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SHEDA SCIENCE & TECHNOLOGY COMPLEX
ABUJA

PROCEEDINGS

SYMPOSIUM ON IRRADIATION FOR NATIONAL DEVELOPMENT

SHEDA SCIENCE & TECHNOLOGY COMPLEX
OCTOBER 16th - 17th 1996

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1996

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PROCEEDINGS OF THE SYMPOSIUM ON IRRADIATION TECHNOLOGY FOR NATIONAL DEVELOPMENT

EDITORS

PROF. G. H. OGBADU
DR. C. A. ADESANMI

OCTOBER 16 - 17, 1996.

SHEDA SCIENCE AND TECHNOLOGY COMPLEX (SHESTCO)
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FOREWORD

Sheda Science and Technology Complex (SHESTCO) was established by the Federal Government of Nigeria as a national Centre of excellence to provide a conducive environment for high level research in hi-technology on a multidisciplinary basis. The Complex consists of a Nuclear Technology Centre (NTC), Information Technology Centre (ITC) and the Advanced Laboratories. When the Complex takes off it will attract national and international researchers from the universities, research institutes, organisations and industries to carry out their research work using the facilities to be provided at the Complex on short term residence. The management will identify areas of industrial potentials and orientate its research and development programme towards achieving these goals

One of the programmes of the NTC is Irradiation Technology and to promote it, a symposium on Irradiation Technology for National Development was held at Sheda Science and Technology Complex (SHESTCO), Abuja, Nigeria, between 16th - 17th October, 1996. The symposium attracted about 75 participants and papers were presented by experts on different aspects of the uses of irradiation technology in agriculture, health and industry.

The proceedings contain all the invited papers and abstracts of the technical papers presented at the symposium. The invited papers were delivered under four categories: Regulation, Code of Practice and Facility; Irradiation Technology in Agriculture; Industrial Applications and Health; Radiation Protection and Dosimetry.

All the technical sessions were well attended and several areas of application of irradiation technology were covered. They include preservation of foodstuffs and agricultural products, mutation in plants for high yielding and disease resistant varieties, sterile insect technique, sterilization of medical devices, pharmaceutical and cosmetic products and packages, improvement of properties of plastics through radiation-induced cross-linking and vulcanization of natural rubber latex.

The management of SHESTCO is grateful to our sponsors, particularly International Atomic Energy Agency (IAEA), Vienna, Austria and SIEMENS, Germany, for their support.

Prof. E. U. Emovon, FAS

OPENING REMARKS

BY

THE CHAIRMAN, LOCAL ORGANISING COMMITTEE
PROF. G. H. OGBADU

On behalf of the Sheda Science and Technology Complex and the Local Organising Committee (LOC), it is my singular honour and privilege to welcome you to the symposium on Irradiation Technology for National Development taking place at our permanent site.

The Complex is acquiring a ^{60}CO gamma irradiation plant with a source strength of 300kCi(1.11×10^{16}Bq) for semi-commercial operation. When people hear of atomic energy they often have nuclear reactors in mind or nuclear accidents such as that of Chernobyl. Few, however, realise that another aspect of atomic energy has changed their daily lives during the last 30 years.

A few examples will help to drive home the pervasive role radiation plays in our lives. Those of us who drive automobiles to work are almost certain to encounter irradiated components. The paint on the dashboard is often cured by electron beams. Most of the foamed plastics used to insulate us from noise, shock and extreme temperatures are irradiated plastics. Components of the ignition system consist of radiation cross-linked insulations. There is a fair chance that the tyres contain irradiated components. Batteries for digital watches, calculators and the likes almost certainly contain separator materials made by a radiation grafting method. Oil and gas travel through pipelines protected from corrosion by irradiated products. Just about every telephone message conveyed goes over wires covered with insulation cross-linked by electron beams.

If one was indisposed as to require treatment in the hospital, there is a reasonable probability that sterilized disposable materials, such as, syringes, blood transfusion kits, catheters, etc were part of that melancholy experience. Many miscellaneous irradiated products such as plastic rivets, adhesive tapes, gems, coated plastics, coatings for fry pans, lubricants and so on are encountered in daily life

In a hungry world, it is too great a luxury to lose 25 to 35 percent of the harvested foods to spoilage, microbes and pests. What is even more regrettable is that these losses are largest in developing countries like Nigeria. To supply the world's demand for food, it is more reasonable to conserve what is produced than to produce more to compensate for subsequent losses. Food must be effectively conserved, distributed and consumed if hunger is to be prevented and health maintained.

More than 35 years have passed since radiation was found to be applicable to extend the shelf-life of certain foods. Since then, millions of dollars have been spent to test the wholesomeness of radiation-processed foods. In the period of testing such foods, no harmful effects to animals or humans have been found. The results obtained have become so convincing that the attitude of the relevant authorities in developed world has changed and some irradiated foods are being released unconditionally for general consumption. Unfortunately, Nigeria has not fully recognised the potentials for such a process.

In the next two days, we shall be deliberating on some of these issues with the hope that with each effort made through this symposium, that we are one step closer to convincing the authorities on seeing the full import of utilising irradiation technology. Finally, I wish you a successful time and thank you.

WELCOME ADDRESS

BY

THE HONOURABLE MINISTER OF FEDERAL CAPITAL TERRITORY
LT. GEN. J.T. USENI fss, mni

The Honourable Ministers
Yours Excellency
Distinguished Guests
Ladies and Gentlemen

It is a great pleasure to welcome you to the opening ceremony of the symposium on Irradiation Technology for National Development taking place here in Sheda.

The symposium arose from the training programme on Irradiation Technology by some staff of Sheda Science & Technology Complex (SHESTCO). I understand the training was highly successful and facilities for the gamma irradiation are now being put in place. The Irradiation Unit, I understand, is for research and semi-commercial purposes in the fields of agriculture, health, industries and the environment. It is a programme that cuts across the entire socio-economic aspects of life in Nigeria, I have no doubt that the significance of SHESTCO to national development will soon begin to be realised. It gives me a sense of pride and purpose particularly when viewed that this is only an aspect of the SHESTCO mandate. May I seize this opportunity to congratulate the entire staff of SHESTCO for their dedication to duty.

Ladies and Gentlemen, I, on behalf of the Federal Capital Territory and indeed the Sheda Community, welcome you to this lively academic gathering. I equally congratulate you for participating to chart a course for the industrial development of this nation.

The Federal Capital Territory is ever ready to give SHESTCO and its sister establishments all the necessary support for their development.

I wish you a pleasant deliberation.

You are most welcome.

Thank you very much.

KEYNOTE ADDRESS

BY

THE COORDINATOR, SHEDA SCIENCE & TECHNOLOGY COMPLEX
PROF. E. U. EMOVON, FAS

Honourable Ministers,
Director-Generals and Directors,
Research Colleagues,
Distinguished Ladies and Gentlemen,

I welcome you all most heartily to this symposium on Irradiation Technology for National Development which is holding in Sheda Science and Technology Complex (SHESTCO). In particular, I welcome you to the Complex and I hope you will interact with the staff of the Complex for greater insight into its mission. This is one of such occasions when policy makers, industrialists and researchers meet to exchange views on our common problems of development, with science and technology (S & T) playing a front-line role in providing solutions. I thank the Honourable Ministers of the Capital Territory, Science and Technology, Industry, Agriculture, Health and their representatives for gracing the occasion. I also acknowledge the presence of the Captains and representatives of industries, the Universities and the research personnel from the National Research system and from international organisations. I hope that the interaction we are to have at this symposium will rub on mutual understanding and greater awareness of the primary role of science and technology in national development process in line with the words of David Noble in his essay on 'America by Design' when he said:

> 'Those who are able to harness science itself and direct it to their own ends have gained considerable advantage. For them, the competitive task of anticipating the future has become easier since they now have the means of determining the future themselves'

As a brief reminder, the SHESTCO is designed as a national science and technology village to provide a conducive environment for high level research in hi-technology on a multidisciplinary basis. Its main components of nuclear technology centre (NTC), the national advanced laboratories centre (ADLC) and the information technology centre (ITC) are being put in place albeit slowly. It is to provide facilities at the highest level for national and international researchers to carry out their work on short term residence. Also the facilities will be used to service other areas of development in close association with the industries and the universities. In this connection, it will identify areas of industrial potential and orientate its research and development (R & D) programmes towards achieving those goals.

