G. LESCANO
Comisión Nacional de Energía Atómica,
Buenos Aires, Argentina

The purpose of this investigation was to compare the sensory evaluation data between irradiated hake, stored at (0+1)°C, and frozen hake, to be able to determine whether irradiation could be used to increase fish shelf life, hoping a good trade.

A commercial, high quality hake, headless, scaled, clean and vacuum-packed, caught in the South Atlantic Ocean, was irradiated with a dose of 3.3 kGy in a Semi Industrial ^{60}Co Plant at the Argentine Atomic Energy Commission. Other samples, were dipped in 10% Na polyphosphate for 30 minutes, before packing and irradiation. A third batch was air-packed and frozen at -35°C as soon as it was put ashore, and stored at -20°C since then.

The testing panel (TP) was composed of 5 to 7 judges, who were selected by acuity; the industrial expert testing panel (IETP), by 6 judges belonging to different Fishery Companies, which buy fish for exportation to Europe, USA, and Japan;

Preference scales and magnitude estimation were used for scoring raw and cooked fish.

Evaluation of each treatment was performed by variance methods. The least significant difference, $p<0.005$, was determined by a Dunnett test.

The evaluated attributes were: on raw samples: external appearance, elasticity, shine, bone adhesion, muscle cohesion, visual colour, odor intensity, natural odor, off odor, drip loss, and purchase acceptability; on oven cooked samples: odor intensity, natural odor, off odor, natural flavour, off flavour, hardness, flakiness, chewiness, fibrousness, moistness, and general acceptability.

The TP evaluated fish samples on the 8th, 16th, 45th, 51st and 58th storage days; the IETP only on 35th storage day, independently of TP.

The results were as follows: the TP judgement was that nearly all of the attributes evaluated on raw irradiated fish samples were significantly better than those of the frozen ones On cooked samples, most of the tested attributes were not found significantly different.

45th storage day was the last one of consumer acceptability of irradiated samples; however, up to 58th they had not been rejected yet.

There are essential agreements between both panels evaluations, but the IETP detected an off odor on an irradiated cooked fish; this difference was not appreciated by the TP.

Although taste panels are not considered to be predictive of the consumer response, we can take this result as an index of the acceptability of an irradiated fish (hake) by the consumer market.

STUDIES ON RADIATION PRESERVATION OF FRESH POMFRETS

Shaochun LAI
Crops Institute,
Academy of Agricultural Sciences,
Tianjin, China

This paper described the radiation preservation of fresh pomfrets with γ-ray. The samples were made from pomfret pieces which had been ridded of head and internal organ. All samples were vaccum-packed with plastics bogs. Experiment results indicated:

(1) There was an obvious negative correlation between the dose of irradiation and log N; the N is TBC. The correlation coefficient was equal to -0.9572. The average D_{10} values was 1.6 kGy. The correlation between the dose of irradiation and preservation period (in days) was positively obvious, the correlation coefficient was equal to 0.9899.

(2) The average TVBN values of pomfrets was 19.1mg/100g, and they were not affected by irradiation. Then TVBN values were increased with increasing storage time, howere there was an negatively obvious correlation between dose of irradiation and preservation period (in days) on TVBN.

(3) The total dose was affirmed 3KGy. The preservation period of pomfrets irradiated was 20 days longer than non-irradiation.

(4) The irradiation less affected the contents of samples such as amino acids, vitamin A, B_1, E, protein, fat and ash etc.

EFFECT OF NaCl ON IRRADIATED FOODS (I): RADIATION CHEMISTRY OF ESTER-NaCl-H_2O MODEL SYSTEMS

Rongyao YUAN, Jilan WU
Department of Technical Physics,
Beijing University,
Beijing, China

Sodium chloride is a common additive of foods such as salt meat, ham, sausage. Pulse radiolysis experiments have shown that Cl_2^- ion is detected when concentrated neutral chloride solutions are irradiated. Cl_2^- is an active species, consequently to pay one's attention to the effect of NaCl in the irradiated food is necessary. In this paper radiation chemistry of ester-NaCl-H_2O model systems have been developed by ^{36}Cl radioactive tracer method and Cl^- ion selective electrode method. Both methods verify existence of organic chloride compounds in the system when it is irradiated under ^{60}Co γ irradiation. Experiment results carried out by ^{36}Cl radioactive tracer method were shown in the table

Table Dependence of G value of organic chloride on the water content of the ethyl stearate-NaCl-H_2O model system

$\frac{\text{moles of water}}{\text{moles of ester}}$	19	8	6	5	3.5
$G_{(RCl)}$	0.07	0.17	0.35	0.47	0.71

Results reveals that the formation of organic chlorides takes place at the interphase of water and ester. G value of organic chloride are also dependent on the condition of mixing.

ELIMINATION OF N-NITROSAMINES IN FOODS BY ^{60}Co IRRADIATION

Jifan HU, Puju SONG
Beijing Medical University,
Beijing, China

Volatile N-nitrosamines, a class of potential carcinogens to which human are exposed, have been found in a variety of foods. The reduction or elimination of N-nitrosamines in foods has become a major issue. The present study was conducted to observe the effect of ^{60}Co-irradiation on the levels of N-nitrosamines and their precursors in foods.

Dried shrimp bran and fish meal which had high levels of N-dimethylnitrosamine (NDMA), and salted eel in which 1.92 ug NDMA had been added, were chosen for samples of irradiation. A 200-g ground sample was placed in a polyethylene bag and irradiated with a ^{60}Co source at room temperature. The doses were 0,5,10,15 and 20 kGy. The residual nitrosamines in these samples were analysed with gas chromatography-thermal energy analyzer (GC-TEA).

Dried shrimp bran contained 54.6 ppb NDMA prior to irradiation, but only 29.3 ppb, 8.8 ppb, 11.4 ppb and 1.9 ppb NDMA were detected after irradiation. The corresponding reduction of NDMA were 46.3%, 83.9%, 79.1% and 96.6%, respectively. Similar results were also obtained in fish meal and salted eel. The levels of NDMA were reduced from 55.3 to 34.4 ppb, 30.2 ppb, 23.8 ppb and 16.1 ppb in fish meal, and from 34.7 ppb to 25.8 ppb, 22.4 ppb, 18.4 ppb and 12.0 ppb in eel. The results showed that the levels of nitrosamine in these samples could be drastically reduced by ^{60}Co-irradiation and there was a good dose-response relationship between irradiated dose and reduction of nitrosamine.