It is a truism that land, labour, raw materials and capital are the main factors of production and that we have most of them as our natural endowment. However, the dominance of world economy has been based more on the ways in which knowledge is created and exploited. While those other factors of production are finite, knowledge is inexhaustible and its right inputs into any economy guarantee high productivity and competitiveness. We can seek and acquire this knowledge through research and development particularly in high technology including information. To be in a position to generate and exploit knowledge in the sciences and technologies, as we go into the 21st century, we must have the necessary infrastructural facilities with conducive environment in place such as the Complex is designed to provide. This was why I was much elated when the Head of State in his Independence Day broadcast to the nation referred to the development of science and technology as a major commitment in the nation's development strategies. This signals a readiness on the part of government to fund science and technology adequately and by extension, I look forward to the government actualising it in respect of the funding for the Complex. At the same time and equally importantly, this statement also signifies a challenge to the science and technology community requiring them to invest their capability in R & D activities. I am sure that this challenge will be taken up by them with commitment and enthusiasm.

The topic of this symposium is **'Irradiation Technology for National Development'**. Radiation has awesome recollection because of its association with nuclear armament which carries a very negative image. When one recalls the events in Hiroshima and Nagasaki, in Three Mile Island, in Chernobyl, etc, any mention of radiation puts everybody's back up. But this needs not be the case for as Shakespeare succinctly puts it,

'....there is a soul of goodness in things evil, would men observingly distill it out'...

Science and Technology have indeed distilled much goodness out of nuclear technology and the associated radiations. Today, they are being applied to peaceful uses for the benefit of man-kind.

Radiations derive from the structure of the atom which constitutes the basic component of matter. It is composed of a nucleus which contains neutrons and protons and surrounded by electrons arranged in orbits similar to the solar system. The protons carry positive charges and the electrons, negative. Since the atom is neutral, the number of protons and hence the total positive charge is equal to the number of electrons, i.e. the negative charge. Inspite of the concentration of positive charges in the nucleus, it is stable. This stability is dependent on the ratio of protons to neutrons, suggesting an inter-play between the two sets of particles through mesons. For light elements, the requirement for stability is 1:1 ratio of proton to neutron and up to 1:1.5 ratio for heavy atoms. A deviation from this ratio leads to the spontaneous disintegration called radioactivity of the atom to release radiations which are themselves particles or electromagnetic waves, enormous energy and a residual stable atom with lower atomic mass and number. Examples of such unstable atoms are potassium ^{40}K, hydrogen (tritium)^{3}H, Uranium ^{235}U Caesium ^{137}Cs, etc. They decay at different rates which are measured in terms of half-life.

Atoms of the same element may exist with the same chemical properties and hence the same atomic number but with different mass numbers (atomic weights) due to differences in their number of neutrons. These are called isotopes. Examples are ^{40}K and ^{39}K; ^{3}H; ^{2}H and ^{1}H; ^{137}Cs and ^{136}Cs; ^{238}U and ^{235}U; ^{14}C and ^{13}C and ^{16}O and ^{18}O. Each element whether by itself or in a compound with other elements will comprise proportions of its isotopes with the most stable being preponderant. For example, water contains hydrogen, deuterium, as H_2O, D_2O etc.

The fear of excessive increase in radiation level in the environment by the installation of reactors and other controlled radioactivity plants has no basis because such sources barring accidents or 'nuclear events' contribute only a small proportion to natural radioactivity to which we are all exposed. The human body contains elements such as potassium, hydrogen, carbon, etc which exist in isotopic forms, some of which are radioactive. Also plants contain the same elements which behave the same way thus producing radiation continuously by their natural radioactivity.

The soil contains quantities of radioactive elements. For example, the soils in Bauchi-Borno-Plateau areas contain uranium, thorium, etc which are radioactive. The soil in Abakaliki area where zinc and lead are known to exist will contain some quantities of uranium, thorium, etc. since lead is known to be a component of the ultimate in the disintegration of uranium, thorium and their daughter series. Coal also contains some radioactive elements, adding to the background radiation level in the environment.

The above show that radiations including those from the sun are constantly impinging upon us from natural sources. It has been proved that the contribution of the installed radiation sources including nuclear plants and X-rays is 'no more than 2% while the remaining of the background level of radiation arises from 'unavoidable natural sources' including those within our bodies. The danger usually arises from the dust particles of those radioisotopes or radionuclides generated during nuclear event such as nuclear bomb testing. 'Nuclear events' are now rare because of improved design of nuclear plants and various attempts to ban nuclear tests.

The taming of atomic reactions has become of immense benefit. The disintegration of the atom produces enormous energy which is harnessed to produce electricity and other forms of energy; the associated radiations are applied through the process of irradiation in agriculture, health, industry and so on. Progress in these areas of application relate to national development. The common radiations produced during nuclear disintegration are alpha (α), beta (β) and gamma (γ)rays. These are streams of high energy particles with tremendous penetrating power, the most penetrating of them being the gamma rays. Other rays not immediately derivable from radioactivity are x-rays and accelerated electron beam which are machine generated. All these rays are used in irradiation process. The materials to be irradiated are exposed to them to promote both chemical and biological reactions resulting in the desired effect of preservation and sterilisation.

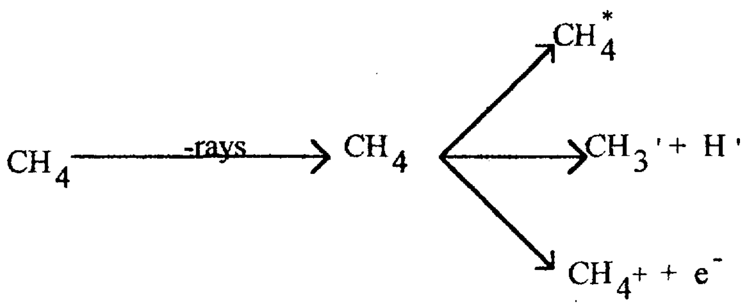
The mechanism of the chemical interaction of the rays with materials depends on their energy which enables them to cause changes in the atoms and molecules of the substrate. For example, the absorption of the high energy of the radiation results in the following primary reactions:

(i) excitation when the electron(s) of the atoms/molecules are promoted to higher energy level;
(ii) dissociation, in which the weakest bond(s) in the molecules are broken to produce free radicals; and
(iii) ionisation where electron(s) are knocked off the atoms/molecules to produce cations;

For example, methane interacts with radiations to produce

(i) excited methane molecule;
(ii) methyl and hydrogen radicals; and
(iii) methane cation and electron

as shown below:



All these primary products are unstable and undergo secondary reactions which effect sterilisation and preservation.

The main products of the reactions with organic molecules which constitute agricultural, health and industrial products are carbon dioxide, aldehydes, fatty acids, etc. most of which are not toxic and disappear from the reaction site with time.

The biological effect arise from the water content, nucleic acids, etc of the cell absorbing the high energy radiation to form free radicals which subsequently react with other vital molecules like the DNA of the cell leading to its death. This particularly affects microorganisms and other disease causing organisms.

Like I said earlier, the radiations that can be used in irradiation process are α-rays, X-rays, γ-rays and beams of electrons and neutrons. They have high energy and are ionising. However, not all of these are suitable for commercial irradiation because of their:

(i) poor penetrating qualities
(ii) tendency to excite radioactivity
(iii) high cost of production

α rays have high mass to charge ratio and so do not penetrate matter adequately for them to be effective as irradiation beam. Also high energy x-rays and electron beam promote radioactivity unless they are generated at lower energy levels below 5 and 10 million electron volts (MeV) respectively. The most suitable radiation is the gamma (γ) radiation which consists of light weight photons, carrying no charge and are highly penetrating. These are generated from Cobalt-60 (^{60}Co) which is obtained from reactors by bombarding Cobalt-59 (^{59}Co) with neutrons for 1 to $1^1/_2$ years and from Caesium-137 (^{137}Cs) which is obtained from the reprocessing of spent fuel rod of a reactor. This latter substance is now not much used in modern irradiation plant. Other factors which make the choice of ^{60}Co more suitable include:

(i) high dose rate;
(ii) low cost of production with high output rate;
(iii) environmental safety due to low ioinising properties.

The equipment designed for its use in irradiation process will be fully described and illustrated in the course of this symposium.

<u>Applications of Irradiation Technology</u>

These include:

Agriculture:

Efforts in agriculture are geared towards assuring food security so as to alleviate hunger and to provide basic materials for industrial development. In this connection, the government provides packages of modern farming methods most of which are generated from our agricultural research institutes and also makes agricultural inputs like fertilisers, chemicals for pest control, improved seedlings, cultivars, agricultural loans and so on available to the farmers. The effect of these inputs can be seen in our markets where foodstuffs are plentiful at their various seasons. Unfortunately, they become very scarce and doubly expensive out of season and so become almost unaffordable to the greater mass of Nigerians. For example, yams, tomatoes, onions, beans, fruits, vegetables, etc are stacked in the markets and by the roadside at seasons but disappear rapidly out of season due mainly to massive spoilage which result from infestation by microorganisms, insects, bacteria, etc. This gives the impression that the country cannot feed itself. It has been said that up to 40% of agricultural products are lost annually to these spoilage agents particularly in the tropical countries where high humidity and high ambient temperatures provide conducive environment for them to thrive. This situation distorts the effort of government to boost agricultural production and so a most effective method of controlling the spoilage must be put in place.

Most countries of the developing world do not have adequate storage facilities and they lack effective preservation techniques. The traditional methods of drying (heating), freezing, salting, smoking, spraying with chemicals (pesticides and insecticides) etc are unable to reverse the trend in the deterioration of these products. In some instances, spraying with chemicals produce health risks like what was reported recently in the case of beans in some of the newspapers. However, the National Stored Products Research Institute (NSPRI) provides additional methods to reduce the losses. Irradiation method has become a very effective alternative for reversing these losses of foods. It has been described as 'the greatest invention in the food industry since Nicholas Appert developed food canning'. The World Health Organisation (WHO) view it as 'having an important role to play in ensuring food safety and reducing food losses'.

Irradiation inhibits sprouting of tubers like yams, potatoes, onions, etc thus making them more viable cultivars; delays maturation/ripening of fruits and vegetables so that they can be available to the consumer for much of the year and controls insect infestation of stored products such as grains and cereals, flour, cocoa beans, beans, palm kernels, etc.

The availability of higher yielding and more disease-resistant varieties of cultivars is crucial to increasing agricultural productivity. This can be achieved by hybridisation method but it usually takes a very long period. Irradiation which induces mutation provides an alternative method. It works by bringing about changes in the genetic materials of the cells of the original plant so that when these cells develop, new characteristics emerge. The selection and breeding from the mutant lines produce higher value characteristics such as better yield, increased disease resistance, etc. Indonesia used this method to solve her problem of rice stem-borer insect by developing special characteristic in the rice seed which made the rice stem unpalatable to the insects. It has also been used to produce cassava mutant with low cyanide conter.

Insects compete with man for food and fibre. They are also a threat to human and animal health. These insects can be controlled by applying chemicals (pesticides and insecticides) but this is usually a short lived success as these insects subsequently develop resistance to them. Science needs to be a step ahead. In addition, these chemicals often constitute environmental hazards and sometimes traces of them persist in food to cause health problems. Irradiation has become a suitable and effective alternative. The Sterile Insect Technique (SIT) is a non-polluting method of insect control. In this approach, sexually sterilised insects are produced in large rearing plants using gamma (γ) radiation and then released into the native population. The mating of these sterilised insects with females produce no new offspring and eventually leads to a reduction in the population of the insect. This method has been used in Nigeria under the Biological Insect Control (BICOT) Programme for reducing infestation by tse-tse flies which are inimical to animal husbandry and human development. It has also been used successfully against screw-worm in Mexico and the USA, pink bollworm in Central California, USA and melon fly in Japan.

Irradiation offers a good prospect for international trade in agricultural products. A wide variety and large quantities of fruits and vegetables are produced in tropical countries like Nigeria but only a few of these are traded in international markets. This is because of their infestation by insects and bacteria which cause much spoilage in addition to the stringent plant protection and quarantine regulations which prohibit entry of such fruits and vegetables from countries that are endemic with quarantine pests such as fruit flies of the Tephritidae family 1Y into other countries.

Irradiation is a valuable tool for the effective treatment of these fruits and vegetables to satisfy these requirements. A low dose of gamma (γ) -radiation effectively provides quarantine security against such fly infestation without damaging the fruits and vegetables. This process has become particularly useful because most fumigants like ethylene dibromide are now being banned for environmental safety reasons, thus strengthening the case for irradiation.

Medical Application

The health of the citizen is an important factor in the productivity of a nation. Poor health due to many causes reduces the man-hour input in national productivity. Hence the government invests much resources in various health-care programmes to reduce the disability of the citizen in production. Irradiation is one of such investment in the medical field, particularly in diagnostic work as well as radiotherapy. Thus X-rays have been used for imagery in various types of illnesses such as in orthopedics. Gamma (γ) irradiation is also a common recourse in cancer treatment. Relatively recently, irradiation techniques has become very important in inactivating food spoilage organisms including bacteria, moulds, yeasts, etc which are health hazards. For example, spices and other vegetable seasonings are now irradiated commercially to control food-borne pathogens particularly salmonellosis in many countries. Irradiation also enhances the shelf-life of processed foods thus assuring human health

However, questions have been asked about the radiological and toxicological consequences of irradiated foods. There is also the possibility that the radiation may destroy the essentials of foods such as vitamins and effect a change in the taste. These uncertainties led to the sponsorship of many researches in various countries by the International Project in the Field of Food Irradiation (IFIP), a joint expert committee of the World Health Organisation (WHO) and the Food and Agricultural Organisation (FAO) and by the Joint Expert Committee on Food Irradiation (JECFI) established by the FAO, the WHO and the International Atomic Energy Agency (IAEA). The codex Alimentarious also carried out studies to determine the threshold energy of γ -radiation required for a variety of foods. The conclusions from these studies show that:

(i) the maximum energy of γ -radiation (1.33MeV) used in irradiation process is much below the threshold energy capable of inducing radioactivity in elemental content of foods;

(ii) irradiated food commodity by up to an overall average dose of 10 kGy presents no toxicological hazard and hence toxicological testing of foods so treated is no longer required;

(iii) while the macronutrients such as proteins, carbohydrates and fats of foods are stable to radiation doses for up to 10 kGy, some vitamins are however labile and sensitive to them. But this sensitivity has also been shown not to be different from the effects of such processes as boiling, heating, etc;

(iv) tastes are not changed. I have eaten beacon, salad, meat and potatoes irradiated with gamma (γ) radiation during my visit to the laboratories of the South African Atomic Energy Corporation (AEC) and found no change in their taste.