In other experiment, a nitrosamine mixture, composed of 1.92 μg diethylnitrosamine (NDEA), 2.4 μg dipropylnitrosamine (NDPA), 3.2 μg dibutylnitrosamine (NDBA) and 2.8 μg N-nitrosopyrrolidine (NPYR), was added into a tube which contained 20 ml water. The samples were irradiated with the same doses as above. The irradiated nitrosamine aqueous solution were directly extracted with dichloromethane, then analysed with GC-TEA after concentration. No nitrosamine could be detected in any of the irradiated samples. The result showed that effect of ^{60}Co-irradiation in aqueous solution was much more markable than in food samples. it also showed that the major irradiated products of NDMA in aqueous solution were dimethylamine and nitrous acid. No reformation of nitrosamines in irradiated nitrosamine aqueous solution could be observed in three months' storage, even in the lowest dose group (5 kGy).

^{60}Co-irradiation could eliminate nitrite from 41.2 ppm to 21.0 ppm, 16.5 ppm, 10.6 ppm and 4.0 ppm in eel and from 49.8 ppm to 38.1 ppm, 32.2 ppm, 24.5 ppm and 10.9 ppm in aqueous solution after irradiation with the same doses as did for nitrosamines. ^{60}Co-irradiation can significantly decrease the content of nitrite in foods and therefore reduce the possibility to form nitrosamines with amines in foods or to undergo nitrosation in human body. Unfortunately, no effect of ^{60}Co-irradiation on nitrate could be observed.

In one word, ^{60}Co-irradiation could not only be used for preserving foods, but also eliminate carcinogenic nitrosamines and nitrite present in foods, thereby reducing human's intake of these carcinogens from foods.

SEMI-PILOT SCALE STUDY ON THE IRRADIATION OF RICE IN MALAYSIA

N. YUSOF, R.M. NORDIN
Nuclear Energy Unit,
Puspati Complex,
Bangi, Selangor,
Malaysia

A Semi-pilot scale of milled-rice preservation project using gamma irradiation was started in 1984. The project was aimed to study the possibility of using irradiation in reducing losses during storage. Six tonnes of rice were subjected to doses ranging from 0.2 to 2 kGy and stored in stack under the conditions similar to a typical rice godown. Rice sampling was done every three months to determine the effect of irradiation on nutritional value, organoleptic characteristics, insects infestation, fungal and bacteria infection, packaging and storage life extension.

After a year's storage, radiation was found to produce no effect on nutritional value ($P < 0.05$) i.e. reducing sugar and amino acid content, water content ($P < 0.05$) and organoleptic characteristics. However, gel viscosity was markedly reduced with increase in irradiation dose and storage time. The rapid change was recorded between 0 - 3 months and declined slowly after 6 months. Free fatty acid used as index of grain deterioration was higher in unirradiated than in irradiated samples. Further study on fat extraction is required.

Irradiation has been proven capable of controlling insect infestation, microbial and fungal infection in stored rice even though the selected doses caused no immediate lethality. Since radiation is in no position to stop insect reinfestation, a study on combined treatment namely radiation and insect repellents was initiated and is in progress.

Packaging materials (gunny sack, heavy duty plastic, woven laminated plastic and non woven laminated plastic) do not influence both chemical and physical quality of irradiated stored rice. However, heavy duty plastic bag was found not be able to stand the stress during handling and transportation.

RADIATION TREATMENT OF CIGARETTE AND LEAF TOBACCO TO PREVENT ATTACK BY MILDEW AND MOTHS

Chengkui TANG, Yun ZHANG, Huimin XU,
Jinju XU
Kunming Institute of Zoology,
Academia Sinica,
Shanghai, China

We seperated 30 strains of mould belonging to 7 genera from cigarettes and leaf tobacco from Yunnan province, they were those of the genera Aspergillus, Penicillum, Monosporium, Cladosporium, Rhisopus, Mucor, scopulariopsis. After the satisfactory seperation, We studied the piological effect of radiation on these 30 strains of moulds seperatly on culturemdium. Besides, we inoculated mixture of these 30 strains on culturemedium and leaf tobacco for radiation experiment. Results of all the above experiments indicated that through the radiation treatment of 9KGY Co-60r rays, it might keep the cigarettes and tobacco leaves unattached from moulds and tobacco insects for more than one year, at 30C temperature and 90% relative humidity. This method fulfilled the requirements of the prevention against moulds and tobacco insects for the preservation and transportation of cigaretts and leaf tobacco.

We also seperated 4 kinds of bacillus responsible for the decaying tobacco leaves. Through radiation experiment we found that they showed the simillar sensitivity as the moulds.

After 5KGY radiation dose treament, all the main storehouse tobacco insects (Lasioderma serricorne and Ephestia elutella) were immediately killed.

IAEA-SR-129/P-I-9

STORAGE OF IRRADIATED DRIED JUJUBE

Zhao LIU, Yinchang WANG,
Guizhi WANG, Yuntang CHEN
The Isotope Institute of Henan Province,
Zhenzhou, Henan, China

The dried jujube packed with plastic film was irradiated with 60^{Co} gamma rays. The dosage used was 1 kGy. The irradiation effectively prevented the destructive insect growth in the preserved jujube, such as lepidoptera. After one year preservation of the irradiated jujube, more than 90% of the jujube were still alright.

Aiming at killing the destructive insect, the main nutrition of the irradiated jujube, such as dissolve sugar, amino acid, vitamins and inorganic salts, does not change evidently. Also the irradiated jujube is harmless to man because of hte low dosage of irradiation. With its obvious economic effect, this is one of the new technical methods in the field of dried jujube preservation.

EFFECT OF IRRADIATION ON DRIED LONGAN PULP

Renzhong LIU, Beibei SHI,
Xuepeng LI, Leidong XIE
Shanghai Institute of Nuclear Research,
Academia Sinica,
Shanghai, China

Radiation treatment of dried longan can prevent the outgrowth of moulds and control the proliferation of insects. The cane sugar, glucose and fructose are main components in dried longan pulp. The contents of cane sugar, glucose and fructose in irradiated dried longan pulp with different doses have been determined by HPLC. A linear relationship between their contents and the radiation doses was obtained. Their contents reduced lightly with the doses increase. It has been reported that the free radicals are formed in irradiated dried longan pulp. The ESR signals of the radicals have been detected in our experiments. The ESR signal intensities of radicals in the dried longan pulp increase with the increasing of radiation doses, but decrease with the increase of content of the water in the dried longan. When the content of the water is less than 10%, the ESR signal intensities of the radicals increase intensely with the decrease of content of the water, but as the content of the water is over 20%, the ESR signal intensities of the radicals decrease slowly. The decay of radicals in irradiated dried longan pulp has been investigated by ESR. The signal intensities reduced rapidly at first, and then changed slightly. As the irrdiated samples were heated at 100 ^{o}C for 5 minuts, the ESR signal intensities reduced obviously, but signal intensities of the residual radicals unchanged when the samples were heated again at 100 ^{o}C for 5 minutes.