In addition to the above, irradiation technique has been used for the sterilisation of medical appliances in preference to the conventional sterilisation methods involving steam or chemical treatment. Local capability in gamma irradiation for sterile medical supplies to health-care system is being encouraged in many developing countries of the Middle East, Latin America, Asia and Africa. It is already common place in the developed world. Gamma (γ) radiation from cobalt - 60 source is of common use for the sterilisation of medical appliances such as surgical dressings, sutures, syringes, surgical gloves, needles, catheters, biological tissues to be used in grafts and so on. It has helped to effectively eliminate the risks of infecting patients in clinical interventions.

Also, radiation treatment has been applied to decontaminate primary and auxiliary materials in pharmaceutical and cosmetics industries. For example, it has been used to sterilise some parental antibiotic preparations which have oil base such as testesone propionate tetracycline ophthalmic oil suspensions and physostiginine salicyclate which would be adversely affected by heat.

Industrial Application

Irradiation processing has become widely applicable in the industry. Like was said earlier, the mechanism of the process is through the generation of free radicals and ions. These intermediates cause further reactions that are capable of enhancing the quality of products thus making them more competitive. Relative to other methods of production, irradiation process has the following advantages:

(i) high energy efficiency;

(ii) ease of control through the injection of scavengers

(iii) applicability to a wide variety of material.

It has played increasing roles in the cross-linking process of polymers in the manufacture of such everyday materials as wire and cable insulators, automobile tyres, plastic films and sheets, heat-shrinkable films for packaging, crash padding, float-jackets etc. Non-destructive testing of welds, casting machinery and ceramics for safety also use irradiation technology. Irradiation treatment has been applied in the disinfestation of timber in the lumber industry as well as in the preservation of antiques, archives and books.

Environmental Protection

Irradiation technology also plays a role in the sanitisation of our environment. It is found to be useful for converting the microbes infested waste into valuable agricultural inputs. The radiations eliminate pathogenic organism from the sludge without changing the moisture, nutrient and heavy metal contents to make it a valuable fertiliser. Electron-beam derived from machines has been found to be effective in the disinfectation of drinking water and waste-water.

Ladies and Gentlemen, it is obvious from the above that the downstream activities of nuclear science can be harnessed for our own benefit. The world is moving in this direction to exploit this science to the fullest. Nigeria must not be at the side line in this development but must try to keep in step in the dance floor of modern technology.

The Complex is acquiring the facility for gamma (γ) irradiation to enable us utilise the potential of irradiation technology to assure food security, promote good health, make our industrial production more competitive and help to sanitise our environment. A Committee is being contemplated to formulate regulations for the application of irradiation technology to foods, etc to be presented to government for consideration and enactment.

Thank you for your audience.

SPECIAL GUEST OF HONOUR'S REMARK

BY

THE HONOURABLE MINISTER OF SCIENCE & TECHNOLOGY
MAJOR GENERAL SAM MOMAH FNSE, mni

Lt. General (Dr) Jerry T. Useni,
Member of the PRC and
Honourable Minister, F.C.T.
Honourable Ministers,
Distinguished Guests,
Ladies and Gentlemen,

I wish to welcome you to the opening ceremony of the symposium on Irradiation Technology for National Development taking place here in the Sheda Science and Technology Complex (SHESTCO) this morning.

A parastatal of my Ministry, SHESTCO, was formally established by Decree No 43 of 1991, with the objective of engaging in advanced research and development activities in all areas of science and technology for National Development with a major focus on high technology. The Complex, which began its existence in the Ministry in the eighties, was transferred to the Presidency in 1990. Its recent return to the Ministry is to ensure the coordination and proper implementation of its programmes. The SHESTCO management has been living up to the high expectations vested on it. This is certainly not surprising given the enviable track record of the Coordinator when he was the Minister of Science and Technology. My Ministry and indeed Nigeria feels justified in entrusting the Coordinator and his team with the SHESTCO project.

Irradiation Technology is new to the Nigerian society. It is a programme to ensure good health, safe environment and promote socio-economic development. It is a technology that will also promote the quality of life. Those entrusted with its development are men of vision and integrity who have managed lives and material resources successfully at different times and in various places. Their presence here testifies to the soundness of the project.

This symposium will look extensively and in depth into the pertinent issues and perspective of Irradiation Technology. The authorities in this field are assembled here to discuss and advise the government on all these.

As already explained, the Federal Ministry of Science and Technology conceived the idea of SHESTCO. Now that it is mandated with the authority to see to its implementation, you can rest assured that it will nurse its baby to adulthood. I wish to assure the experts on this important project of all the support that the Ministry can muster.

Distinguished Ladies and Gentlemen, I wish you all happy deliberations. Thank you.

VOTE OF THANKS

BY

DR. A. J. COKER
DIRECTOR, SHESTCO
ABUJA.

On behalf of the Management of the Sheda Science and Technology Complex, I thank those who have contributed in whatever capacity to the success of the symposium. These include staff members and members of the local organising committee who prepared the venue, put in place all the facilities required for a successful hosting of the event and made adequate arrangement to feed and accommodate participants. Special thanks go to our scientists who presented well researched papers from which we have all been enriched. The effective participation of the organised private sector who are the beneficiary of our research output is acknowledged. We thank them most sincerely and hope they will continue to nourish the symbiotic relationship.

I wish all participants safe trip back to their various destinations and more success in their researches. God Bless.

Dr. A. J. Coker
Director (Admin.)

TECHNICAL SESSION 1
IRRADIATION TECHNOLOGY FOR NATIONAL DEVELOPMENT

i. Regulations and Control of Food and Drugs in Nigeria
by Prof. G. Osuide - NAFDAC

ii. A Case for Food Irradiation Regulations & Code of Practice in Nigeria.
by Dr. B. W. Jimba - C. E. R. T, ABU, Zaria.

iii. Design of the Gamma Irradiation Facility of SHESTCO
by Engr. T. Friebe - Siemens AG, Erlangen-Germany.

iv. Information and Media Mobilization for Irradiation Technology for
National Development by S. A. Shaibu - FRCN, Abuja.

REGULATION AND CONTROL OF FOOD AND DRUGS

by

G. E. OSUIDE
Director-General, National Agency for
Food and Drugs Administration & Control, Lagos.

Abstract

Effective control of processed food and medicines is crucial for the maintenance of public health. Issues of wholesomeness, quality, efficacy and safety are of paramount concern to both consumers and regulatory agencies alike.

Laws and regulations are put in place to ensure minimum standards of practice by the various operators in the food and pharmaceutical sectors, such as will guarantee that the regulated products (food, drugs, cosmetics, medical devices, chemicals and packaged water) they deal in satisfy all the parameters of quality, wholesomeness, efficacy and safety.

National Agency for Food and Drug Administration and Control (NAFDAC) was established to enforce all relevant laws and regulations on food and drugs among other regulated products. NAFDAC has put in place appropriate administrative structures and procedures in its efforts to fulfill its mandate.

The agency is in the process of extending its regulatory and control activities to cover irradiated food and pharmaceutical products in order to safeguard public health.

Introduction

As you are no doubt aware, the topic of irradiation technology has assumed global importance and significance. This is in view of its acknowledged potentials, particularly in agriculture and medicine, among others. Irradiation technology has found useful application in other parts of the world, most notably in the developed countries, in preserving agricultural and food products thereby preventing post-harvest and storage losses. It has also been found useful in medicines in such areas as

(i) radiodiagnosis
(ii) cancer therapy
(iii) sterilisation of medical and pharmaceutical products, e.g. medical devices and appliances, and surgical dressings.