IAEA-SR-129/P-I-11

STUDY OF THE INSECTICIDAL AND BACTERICIDAL EFFECTS OF IRRADIATION ON FLAVOURINGS

Kwangfah CHU, Kiahwa CHENG
Shanghai Import and Export
Commodity Inspection Bureau,
Shanghai, China

The quality and the storing period of the flavourings were affected by the contamination of insects and microorganisms during the processing.

According to the informations came both from this country and abroad, Co 60 gamma rays used in the food processing could attain the goal of insecticidal and bactericidal effects and delay the duration of storage. We have studied the microbiological monitoring and the nutritional analysis of the flavourings before and after irradiation since 1983.

The research work was prosecuted by two steps. In the first step, irradiation was applied in the mimic specimens innoculating quantitatively with known microorganisms. The bacterial counts of each specimen varies from thousands to millions. The dosage of radiation ranged from 30 Krad to one Mrad. The results showed that the Gram's negative rods and Gram's positive coccus were fundamentally destroyed under the radiative dosage of 200 to 400 Krad, while the Gram's positive spore-producing bacilli were destroyed only in the dosage of a million rad. In the second step, we tested directly with the flavourings itself. The radiation dosage was defined in 30, 50, 100, 200 and 400 Krad; the investigative items contain the microbiological detection and the nutritional analysis results before and after irradiation; the identification of organoleptic quality; and the efficiency of killing insects. The outcome of experiments through the mimic specimens and the specimens of 46 lots show that the bacterial counts per gram was decreased and conformed the sanitary requirements; the nutritive value varied insignificantly; the organoleptic quality was approached to that of unirradiated specimen; the pesticidal effect was significant.

STUDY ON THE PRESERVATION OF GINGER *(Zingiber Officinale Roscoe)* BY IRRADIATION

Caixuan WU
South China Agricultural University,
Guangzhou, China

Ginger is grown in the Southern Provinces of China. It is a kind of useful condiment, which contains various nutrient components. Ginger is usually stored at room temperature for a few months after harvest at the end of winter. During storage, its market value will often decline due to sprouting and rooting. For solving this problem, we initiated the study of ginger preservation with irradiation in 1982. Some results obtained in the past three years showed that:

1. The sprouting of stored ginger can be effectively inhibited with ^{60}Co-γ rays at a dosage of 200-300 Gy. The irradiated ginger can be stored at room temperature for 3-4 months without sprouting.

2. Quantitative analysis of various nutrients, i.e. protein, fat, carbohydrates, vitamin C, and seventeen kinds of amino acids, showed no significant difference between fresh ginger and ginger irradiated with a dose of 200-300 Gy.

3. Comparitive organoleptic tests of irradiated and fresh non-irradiated ginger were done by cooks from several restaurants. The results showed that they were similar in flavour and colour, and no peculiar odour was found in the irradiated ginger.

4. Preliminary estimation of the cost effectiveness indicated that the net profit from ginger irradiation treatment was about RMB ¥ 20-30 yuans per 100 kg ginger. The irradiated ginger can be stored and transported more easily than non-irradiated ginger, and the shelf-life of the former was much longer than that of the latter. By using the irradiation preservation method, one can supply the domestic and foreign market with good quality ginger out of season. So, the economic benefit of irradiating ginger as a method of preservation is beyond doubt.

IAEA-SR-129/P-I-14

PRELIMINARY RESEARCH ON THE TECHNO-ECONOMIC FEASIBILITY OF IRRADIATION PRESERVATION OF MUSHROOMS *(Agaricus bisporus)*

Shaode LIU, Caixuan WU, Aiyuan LIN
South China Agricultural University,
Guangzhou, China

Comparitive experiments and analysis of techno-economic effects of three kinds of preservative methods for fresh mushrooms, i.e. irradiation, salt solution-soaking, and refrigeration, were done in the past two years. The results indicated that irradiated mushrooms were superior in improving storability and shelf-life, reducing weight reduction and transportation cost to that of refrigerated or salt solution-soaked mushrooms. The weight reduction in salt solution-soaked mushrooms was 40%, if the salt solution-soaking method were used in treating all the mushrooms produced in Guangdong Province, the loss in weight reduction would cost US$ 2,200,000 per year. however, the weight reduction for irradiated mushrooms was only 10%. Also, the flavour of canned or fresh mushrooms treated with irradiation was much better than that of mushrooms soaked in salt solution, and the analysis of nutritive compositions showed no significant difference between these two kinds of treatments.

The long-term experiments on animal-feeding and volunteer-eating of irradiated mushrooms have been done and no deleterious effects have been found. The effective dose used in this study is 0.6-1.0 kGy, which is only one tenth of the international known safe dose. The hygienic standard of irradiated mushrooms has been approved by the Ministry of National Public Health. So, it's edibility is undoubted.

This study demonstrated that the irradiating mushroom method for preservation would be feasible technologically and economically, if first class fresh mushrooms were selected for treatment, the dosage used was kept uniform, and the underground radiation resources were used for their low building cost. After extended test for semi-commercial scale production, factories can be set up for commercial scale production.

IAEA-SR-129/P-II-1

FEEDING TRIAL OF DIET MAINLY COMPOSED OF IRRADIATED FOODS IN HUMAN VOLUNTEERS

Chi HAN*, Shiping GUO**, Maogi WANG**,
Zegin LIU*, Wenming CUI*, Yin DAI**

* Institute of Health,
China National Center for
Preventive Medicine,
Beijing

** Institute of Food Safety Control
and Inspection,
Ministry of Public Health,
Beijing

China

A double-blind feeding trial of diet mainly composed of irradiated foods in human volunteers was carried out in 1984 in order to obtain further evidence on the acceptability and wholesomeness of irradiated foods. Forty-three (21 males and 22 females) adult healthy institute staffs of 21-47 years old were randomly assigned to a control and an experiment group, matched by sex and age.

The experiment group which consisted of 22 subjects consuming diet mainly composed of irradiated rice, wheat (Co-60 irradiated up to 0.4 kGy, stored at 0°C for three months), 14 different varieties of vegetables (Co-60 irradiated up to 0.3 kGy, stored at room temperature for two weeks) including tomatoes, potatoes, garlic sprouts, cucumber, cauliflower, cabbage, carrot, peking cabbage, rape, chinese chive, hyacinth bean, celery, sweetbell redpeppers, lettuce, meat products (Co-60 irradiated up to 8 kGy, stored at room temperature for two weeks) including pork sausage and pork floss, mustard tuber preserved with chili (Co-60 irradiated up to 1 kGy, stored at room temperature for two weeks) and peanut (Co-60 irradiated up to 0.1 kGy, stored at room temperature for one week). The irradiated foods should afford 62-71% of the total calorie of their diet The control group which consisted of 21 subjects, consumed the same varieties and amounts of non-irradiated foods. The feeding trial lasted for 15 weeks including an acclimation period for two weeks. The parameters examined were acceptability, appetite and physical conditions; anthropometric measurements; routine hematology tests, serum albumin and A.G ratio; serum GPT (glutamic pyruvic transaminase), GOT (glutamic oxalacetic transaminase) γ-GT (γ-glutamyl transpeptidase) and alkaline phosphates, urea nitrogen, urinary 17-hydroxy cortisol, serum cholesterol and triglyceride, chromosome aberration of peripheral lymphocytes as well as ECG (electric cardiography) and ultrasonic examination of liver, spleen and gall bladder.

Subjects in both groups had normal appetite and no intestinal disorders were found. There was no significant difference between the control and the treated group in the above measurements and examinations.

The results showed that there was no adverse effect from the consumption of diet mainly composed of irradiated foods.

SUITABILITY OF CHEMILUMINESCENCE AS A SINGLE TOOL TO IDENTIFY RADIATION PROCESSED SPICES

H. DELINCÉE, D.A.E. EHLERMANN
Federal Research Centre for Nutrition,
Karlsruhe, Federal Republic of Germany

Radiation processing of foods has been cleared in many countries for a broad range of applications. The elimination of microorganisms from spices is one such application which became very important after the ban of ethylene oxide used formerly. most clearances demand labelling of at least the first generation of the produce, i.e. as long as it is not used as a minor ingredient of other products. Some countries - among these the Federal Republic of Germany - have not yet adopted radiation processing of spices; if they do so an injunction on labelling can be expected. To control trade and import of irradiated spices and to enforce labelling according to the food law some reliable and sufficiently fast methods for the identification of radiation processed spices are indispensable.

There is no lack of efforts to develop a method for the identification of irradiated foodstuffs, but no general solution has yet been found. In some cases reliable methods have been found, but they are not fast enough to be used under practical circumstances. Most of the reported methods work only under certain preconditions and they may be circumvented by some fraudulent additional treatment of the product. However, the application of a broad set of identifiation methods and the combined evaluation of all the multivariate measurements could be a solution. It would require serious effort in the execution of all the necessary analytical dpterminations and would, therefore, not be suited for practical applications such as on the spot identification.

Consequently, there is still a need to determine the suitability of the proposed methods which may serve as a single means for the identification of irradiated spices. Chemiluminescence of radiation processed spices /1/ is a promising tool. Preliminary studies have shown that this method seems to be applicable only to a limited variety of spices. Whereas, after irradiation, curcuma, celery and juniper berries exhibited increased chemiluminescence using luminol as enhancing agent, this was not the case for paprika or chilli powder.

Many spices and condiments contain salt which also contributes to chemiluminescence. The salt content must therefore be observed carefully. Spices from various produced show different behaviour.

Numerous intefering factors, such as lipid oxidation, heating or humidity changes influence the decision as to whether spices have been irradiated or not.

Further elaboration and standardization of the chemiluminescence methods seems necessary before applying it as a single tool for the identification of irradiation processed spices.

References

/1/ W. Bögl and L. Heide, Nachweis der Gewürzbestrahlung. Identifizierung bestrahlter Gewürze durch Messung der Chemilumineszenz, Fleischwirtschaft 64 (1984), 1120–1126.

/2/ D.A.E. Ehlermann, H. Delincee, W. Kalus and Th. Grünewald. The suitability of chemiluminescence in irradiated spices to identify their being radiation processed, Int. Symposium on Food Irradiation Processing, Washington, D.C., USA, 4-8 March 1985, to be published.

ALANINE/ESR SYSTEM USED FOR DOSIMETRY IN FOOD IRRADIATION

Juncheng GAO, Zaiyong WANG
National Institute of Metrology,
Beijing

Peigen SHENG, Zhimin SHEN, Huali WANG
Shanghai Institute of Biochemistry,
Academia Sinica,
Shanghai

China

The alanine/ESR dosimetric method is a new method developed in recent years for high-level radiation dosimetry. It is very suitable for the range of dosimetry commonly used in food irradiation (0 1-10 kGy). We selected this system as the transfer dosimeter for measuring high-level doses in China

After irradiation of alanine, Radical CH_3-CH-COOH arises and its total number contained in a sample, in the range commonly used for food irradiation (0.1-10 kGy), is proportional to the irradiation dose. Moreover, the radical is considerably stable. We use powdered L-alanine and press it into a cylindrical specimen with a diameter of 4.5 mm, a height of 10±0 2 mm and a density of about 1.27g/cm^3. It is placed in a specifically designed black plastic casket for irradiation. The irradiated alanine specimen is calibrated with Fricke dosimeter which has been used as the absorbed dose standard. The calibration is carried out in a water phantom and Fricke dosimeter has an uncertainty of ±2%. Specimens are weighed on a precise balance and the measured values are normalized with mass number for eliminating the effects of mass dispersion of specimens. The irradiated specimen is placed into a quartz tube 9with an inner diameter of 5 mm and an outer diameter of 6.3 mm) which shows no ESR signal itself. The middle main peak amplitude h of the ESR spectrum is measured on JES-FE-1X ESR spectrometer and its change is monitored with a standard sample which is made of anthracite and containing a known spin number. For each measurement, the depth of insertion of the quartz tube into the cavity is strictly controlled and all parameters of the ESR spectrometer are kept as constant as possible.

The lower limit of detecting the abosorbed dose of ^{60}Co γ rays with the present system is found to be 5Gy and the short-term stability is about ±0.2%. in a range of 0.05-17kGy, for alanine specimens irradiated with ten different doses, the correlation coefficient between the main peak amplitude h of the ESR spectrum and the dose D is calculated to be 0.9997.

AN ANIMAL STUDY OF IRRADIATED FOOD

Wenyu YIAN, Xun XU
Department of Nutrition and Food Hygiene,
Shanghai Medical University

Weiqiao JIN, Jiakuan YAN
Industrial Health Institute of Shanghai,
Shanghai Medical University

Zichen XU, Renzhong LIU
Shanghai Institute of Nuclear Research,
Academia Sinica

Shanghai, China

Consumption of multiple irradiated food in animals was studied to simulate what human takes.

216 Wister rats were divided into three groups with 36 male and 36 females in each group. Group A fed with 80% irradiated food, Group B fed with 3% irradiated food and Group C fed with non-irradiated food as control. Absorbed dosage of r-ray was 0.1-8.0 kGy. besides irradiation dose, components of foods were the same in all the three groups. Study lasted for 150 days.

Nutrient composition, availability of protein, growth of animals and hematological, mutagenic and pathological examination were performed.

Nutrient assay meet with the original plan, with protein-calorie 18-20% of total. The apparent digestibility of protein was 84.5-89.8%.

Feed efficiency showed no difference among three groups.

Ratio of viscera weight to body weight was close in each group.

There were no significant differences in hematological and biochemical indices.

No significant difference in blood lymphocytes T- and B cell count.