It is therefore highly commendable that SHESTCO, apart from sponsoring this symposium, has also acquired a commercial scale Gamma Irradiation Plant which will certainly stimulate the early application of the technology in Nigeria.

The main objectives of introducing irradiation technology in Nigeria has been highlighted as

(i) preserving food and agricultural products and consequently reducing losses and food scarcity at off seasons, thus ensuring food security and price stability,
(ii) providing a better alternative to chemical methods used in food industry;
(iii) introducing a cheaper alternative to existing methods in the sterilisation and decontamination of medical and pharmaceutical products and packages;
(iv) promoting the application of irradiation cross-linking in the plastic, rubber and particle board industries and
(v) encouraging private investments in the use of irradiation technology.

These are very laudable objectives which when realised will yield rich economic and social dividends to the nation.

I have been requested to speak on the topic "Regulation and Control of Food and Drugs" and in addressing the subject, I would like to highlight the following:

(i) the need for regulation and control;
(ii) the nature of control;
(iii) the strategies for effecting control including the role of NAFDAC;
(iv) NAFDAC and the challenges of irradiation technology.

THE NEED FOR CONTROL

The importance of food and drugs to man is very obvious. Man needs food in order to grow and sustain life While the Biblical injunction which says "man does not live by bread alone" is valid, it is equally valid that without bread, man cannot live at all. In other words, food is one of the most basic of all life's necessities. That is why governments all over the world take the provision of food for their respective population very seriously by adopting various strategies aimed at boosting agricultural and food production and ensuring food security. On the other hand, medicines are needed either to prevent illness through the use of vaccines for example or to restore health during ill-health.

In the case of food, the issues of control becomes relevant right from the point of primary agricultural production. Agricultural chemicals, herbicides and pesticides are often employed, particularly in Nigeria, to control pests and boost food production. Since these chemicals are potentially hazardous substances whose usage requires careful handling and control, it is mandatory to ensure that they do not contaminate the harvested food crops and the environment or leave harmful residues in the final processed food products.

When food is processed, additives such as preservatives, flavours and colours are sometimes incorporated for a variety of reasons such as

(a) prevention of spoilage
(b) maintenance of satisfactory organoleptic characteristics or
(c) sustaining consumer appeal.

The issues of wholesomeness and safety become crucial and evident when food is processed and made available to the public as there is need to guarantee that the final product being offered to the consumer.

(i) contains the appropriate nutrients declared by the manufacturer
(ii) contains only permitted additives, and at the permissible levels
(iii) is free from harmful residues, microorganisms, or vermins which could render the food unsafe or unfit for human consumption.
(iv) is produced in a hygienic environment and that the principles of Hazard Analysis Critical Control Points (HACCP) where applicable, have been followed to ensure that the final product not only contains the declared constituents but are free from contaminants.

In the case of medicines, the issue of control becomes equally crucial since to be acceptable, the medicine must not be deleterious to the body but should rather produce a positive effect which leads to restoration of normal life. For this desirable goal to be achieved, the process of manufacture of the medicinal product must satisfy the conditions which will ensure quality, safety and efficacy. It must not only contain the right amount of the desired active ingredients (and excipients), the process of manufacture must not introduce any adulterants or contaminants capable of rendering the product unsafe for the patient's use. In other words, for the product to be acceptable for the intended use, the manufacturer must have complied with the tenets of Good Manufacturing Practice (GMP).

The need to exercise effective control of food and medicines offered in commerce as highlighted above is therefore informed by the overriding need to promote and protect public health. This control, of course, extends beyond the manufacturing process to cover other activities such as importation, exportation, marketing, distribution and sale. The control is to ensure that the operators in the food and pharmaceutical sectors adhere to those practices that will guarantee that the products offered to the consumer or the patient are of good quality, wholesome, efficacious and safe and that they are used or consumed for the best advantage of good health of the individual and the community at large. This is obvious from the fact that a good medicine or nutritious food must be taken or administered rationally to promote health, otherwise it would be harmful to public health.

THE NATURE AND SCOPE OF CONTROL

As highlighted earlier, the control of food and drugs covers such areas as manufacture, importation, and exportation, marketing, distribution and sale. While acknowledging that importation still plays a very dominant role in the supply of consumer products, processed food inclusive, as well as drugs, it is worth noting that the local manufacture of food and drugs is acquiring a prominent significant place in the industrial sector of the nation's economy. Thus, two sectoral groups of Manufacturers Association of Nigeria (MAN), i.e. the Pharmaceutical Manufacturers Group of MAN (PMGMAN) and Association of Food, Beverages and Tobacco Employers (AFBTE) are among the most prominent industrial groups in Nigeria today. It becomes obvious therefore that the regulation and control of these sectors also receive significant attention.

Although the exportation of food and pharmaceutical products is only marginal compared to aggregate volumes of local production and imports, it is a sector that also deserves adequate attention in view of the possible impact on the nation's image. Government has the onerous responsibility to ensure that exported regulated products including food and medicines meet international standards of quality and safety.

Apart from importers, exporters and local manufacturers, other operators in the sectors whose activities deserve regulation and control include several distributors, marketers and several retail outlets including supermarkets. The chain of quality, wholesomeness, and safety must be maintained throughout until the product reaches the ultimate consumer.

STRATEGIES FOR EFFECTING CONTROL AND THE ROLE OF NAFDAC

The main strategies normally employed for ensuring effective control of processed food and medicines as well as other regulated products are regulatory strategy and institutional strategy. I will now elaborate on each of them.

REGULATORY STRATEGY

The maxim "where there is no law, there is no sin" becomes very relevant here. Laws and the regulations to facilitate their enforcement, are enacted to provide broad guidelines which ensure that the operators in the food and pharmaceutical sectors adopt such practices which will guarantee the wholesomeness, quality, safety and efficacy of the products offered to the public. Laws and regulations prescribe the requirements and conditions governing activities such as

(i) importation and exportation of regulated products,
(ii) manufacture
(iii) marketing
(iv) distribution and sale.

They also define sanctions and penalties for offences.

INSTITUTIONAL STRATEGY

Laws and regulations, no matter how perfectly crafted and beautifully drafted, will not in themselves ensure compliance. For effective control, laws and regulations must be obeyed by the different groups affected. While it is desirable that these statutes be voluntarily obeyed by those whose activities they regulate, it becomes necessary quite often to enforce them. Relevant institutional framework must be in place to ensure the desired compliance. This is where regulatory and control agencies such as NAFDAC become relevant. Similar bodies exist in other countries e.g., Food and Drug Administration in the United States of America, Canada and India and the Medicine Control Agency in the United Kingdom. These regulatory and control agencies are normally provided with adequate legal framework and appropriate administrative structure to enable them function effectively.

ROLE OF NAFDAC

NAFDAC was established through the instrument of Decree No. 15 of 1993 primarily to promote and protect public health. That decree sets out the functions and responsibilities of the agency with regard to the regulation and control of food, drugs, cosmetics, medical devices, packaged water and chemicals. It also prescribes the administrative structure including a governing council and six operational directorates. The directorates are

(i) Finance and Administration
(ii) Planning, Research and Statistics
(iii) Regulatory and Registration
(iv) Inspectorate
(v) Laboratory Services

The Laboratory Services Directorate provides the scientific and technical support for the effective operations of the regulatory and control directorates of Inspectorate, Regulatory and Registration (and Narcotics and Controlled Substances).

MODALITIES FOR ENFORCEMENT

Product Registration

The requirement that food and drug products be registered with NAFDAC before being offered for sale and use by the public is the most important regulatory provision. It sets the tone for other regulatory and enforcement activities.