Serum microelements were in normal range.

Micronuclei of bone marrow polychromatic erythrocyte showed no significant difference.

Inflammation were found in the heart, liver, kidney, testes, spleen, ovaries and adrenal of some animals with no significant difference in each group.

The ultramicrostructure of liver, kidney, testes and ovary proved that individual animals might be different, but as a whole the difference was not significant.

The result proved that irradiated food is safe.

IAEA-SR-129/P-II-6

WHOLESOMENESS EVALUATION OF GAMMA RAY IRRADIATED RICE — TOXICOLOGICAL STUDIES AND HUMAN TRIAL

Ruishu WANG, Zihua WU, Lingfu ZENG,
Yanhua HOU, Shusheng PENG,
Zhaiquan LI
Department of Nutrition and Food Hygiene,
West China University of Medical Science,
Chengdu, Sichuan, China

0.37 and 0.92 kGy dosage gamma ray irradiated rice after preserving for 6 months have been used for multigeneration long-term feeding, teratology and micronucleus studies in rats, and dominant lethal assay in mice, and Ames test with five strains of salmonella typhimurium respectively. No deaths were found in any group. No significant differences were seen in the body weight gain, food intake, food efficiency, reproductive performance in the parent, first and second generations. No teratogenic effects were observed. No abnormal changes were noted on the other parameters such as biochemical parameters of serum and liver, organ/body weight ratio.

There were no significant differences in frequency of micronucleus appearing in the bone marrow erythrocytes but the positive group showed significant increase. Ames test $Rt/Rc < 2$. Dominant lethal index < 15 in the experiment groups.

Sixty healthy adults (34 males and 26 females) aged 18-48 years were paried according to body weight and sex respectively and then randomly assigned the two paried members in every pair into two groups, i.e. gamma ray irradiated rice group and unirradiated rice group.

The tested rice is pesticide free and has been irradiated by the radiation source of ^{60}Co up to the dosage of 0.37 KGy and stored immediately for 2 months before starting consumption. The trial proceeded for 13 weeks.

There was no significant difference being found between the control and the tested subjects in all the parameters examined and no organoleptic abnormality was found. This fact implies that consumption of the irradiated rice could not bring about any adverse effects to the human organism.

IAEA-SR-129/P-II-7

IRRADIATION OF SWEET POTATO WINE WITH ^{60}Co GAMMA RAYS IN ORDER TO IMPROVE QUALITY

Qilin YANG, Yuwen WANG, Yuqiong LIU,
Wei LIAO, Runqing ZHANG
Institute of Applied Nuclear Technology,
Chengdu, Sichuan, China

There are various types of wine in our country. The wine which is made from its raw material of sweet potatoes by way of the method of liquid state fermentation is one of them. This wine is in large quantities and in wide distribution. The question is that its quality is unsatisfactory. In general, sweet potato wine has its own raw material taste: unpleasant to the throat and har to the head. It leaves an uncommfortable bitter and astringent taste long after drinking, therefore it has the defects of its qualities. However, when it is irradiated with ^{60}Co gamma rays of the highest absorbed dose 2–4 kGy, its taste turns to be rich mellow, delicious, less bitter and astringent, so its quality is improved. Analyses of physical chemistry routine: GC. UV and ESR. etc. has been established that the total acids, esters and aldehydes increase on the basis of the unirradiated wine. But ketones decrease. No longer-lived radicals are measured out. No new ingredients are found either. The animal safety experiments show that irradiated and unirradiated have no evident difference, and no unhealthy effect. Irradiated can possibly reduce the toxicity.

EFFECT OF ^{60}Co GAMMA RADIATION ON THE INCIDENCE OF JONATHAN SPOT

Yunqin XIAO, Ying WANG, Shiyong TANG
Liaoning Institute of Pomology,
Xiongyue, Liaoning

Defu LI
Physics Institute,
Liaoning Agricultural Academy,
Liaoning

China

In trials from 1978 to 1984 Jonathan apple fruit were irradiated at doses of 25,75,100 and 150 Krad followed by storing in cooled house with natural ventilation. The strength of the cobalt 60 source was 3200 Ci. Dose rate was about 45 rad/min with 4 to 7 replications for per treatment. During the six-year test period about 5 tons fruit had been treated. Six-year trial showed that the irradiation significantly reduced the incidence of Jonathan spot. The incidence of the fruit irradiated was 5%, control was 55%, Appropriate radiation dosage was 50-75 Krad. Irradiation did not affect fruit taste quality and chemical components.

ESR STUDIES OF IRRADIATED APPLES AND MUSHROOMS

Nianyun LIN
Shanghai Institute of Nuclear Research,
Academia Sinica,
Shanghai, China

The Features of ESR Spectra and the life Times of the free radicals from irradiated apple and mushroom have been recorded on a varian E-112 ESR Spectrometer. The ESR patterns from irradiated fresh and frozen dried apple are quite different. Both the ESR spectra from the fresh apple irradiated at 77K upto $3x10^6$ and $1x10^7$ rads reveal predominately the composite spectra of primary active species formed from radiolysis of water in apple, while the ESR spectrum from frozen dried apple reveal an unsymmetrical single peak. After annealing at room temperature the former decaied rapidly and almost disappeared after two days, but the single peak from the latter one was much longer, at least over ten days, alived. The feature of ESR spectrum from fresh mushroom irradiatue at 77K upto $1x10^7$ rads and its life time are quite similar to that from fresh apple, i.e. the composite pattern from primary active species formed from radiolysis of water in mushroom overlapped the ESR signal from the major component of mushroom, and also decaied rapidly after annealing at room temperature.

IAEA-SR-129/P-II-10

STUDY OF FRESH PRESERVATION OF HAMI MELON BY IONIZING IRRADIATION

Jizhen SHENG, Mai SI, Uijie WEN, Delin DU
Xinjiang Institute of Physics,
Academy of Sciences

Nisha NUER, Chiam WEN, Zhe GUO,
Lin TONG
Xinjiang Institute of Biology,
Academy of Sciences

Xinjiang, China

After the irradiation of Hami melons by γ-ray and electron beam, the activity of oxidase, contents of vitamin C, soluble solid substances, ethanol and ethylene of the melons were measured in the period of preservation. The results of preservation at different conditions were compared.

It was found that: After the irradiation of Hami melon by γ-ray the respiratory intensity and ethylene were inhibited, vitamin C was somewhat decreased, while the hydrogen peroxide enzyme was activated. It was also shown there was a tendency of increase in PH value of melon juice and in the content of sugar. Meanwhile the percentage of putrefaction decreased significantly after γ-ray and electron beam irradiation.

This experiment showed the possiblity of controlling physiological activities of Hami melon after plucking. It may also be valuable for preservation of fruits and other melons.

IAEA-SR-129/P-II-11

STUDY OF THE FEASIBILITY OF USING IRRADIATION IN THE STORAGE OF MUTTON

Fuyuan ZHANG
Institute for the Application
of Atomic Energy,
Academy of Agricultural Sciences,
Xinjiang, China

Five hundred grams meat without bone was sampled from Xinjiang fine-wool sheep. The temperature in the irradiation room was between 16 ℃ and 26 ℃. The irradiation dose was 9.5-13.5KGy. The result of storing mutton in the temperature of 21-33 ℃ was not satisfied. Besides, we compared the effect of some other storage methods on mutton in the room temperature, the methods including pretreating with nitrogen, carbon dioxide, different proportions of salt, sodium bicarbonate, sorbic acid, STPP(sodium tripolyphosphate) and lithium carbonate and irradiating with doses of 8-18KGy. It is thought that salt was a kind of additives with the best comprehensive effects. With the addition of 1.5% salt and irradiation of 10KGy, treated mutton can be stored for 25-30 days under the condition of 29±2 ℃, and the total plate counts of bacteria(TPC) were 53.6/g, the volatile basic nitrogen(TVB-N) 16.23mg/100g, the acid value of fat 1.82mg/g and ooze from treated mutton 12.4ml. The room temperature was 25 ℃ for 3 hours and 20 ℃ for the rest time per day. The mutton added with 1.5% salt and irradiated by doses 8KGy can be stored for 25-30 days with TPC 7.4/g, TVB-N 13.91mg/100g and ooze from the sample 11ml. With irradiation of 5-7KGy, the mutton can be stored for 90 days at 3±2 ℃, with TPC 4.4-5.6/g, TVB-N 11.95-12.26mg/g, the acid value of fat 2.37mg/g and ooze from the sample 27.5ml. Coliform group and enterpathogenic bacteria were not found in the mutton irradiated with the test doses, so the above said irradiated mutton met the National Sanitary Standard for fresh mutton(GB 2723-81). The TVB-N of the treated mutton with more then 5KGy was much higher than those of untreated mutton, and the values show very significant positive linear correlation with doses.

In the scientific survey through the Taklamagan Desert in Xinjiang last year, members of the investigation group had eaten the irradiated mutton.

EFFECTS OF GAMMA RADIATION ON SHELF-LIFE AND CHEMICAL COMPOSITION OF YOUNG WINGED BEAN FRUIT

K.H. CHOW, N. SUBHA
Department of Botany,
National University of Singapore,
Singapore

The winged bean (Psophocarpus tetragonolobus (L.) DC) has received wide attention since 1974, and has been considered as the most promising protein food crop in the tropics and subtropics. Its young fruit is the most popular part for human consumption, commonly eaten uncooked as salad or cooked in the same manner as French beans. Due to its juiciness and tenderness, the young fruit is very prone to spoilage, especially under storage conditions in the humid tropics. 13 to 15-day-old fruit irradiated with 100 Krad of gamma rays could be maintained good condition under room temperature (25-28°C) in sealed plastic bags for a period of 22 days compared with only 10 days for control. A nitrogen atmosphere during irradiation showed advantage in maintaining fruit quality and texture. After 25 days of storage, the irradiated fruit stored in sealed plastic bags started to spoil. This indicated that gamma radiation at this dose could delay the onset of spoilage and double the shelf life, but could not induce redappertization.

Gamma ray doses above 200 Krad damaged the texture of young winged bean fruit to an unacceptable degree, although they were very effective in controlling spoilage microorganisms. It was found that textural changes resulted from radiation-induced breakage of the macromolecules of pectin, cellulose, semicellulose, and perhaps starch. This seems to be the most limiting factor in attempts to use irradiation as a means of extending the shelf life of the young winged bean fruit.

In protein content, the irradiated young fruit showed a significant reduction even at 50 Krad, as compared to control. Such protein reduction was due to radiation-induced protein denaturation. Sugar content in young winged bean fruit was low and irradiation did not show any significant effect. Changes in esterase and peroxidase patterns were observed among the irradiated fruit. The effects of these two enzymes on fruit quality and shelf life are still under investigation. The irradiated fresh fruit showed a significant reduction in respiration which certainly contributed to the shelf-life extension.

INITIAL STUDY OF THE MECHANISM OF FRESH PRESERVATION OF BAMBOO SHOOTS BY RADIATION

Chonguan GU
Horticultural Research Institute,
Shanghai Academy of Agricultural Sciences

Wenti CHEN, Pingying MAO
Shanghai Vegetable Company

Zhicheng XU
Shanghai Institute of Nuclear Research,
Academia Sinica

Shanghai, China

Using a certain dosage of ^{60}Co- γ rays to treat bamboo shoots, it keeps the bamboo shoots fresh longer than those unirradiated.

Under room temperature, the storage period can be prolonged to 80-90 days.

Bamboo shoots unirradiated became softened, withered and crusted after 40 days of storage, while those irradiated with excessive dosage became brown colour.

Our experiments started in 1985. Dosages of 10 Krad, 30 Krad, 50 Krad, 100 Krad were chosen.

The outcome of the experiment shows:

1. With 100 K rad treatment top breath intensity of bamboo shoots appeared on 20th. After the climax, breath intensity of 10 Krad and 50 Krad treatments droped faster and then lower. The climax rate of 10 K rad treatment is also lower than that of the 50 Krad treatment.

2. The brown colour of bamboo shoots appeared due to the action of phenolic oxidized ferment. Different dosage of radiation has different effects on the vitality of ferment. The dosage of 10 Krad depresses the vitality of phenolic oxidized ferment of bamboo shoots.

In 150 Krad and 100 Krad treatment the phenolic oxidized ferment was stimulated and vitality increases greatly which produces a strong brown colour.

The ferment vitality of the 30 Krad and 50 Krad treatment was also enhanced slightly.

3. Both experiment and day-to-day observation showed that 10 Krad dosage on radiation produced the best effect.

IAEA-SR-129/P-II-14

COMMERCIALIZATION AND ACCEPTANCE OF FOOD IRRADIATION IN JAPAN

H. WATANABE
Takasaki Radiation Chemistry
Research Establishment,
Japan Atomic Energy Research Institute,
Takasaki, Japan

Initial basic studies on food irradiation in Japan had been carried out during mid the 1950's to mid the 1960's at several institutes and universities. Based on the studies, Japan Atomic Energy Commission established an expert committee in 1965 to promote the research and development of food irradiation. Then two years later, a national project on food irradiation research was started with governmental support. In the program, the following seven items were investigaged; potato and onion for sprout inhibition, rice and wheat for disinfestation, sausage and fish-paste product for shelf-life extension, and orange for killing moulds on the peel. As a result of the project, the irradiation of potatoes was approved in August 1972, and next year commercial plant for potato-irradiation was constructed at Shihoro in Hokkaido. This plant is well-known as a first successful food irradiation plant in the world with an actual result and experience more than twelve years. Just after the approval, the irradiated potatoes were received favourably by food processing industry for the stable supply through all seasons. In addition, the market price fluctuation of potatoes was successfully controlled. On the other hand, a consumer union started the movement against the irradiated foods around 1976. The boycott movement of some consumer unions for the irradiated potatoes had seriously affected food processors.