The registration of a product is an official statement by the competent authority of a national government that a product has been evaluated with regard to its quality, safety and efficacy and has been found acceptable for its intended purpose. In the case of food product, the essential parameters are its wholesomeness, safety and suitability for the intended purpose. Product registration is directed towards protecting the public from health hazard. It entails a complex process in terms of procedures, infrastructures and other resources. NAFDAC therefore takes the matter of product registration very seriously.

As you are probably aware, the Federal Military Government, by Decree No.15 of 1993 vested the authority for product registration in NAFDAC. Furthermore, the compulsory registration of all food and drug products in the Nigerian market was also given a legal backing by the provisions of Food and Drug decree No. 35 of 1971, the Drugs and Related Products (Registration etc.) Decree No. 19 of 1993 and the Food Registration Regulations of 1996.

DRAFTING OF REGULATIONS

As earlier mentioned in this presentation, regulations are put in place to facilitate implementation and enforcement of the various laws. They provide more elaborate guidelines on specific issues in the main enactments, e.g. labelling, advertisement etc. The agency has passed some regulations to further strengthen the control of food and drugs and consequently enhance public health. The regulations include those on

- (i) Food Registration
- (ii) labelling
- (iii) packaged water
- (iv) use of non-nutritive sweeteners in food and their prohibition in drug products
- (v) Food (Table) Grade Salt Iodisation
- (vi) Pesticides registration.

CONSULTATIVE FORA

One other important strategy adopted by the agency in ensuring greater compliance by the various interest groups in the food and pharmaceutical sectors is that of holding regular consultative meetings with them. These consultative fora are designed to achieve among others

- (i) collating views and relevant inputs on draft regulations in order to enrich their contents and ensure greater compliance;
- (ii) dealing with specific problems relating to compliance with regulations as may arise from time to time.

Such interactions have engendered greater spirit of collaboration and understanding between various sectors and the agency.

ENFORCEMENT THROUGH FIELD OPERATIONS

Enforcement activities are carried out to strengthen the registration process. These activities cover

- (i) inspection of regulated products being imported into the country,
- (ii) inspection of establishments manufacturing food, drugs, cosmetics, packaged water, chemicals, medical devices, etc.
- (iii) routine monitoring of distributive outlets such as warehouses and supermarkets,
- (iv) monitoring and inspection of public and private health institutions and pharmaceutical establishments to ensure that narcotics and psychoactive substances are used strictly for scientific, medical and clinical purposes.

The agency has established offices at the various ports of entry and some border posts. It presently has offices in 22 states and Abuja. Activities of these states' offices are coordinated through four zonal offices in Ibadan, Enugu, Kaduna and Kano.

These monitoring and inspection activities are strongly complemented by the operations of the Consumer Affairs Unit which monitors feedbacks from consumers and also investigate consumers complaints.

COMBATING THE PROBLEM OF COUNTERFEIT AND SUBSTANDARD PRODUCTS

Realising that the peddling of fake, substandard and adulterated medicines pose serious dangers to public health and undermines government efforts aimed at effective control of these products, Government enacted the Counterfeit and Fake Drugs Decree No. 17 of 1989 as amended by Decree 99 of 1992. This action, which has been followed up by the establishment of the Federal Task Force on Fake and Counterfeit Medicines, operating within NAFDAC and its counterparts in the states, demonstrates government concern and its resolve to deal seriously with the problem.

There is no doubt that substantial progress is being made in the battle against this scourge. In order to sustain and increase the tempo of enforcement actions against the menace, fundamental issues that tend to encourage this dangerous phenomenon are being addressed. These include problems with existing legislations, logistic and infrastructural facilities and the need to reduce the bureaucratic difficulties in investigation and prosecution of suspects.

THE ROLE OF PUBLIC ENLIGHTENMENT

In due recognition of the fact that information dissemination, particularly to the public, is very important in ensuring the success of programmes designed to benefit the populace, the agency embarked on the first phase of public enlightenment campaign tagged "Information, Education and Communication (IEC)" programme during the last quarter of 1995. The programme carried out through the media of radio and television focused on public health issues relating to the regulation and control of food and medicines.

The IEC programme is premised on the acknowledged fact that the problem of law enforcement is made easier if the people the law is designed to protect fully appreciates the issues in contention. With adequate information, the populace themselves will voluntarily adopt measures that will positively strengthen the activities of government regulatory and control organs.

The second phase designed to be a follow-up of the first phase will soon take off with more emphasis on grassroot coverage.

NAFDAC AND THE CHALLENGES OF IRRADIATION TECHNOLOGY

NAFDAC's keen interest in the application of irradiation technology stems from the perceived advantages that would accrue to public health and well-being. I am sure these advantages have been well highlighted in the presentations of other experts at this symposium. I will therefore confine myself to the regulatory and quality assurance roles expected of the agency when this technology gains acceptance in food and pharmaceutical industries.

As the agency with the mandate to ensure the quality and safety of regulated products including food and medicines, NAFDAC has the responsibility to, among others,

(i) confirm the quality and safety of food and pharmaceutical products subjected to irradiation;
(ii) ascertain that safe doses of irradiation have been applied;
(iii) ensure compliance with appropriate labelling requirements;
(iv) ensure that all food and pharmaceutical products undergo the process of registration before being offered to the public.
(v) ensure that the equipment used for gamma irradiation do not pose any threat to the health of the operatives, the immediate environment and the public.

It is obvious therefore that NAFDAC has a very important collaborative role to play in the irradiation programme. Therefore, let me say without any equivocation that the agency is fully determined to play its own part actively to ensure that public health is adequately safeguarded. To this end, it has undertaken the initial training of some staff who will be further trained to enhance their knowledge and expertise. It also equipped a separate laboratory with some modest equipment which has enabled the agency to carry out radioactive screening of fish and dairy products. Furthermore, there are plans to upgrade facilities in that laboratory to enable it meet the challenge of the application of irradiation technology by the food and pharmaceutical industries. These outlined steps will strengthen the agency's capacity to discharge its statutory responsibility satisfactorily.

CONCLUSION

Efforts have been made in this paper to highlight the critical issues involved in the regulation and control of food and drugs. Mention has been made of the statutory requirement for product registration as one of the most important strategy for ensuring safety and quality of food and pharmaceutical products. The intended introduction of irradiation technology is a most welcome development which will receive the enthusiastic support of NAFDAC; the agency on its part is fully prepared to discharge its statutory responsibility to ensure that irradiated food and pharmaceutical products, as well as other regulated products are safe and fit for their intended use.

FOOD IRRADIATION REGULATIONS AND CODES OF PRACTICE

by

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Abstract

Official attitude towards irradiated food is determined by factors such as: level of scientific knowledge, consumer habits, food shortages, agricultural production and technological know-how. To date, 39 countries have accepted the process for one or more food items while 27 nations carry out the process on a commercial basis. Regulations and codes of practice is essential for consumer confidence while uniformity of regulations, at the international level, will enhance international trade in irradiated food items. The internationally accepted Codex Standard on irradiated food and Codes of Practice for the operation of irradiation facilities, adopted in 1983, forms the basis for International regulations and a template for nations in the development of regulations.

This paper discusses the basic legal requirements for licensing the process, procedures, facility and the operator and suggests a framework for a national regulation based on experiences of Hungary, Brazil and Israel.

Introduction

Three major concerns have beleaguered food irradiation process from inception; these are cost, public acceptance and government persuasion. The issue of cost is basically that of technological competitiveness with other acceptable processes, while the issues of public acceptance and government persuasion to accepting the risks are related to education and demonstration of the process. The level of acceptable risks are outlined in regulatory procedures which is to protect consumers against foods that is injurious to health, unfit for consumption and adulterted or presented in a deceptive manner.