However, the movement is recently decaying although it still continues. The history of food irradiation and future prospect on acceptance of food irradiation in Japan will be discussed.

IAEA-SR-129/P-II-15

STUDIES OF STRAWBERRY IRRADIATION AND THE PHYSIOLOGICAL MECHANISMS INVOLVED

Zhicheng XU, Deyao ZHAO
Shanghai Institute of Nuclear Research,
Academia Sinica

Xinshi TIAO, Hongbin QUI
Shanghai Institute of Plant Physiology,
Academia Sinica

Chonguan GU
Horticultural Research Institute,
Shanghai Academy of Agricultural Sciences

Baoli XU
Shanghai Station of Public Health
and Epidemic Prevention

Shanghai, China

It is a well-known fact that strawberries are subjected to physiological, biochemical and microbial deca. In general, deterioration of straberries is caused by the contaminations of microorganisms. In order to prevent microbial decay irradiation preservation with special package at 2 c has been developed. Storage period of irradiaton strawberries has been reached to 45 days. Tne physiological mechanisms by irradiation. Change in nutrition and determination of microorgainsm at the several storage period after irradiation have been studied.

The physiological mechanisms of irradiated strawberries have demonstrated that the activities of pectinase, respiration of strawberries and released are inhibited by irradiation.

The irradiation reduces clearly the number of pathogenic organisms and moulds, in the strawberries irrelevant from decay losses.

The results of nutritional analysis has demonstrated that the several nutrients losses are insignificant, also including vitamin C. The irradiation preservation is of great advantage to preservation of several amino acids of strawberries. The flavour taste of consumers have established that organoleptic quality of irradiated strawberries have favoured.

LIST OF PARTICIPANTS

Lescano, Graciela	ARGENTINA	Comisón Nacional de Energía Atómica Libertador 8250 1429 Buenos Aires Telex No. 18079 CAE AR
De Caen, G.C.	AUSTRALIA	Australian Department of Health P.O.Box 100 Woden Act 2606 Telex No. AA 61249
Izard, M.E.		Isotope Division Australian Atomic Energy Commission Private Mail Bag Sutherland NSW 2232 Telex No. AA24562
Mitchell, G.E.		Food Research Branch Division od Dairying & Fisheries Department of Primary Industries 19 Hercules Street Hamilton, 4007, Brisbane Telex No. DPIQLD AA 41620
West, G.C.		Ansell International P.O.Box 347 Dandenong 3175 Victoria Telex No.AA 34132
Wills, P. Ms.		Isotope Division Australian Atomic Energy Commission Private Mail Bag Sutherland NSW 2232
Ahmed, M.	BANGLADESH	Institute of Food and Radiation Biology Atomic Energy Research Establishment Dhaka
Hossain, M.M.		Bangladesh Atomic Energy Commission G.P.O.Box 158 Dhaka Cable: BANGLATOM DHAKA
Matin, M.A.		Institute of Food and Radiation Biology Atomic Energy Research Establishment G.P.O.Box No. 3787 Dhaka Cable: BANGLATOM DHAKA

Beers, E.	CANADA	Atomic Energy of Canada Ltd. Radiochemical Company 413, March Road P.O.Box 13500 Kanata, Ontario K2K 1X8 Telex No. 0534162
Kerr, S. Ms.		Scientific Affairs Grocery Products Manufacturers of Canada 1185 Eglinton Avenue East Suite 101 Don Mills, Ontario M3C 3C6
Cao, X.X.	CHINA	Shanghai Municipality Science and Technology Commission No. 30 Fuzhou Road Shanghai
Chen, Q.		Institute of Applied Nuclear Technology Sichuan Province 124 Sha He Bao Chengdu Sichuan
Chu, K.F.		Shanghai Import and Export Commodity Inspection Bureau 13, Zhongshan Road (E.1) Shanghai
Dai, Y.		Institute of Food Safety Control and Inspection Ministry of Public Health 29 Nan-Wwi Road Beijing
Gao, J.C.		National Institute of Metrology 7 District 11 Ho ping-Li Beijing
Gu, C.G.		Horticultural Research Institute Shanghai Academy of Agricultural Sciences Shanghai
Gu, J.		Beijing Institute of Nuclear Engineering No. 1 Mashenmias, Fuwai Beijing
Han, C.		Institute of Health China National Centre for Preventive Medicine 29 Nan Wei Road Beijing

Hu, J.F.	Department of Nutrition and Food Hygiene Beijing Medical Unversity Beijing
Jin, W.Q	Shanghai Institute of Radiomedicine Shanghai Medical Unversity 2094 Xietu Road Shanghai
Lai, S.C.	Crops Institute in Tianjin Academy of Agricultural Science Tianjin
Lin, N.Y.	Institute of Nuclear Research P.O.Box 8204 Shanghai
Liu, R.	Institute of Nuclear Research Academia Sinica P.O.Box 8204 Shanghai
Liu, S.D.	Biophysics Laboratory South China Agricultural University Guangzhou
Liu, Z.	The Isotope Institute of Henan Province Zhengzhou, Henan Province
Sheng, J.Z.	Xinjiang Institute of Physics Academy of Sciences Xinjiang
Tang, C.Y.	Kunming Institute of Zoology Academia Sinica Shanghai
Wang, C.Z.	Beijing Institute of Nuclear Engineering P.O Box 840 Beijing
Wang, R.S.	West China University of Medical Science Chengdu Sichuan Province
Wu, C.	Biophysics Laboratory South China Agricultural University Guangzhon
Wu, W.Z.L.	Institute of Nuclear Research Academia Sinica P.O.Box 8204 Shanghai

Xiao, Y.Q.		Liaoning Institute of Pomology Xiongyue, Gai County Liaoning
Xing, F.L.		Beijing Institute of Nuclear Engineering P.O Box 840 Beijing
Xu, Z.Y.		Institute of Atomic Energy P.O.Box 275 Beijing
Xu, Z.C.		Shanghai Institute of Nuclear Research P.O.Box 8204 Shanghai
Yang, Q.		Institute of Nuclear Applied Technology 124 Sha He Bao Chengdu, Sichuan Province
Yang, Wenxia		National Institute of Metrology 7 District 11, Ho Ping-Li Beijing
Yian, W.Y.		Shanghai Medical University Yi Xue Yian Road No. 138 Shanghai
Yuan, Y.R.Y.		Department of Technical Physics Peking University Beijing
Zhang, F.Y.		Institute for Application of Atomic Energy Academy of Agricultural Science Xinjiang
Zhang, M.Q.		Institute of Atomic Energy P.O.Box 275 Beijing
Zhang, S.J.		The South China Agricultural University Guangzhou
Zhu, J.X.		Shanghai Institute of Nuclear Research P.O.Box 8204 Academia Sinica Shanghai
Henon, Y.M.A.	FRANCE	CEN de Cadarache Département de Biologie B.P. No. 1 F-13115 Saint Paul lez Durance

Sadat, T.-T.		CGR MEV 551 rue de la Miniere F-78530 Buc
Dyroff, H.	GERMANY FED REP OF	NUKEM GmbH Rodenbacher Chaussee 6 D-6450 Hanau 11
Ehlermann, D.A.E.		Federal Research Centre for Nutrition Engesserstrasse 20 D-7500 Karlsruhe 1 Telex No. 7826484
Glubrecht, H.		Institut f. Biophysik Herrenhäuserstrasse 2 D-3000 Hannover 21
Goebel, J.N.G.		NUKEM GmbH Rodenbacher Chaussee 6 D-6450 Hanau 11
Nadkarni, G.B.	INDIA	Bhabha Atomic Research Centre Food Technology & Enzyme Engineering Division Bombay 400 085 Telex NO. 011-71017 BARC IN
Maha, M. Ms.	INDONESIA	Centre of Application of Isotopes and Radiation National Atomic Energy Agency J. Cinere Pasar Jumat Kotak Pos 2 Kebayoran Lama Jakarta Selatan
Baraldi, D.	ITALY	ENEA C.R.E. Casaccia Via Anguillarese 301 I-00100 Roma A.D. Telex No. 613296 ENEACA I
Fiorentini, R.		Istituto Industrie Agrarie dell'Universitá degli Studi Via S. Michele, 4 I-56100 Pisa
Hayashi, T.	JAPAN	National Food Research Institute 2-1-2 Kannondai, Yatabe-machi Tsukuba-Gun Ibaraki-ken 305
Watanabe, H.		Japan Atomic Energy Research Institute Takasaki Radiation Chemistry Research Establishment Watanuku-machi 1233,Takasaki Gunma 370-12

Cho, Han-Ok	KOREA REP OF	Food Irradiation Division Korea Advanced Energy Research Institute P.O.Box 7 Cheong Ryang Seoul Telex NO. KAERI K23241
Min, Byong Yong		Food Research Intitute Agriculture & Fishery Development Corp. Ministry of Agriculture & Fisheries 148-1 Dangsu-ri, Banwol-myon Hwasung-gun Kyongki-do, 170-31 Telex No. AAFDC K2397
Arshad, F.M.	MALAYSIA	Centre for Agricultural Policy Research University of Agriculture Serdang, Selangor
Lebai Juri, M.B.		Nuclear Energy Unit Prime Minister's Department Puspati Complex Bangi, Kajang,Selangor Telex No. ATOMAL MA 31619
Nordin, R.M.		Nuclear Energy Unit Prime Minister's Department Puspati Complex Bangi, Kajang,Selangor Telex No. ATOMAL MA 31619
Leemhorst, J.G.	NETHERLANDS	GAMMASTER Postbus 51 NL-6710 BB Ede
Roberts, P.B.	NEW ZEALAND	Institute of Nuclear Sciences D.S.I.R. Private Bag, Lower Hutt Telex No. Physics NZ3814
Khan, I.	PAKISTAN	Nuclear Institute for Food & Agriculture Tarnab, Peshawar Cable: NIFA, Peshawar
Singson, C. Ms.		Philippine Atomic Energy Commission Department of Nuclear Services Diliman, Quezon City

Chow, K.H.	SINGAPORE	National University of Singapore Department of Botany Lower Kent Ridge Road Singapore 0511 Telex No. UNISPO RS 33943
Ameresekere, R.V.W.E.	SRI LANKA	Food & Nutrition Policy Planning Division Ministry of Plan Implementation Ceylinco House Colombo 1
Munasiri, M.A.		Atomic Energy Authority H.P.T. Building Colombo 08
Nouchpramool, K.	THAILAND	Office of Atomic Energy for Peace Vibhavadi Rangsit Road Bangkhen Bangkok 10900 Telex No. 87161 ATENPEA TH
Pothisiri, P.		Food Control Division Food & Drug Administration Ministry of Public Health Samsen Road Bangkok 10200
Rattagool, Pongpen Ms.		Fish Technology Development Department Yannawa, New Road Bangkok
Brynjolfsson, A.	USA	7, Bridle Path Wayland, MA 01778
Chin, A.		Radiation Sterilizers Incorporated 3000 Sand Hill Rd. 2-190 Menlo Park, CA 94025
Moy, J.H.		University of Hawaii Food Science & Human Nutrition Department University of Hawai 1920 Edmondson Road Honolulu, HI 96822 Telex No.SPRAD 743-0725 HR
Schlicht, R.		G.A. Technology P.O.Box 85608 San Diego, CA 92138
Sivinski, J.S.		CH2M Hill Inc. 6121 Indian School Road, N.E. Suite 206 Albuquerque, N.M. 87110 Telex No. 4742047 CH2M PTL

Valencia, V.I.		ITT Electron Technology Division ITT Corporation 3100 Charlotte Avenue P.O.Box 100 Easton, Pennsylvania 18044-0100
Dinh Ngoc Lan	VIETNAM	National Institute for Atomic Enregy of Vietnam 67 Nguyen Du Hanoi Cable: VINATOM-HANOI

INTERNATIONAL ORGANIZATIONS

Bögl, W.	WHO	Federal Health Office Institute of Radiation Hygiene Ingolstädter Landstrasse 1 D-8042 Neuherberg
Nam, J.W.	IAEA	Division of Life Sciences Dosimetry Section Wagramerstrasse 5 P.O.Box 200 A-1400 Vienna Telex No. 112645 ATOM A

SEMINAR SECRETARIAT

M. Zifferero	Representative of Sponsoring Organizations, Deputy Director General, Head, Department of Research & Isotopes, IAEA, VIC, Wagramerstr. 5, A-1400 Vienna, Austria
P. Loaharanu	Scientific Secretary, Head, Food Preservation Section, Joint FAO/IAEA Division of Isotope and Radiation Applications of Atomic Energy for Food and Agricultural Development, IAEA, VIC, Wagramerstr. 5, A-1400 Vienna, Austria
S.B. Hammond	Administrative Officer, Head, Fellowship and Training Section, Division of Technical Assistance & Co-operation, IAEA, VIC, Wagramerstr. 5, A-1400 Vienna, Austria
L. Wedekind	Public Information Officer, Division of Public Information, IAEA, VIC, Wagramerstr. 5, A-1400 Vienna, Austria