A lot of effort has gone into increasing public acceptance of the process to the effect that food irradiation is increasingly being recognised as an effective method for reducing post-harvest food losses, ensuring hygienic quality of food and facilitating wider trade in certain food items. Food irradiation, covering fresh and dried products, have been endorsed by experts from FAO, WHO, IAEA and ITC-UNCTAD/GATT (IAEA 1989). Although 39 countries have accepted the process for one or more food items, some countries (as at 1989) such as, Australia and Iran still prohibit the process and forbid sale and importation of irradiated foods. Based on International Consensus on data on wholesomeness of irradiated foods, the FAO, WHO Codex Alimentarius Commission in 1983 accepted food irradiation as a safe and effective technology by adopting a Codex General Standard for Irradiated Foods and an associated Code of Practice. Hence, from all indications, food irradiation under Good Manufacturing Practices is not only considered safe and nutritionally adequate but result in public health benefits in terms of disease control.

The Codex standard provide an important incentive for national authorities to introduce regualtions in their countries. In 39 countries, more than 50 different kinds of food are now approved for radiation processing. Approvals are usually based on the principles of the Codex Standard Technical documents to compliment the Codex Standards are continuously being developed by the International Consultative Group on Food Irradiation (ICGFI) (IAEA 1989)

Basis for a Regulatory Framework

Regulation is only a part of the regulatory programme which comprise of four basic items; regulations, licensing or registration, compliance monitoring and enforcement (IAEA 1992b). The regulations define the principles governing the authorization to use ionizing radiation and criteria to be met during use. In the application to radiation processing of foods, regulations must cover both the radiation protection and the wholesomeness aspects. Regulations can be either performance or prescription oriented. Performance oriented regulation is more general and simply specific operational parameter and requirments. An example of such in the field of radiation protection would simply require user to conduct adequate work place monitoring, using appropriate equipment for the purpose of restricting exposure to radation to As Low As Reasonably Achievable (ALARA). Prescription oriented regulationis specific and states how things should be done. An example of this would be practice specific, defining exact procedure, record to be kept and equipment to be used, eg. for radiation protection, a statement of what exposures are acceptable is clearly made.

Performance oriented regulations have an advantage in that they are relatively simple to develop and can be made applicable to a range of practices and do not require frequent changes but need to be interpreted with evolving changes in the practice. Prescriptive regulations have to be practice specific. Although it provides clearly defined requirements, it is more difficult to prepare and need more frequent changes.

In practice, most regulations contain elements of performance and prescriptive regulations. The prescriptive regulation is most times woven into a code of practice which is targeted towards equipment or process. The code of practice could regulate radiation dose, dose rate, operating temperatures and atmospheric conditions, all of which affect the outcome with specific foods (Thayer, 1990).

Licensing grants authority to both the operators and the facility to adopt the practice involving food irradiation subject to the conditions specified in the license and applicable regulations. This is a legal instrument tha requires an operator to comply with regulations and may include a process of inspection and certification. Licences are usually valid only for a set time and revalidated after satisfying some conditions which may include updating or upgrading facility and personnel records. A facility may also require registration. This process is usually simpler than licensing and provides the source type in use and qualification of operators.

Compliance monitoring either provides assurance that requirements are met or the opportunity to enforce corrective actions. It can take the form of on-site inspections or regulatory mechanisms which may be notification of the authority of specified situations eg. overexposure.

A strong and effective enforcement programme is a key component of the regulatory infrastructure for assuring the success of regulatory objectives. Provision for sanctions might be incorporated in the regulations. Enforcement actions which might be taken up by one or more organs of government may be one or more of the following;

- i) On-site instructions by inspectors to correct problem.
- ii) Formal notifications to user specifying violation.
- iii) Orders requiring corrective actions.
- iv) Demand for replies regarding corrective actions
- v) Revocation of license.

Basic Requirements

The international requirements for the certification of irradiated food as outlined in the Codex Standard, is based on the Joint Expert Committee on Food Irradiation (JECFI) conclusion "that irradiation of any food commodity up to an overall average dose of 10 kGy causes no toxicological hazard, and hence toxicological testing of foods so treated is no longer required" (WHO, 1981). Embodied in this conclusion, are the requirement for wholesomeness and radiation protection which can be verified from information supplied on;

- i) Type of radiation (below 10 MeV) source applied,
- ii) Dose absorbed and method of dose measurement,
- iii) Safety, efficacy, staff and record keeping requirements needed for satisfactory operation and official inspection;
- iv) Packaging to nutiritional and hygienic quality,
- v) Maintenance of good manufacturing practices and the prevention of re-irradiation.

The use of irradition in food processing should be allowed only with prior approval from the competent body which issues the regulations. Regulations usually specify acceptable products and allowed radiation source and dose. Sources in use have been Cobalt-60, Caesium-137 and electrons below 10 MeV. The administered dose depends on food type and purpose for which radiation in applied. Table 1 specify some application of the radiation processing of food.

The basic requirements for radiation safety are encompassed in the radiation protection principles of justification, optimization and dose limitation. These principles govern all usage of radiation (IAEA, 1992b).

For the purpose of compliance monitoring and meeting other licensing obligations, appropriate record keeping on facility and process is required. Modification of the installation/mechanism to stop overexposure, faulty operation and other human errors are from time to time made. Compliance with such modifications is required by regulation. Packaging and labelling of irradiated food must also meet standards for safety and consumer acceptance.

Examples of National Regulations

The development of food irradiation regulations for three nations have been chosen for discussion i.e Brazil, Hungary and Israel. Despite the JECFI conclusion on all foods being acceptable for radiation processing, each nation accepts the process on a case by case bases after detailed tests. This discussion covers some history of the developmental process of the regulations. Brazil developed a new decree, Israel modified existing food laws while Hungary has given approval based on the draft Codex standards.

a. The Brazilian Regulations

By 1969 when research into food irradiation began in Brazil, the relevant government authorities had started to show interest and willingness in the regulatory aspects of the process. The Ministry of Health had set out ot define what an irradiated food is and to establish a competent authority to look into standards. By 1973, a specific legislation on food irradiation was already in place (Zonenschain, 1975). Thus, once specific stnadards for each product and instructions regarding equipment, irradiation operation, working conditions and technological processes have been elaborated, irradiated foods was on the way to being commercialized.

Foods of interest to Brazil include, potatoes, rice, wheat, onions, bananas, coffee, etc. For regulatory purposes, clearance for irradiated food could be based on experiments carried out within and outside Brazil, but approved by the competent authority.

The 15 Art Decree (No. 72,718 of 29 August, 1973) which is more of a performance oriented regulation, give general rulings regarding food irradiated (Appendix 1). The first section deals with scope; i.e the physical land coverage to which the decree applies (Brazil), the materials to which the decree applied (definition of irradiated food) and the acceptable items based on scientific results, the irradiation types and energy allowed, and the competent authority to oversee implementation of the decree. The competent authority is charged with issuing instructions governing registration of equipment, operating conditions and technological process to be used by the licensed establishments.

The second section deals with limitations. This section empowers the competent authority to establish acceptable dose levels and dose distribution patterns for the different processes. The third section deals with documentation and involves record keeping and labelling on the irradiation process and product.

The forth section deals with standardization and refers to other national standards and limits that are in force e.g. standards of quality, good manufacturing practices, additives and pesticides residues. The final section deals with legality and enforcement issues as regards liability and punishments and the date of the law been in force.

Two bodies are involved in the implementation of the regulations i.e Commission for Food Regualtions and Standards of Health Ministry and the National Nuclear Energy Commission, the role of each is spelt out. The code of practice for the implementation of their responsibilities is the duty of the bodies.

b. Israeli Regulations:

The clearance of irradiated food for public consumption, which is on an item by item basis, is a long process which starts with a petition to the competent body (Health Ministry). Before legislation was in place the Health Ministry relied on a special committee to provide information on which approval is based. Approval was based on data and regulations in operation in other countries, particularly USA, Canada and USSR.

From study of existing local regulations on foods and the general legal framework, it was determined that the easiest and quickest procedure for obtaining suitable legislation was to treat irradiation as an additive instead of being a process. For new processes, new legislation that will involve several years of legislative work is required. The approach adopted allowed the inclusion of irradiated food in regulations within Public Health Ordinances by an amendment.

The regulation (Appendix 2) was general enough to allow clearance of many foods, provided the relevant data on wholesomeness, technology and economy were supplied with the petition. The regulations comprise paragraphs entitled; foodstuffs permitted to be preserved by irradiation, import of radiated foodstuffs, and marking of irradiated foods (Eisenberg 1975, 1987). In granting clearance, the competent authority will approve in writing, the condition of the process, including control measures, the foodstuff, radiation type and energy, and maximum permissible dose. Potatoes were the first food cleared for the purpose of sprout prevention by use of Co-60 (July 1967). This was followed closely by onions by use of Co-60 (July 1968).

A code of practice expressed in form of legislative requirements, covers the irradiation and storage, and the marketing process. To market any irradiated foods the requirements are that, the food must be considered in the schedule and has been irradiated according to the schedule and is packed and clearly marked by an approved phrase. The requirements of the irradiation process can be summarised as;

a. The irradiation must be effected in an approved irradiation facility, which is capable of performing the type of irradiation required by the schedule without exceeding the maximum permissible dose.
b. There exist appropriate dosimetric techniques fo known reproducibility and error to check the administered dose.
c. Dosimetry results must be kept in special ledger.
d. Irradiation process parameters must be recorded by both automatic recorder and in logbooks.
e. Irradiation must be performed under the supervision of approved persons.
f. The process must be checked frequently by the competent authority.
g. Any product not found saleable must be destroyed.
h. All records must be kept for 7 years.

c. Hungarian Regulations

Permission to conduct irradiation of foodstuff is based on conviction of public acceptance, economic viability of the process and reliability of the technological process. Clearance is based on an item by item basis and on request after conclusive commercial trials. The Federal Ministry of Health, which has jurisdiction on food matters, readily approves after being convinced of the technological process and adequate data on wholesomeness (obtained within and from other nations).

Approval for sale of irradiated food is based on the draft International Codex Standard which cover the standardization of; type of radiation sources and radiation energy, dose administered and its distribution, safety and efficacy of the process and packaging.

In 1969, on the bases of promising research results, the Health Ministry approved the consumer trial on 5 tonnes of irradiated potatoes. By 1974, approval of the irradiation of some 10000 tonnes was granted. The approval for onions gradually increased also. At present, the continual decrease of harvests and the lack of interest from commercial bodies has slowed down both the regulatory and commercialization process of irradiated foods.

Suggestions for National Regulations

The path to establishing an appropriate national regulatory framework depends on the existing legal structure. A performance oriented regulation with some flexibility is recommended. This can be based on new decree or modification of existing food laws. A clearance must be obtained before irradiated foods can be marketed. Information required for such clearance will have such data as to enable the determination of both scientific and administrative competence (Appendix 3).

For effective standardization of irradiated foods, there is the need for guidelines which must include (IAEA, 81);

i. Establishment of basic regulations (performance oriented) to provide regulatory structure and establish a body with the necessary authority for implementation and eventual enforcement.
ii. Development of the competence to generate technical standards and the empowerment to adopt/endorse international recommendations.
iii. The instrument establishing such a body must empower it to embark on mandatory certification, at least of food products. Such certification should apply both to foods manufactured in the country and those imported into the country.
iv. the body must be empowered, where necessary, to prohibit the manufacture, sale and distribution of food items in the national interest.
v. firms or persons must have the right to appeal if they are not satisfied with any action which prohibits the manufacture and sale of goods by them. This will ensure fair play in the county's standaradization and certification activities.
vi. the body must also have power to prohibit the import into the country of foods that do not conform to standards. This way the danger of unwholesome irradiated and other foods being dumped in the nation may be minimized.

vii. membership of, or affiliation to, the ISO and the Codex Alimentarius Commission must be given serious consideration by the body as this will facilitate participation in the drafting of standards and the adoption and endorsement of such standards for national use. Irradiated food standards prepared by the Codex Alimentarius Commission or other such competent body may thus become the national standards.

viii. there must be provision for training all personnel engaged in standardization and related matters including the standardization of irradiated foods.

ix. since food standards are to be mandatory, there must be prescribed penalties for any contravention of the rule governing the certification of such products.

x. there must be a satisfactory working relationship between the national standards body and the Atomic Energy Commission.

Conclusion

Nigeria, at various times has imported foods to meet its food demand and have in recent years had reasons to destroy or give public warning against consumption of some imported foods. Hence the need for a regulatory program, comprising regulations, licensing or registration, compliance monitoring and enforcement. Although the use of radiation has been shown to be safe, local regulations will specify the peculiarities of our environment.

The advantages of food irradiation are many. In harnessing these benefits, for example to reduce post-harvest losses, the nation shall, by the GATT agreements, be required to open its markets to imported irradiated foods. Only a workable regulatory program can therefore be used to protect our interest, be it in international trade or in public health.

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Table 1: Application of Radiation Processing of Food

Target	Dose range (kGy)
ɪnhibition of sprouting (potatoes, onion, garlic, etc.)	0.01 - 0.15
Delay of ripening (fruits and vegetables)	0.01 - 1.0
Disinfestation (grains, cereal products, dried & fresh fruits, dried fish)	0.2 - 1.0
Control of food borne parasites (e.g tapeworm, liver fluke)	0.1 - 1.0
Control of pathogenic micro-organisms (e.g salmonella in poultry, meat, seafood)	2.0 - 8.0
Reduction of spoilage micro-organisms (meat, fish, fruits, vegetables, spices)	0.4 - 10.0
Commerical sterility in shelf-stable food	10.0 - 50.0
Improvement of technological properties (increased juice yield from fruits, reduced cooking time for dehydrated vegetable)	1.0 - 10.0

APPENDIX I

Decree No. 72.718, Dated 29 August, 1973,
In Which Are Drawn Up General Regulations Governing The Irradiation of Foodstuffs.

The President of the Republic, in exercise of the right conferred upon him by Article 81.III of the Constitution and in consideration of the provision of Article 59 of Decree-Law No. 986 of 21 October 1969, ordains that:

Art. 1. The preparation, storage, transportation, distribution, importation , exportation and display for sale or delivery for consumption of irradiated foodstuffs shall be regulated throughout (Brazillian) national territory by the provisions of the present Decree.

Art. 2. For the purposes of this Decree irradiated foodstuffs shall be taken to mean any food which has deliberately been exposed to the action of ionizing radiations with the aim of preserving it, or for some other legitimate purpose, in conformity with such standards as may be established by the competent body of Ministry of Health.

Art. 3. The ionizing radiations applied to foodstuffs shall, as a general rule, be those with energy lying below the threshold of nuclear reactions which could induce radioactivity in the irradiated material.

Art. 4. The irradiation of foodstuffs for purposes of display for sale or delivery for consumption, or for industrial use, shall be effected only by establishments duly licensed by the competent authorities, and after authorization by the National Nuclear Energy Commission.

Special clause: The National Nuclear Energy Commission shall issue instructions governing the registration of irradiation equipment, operating conditions and the technological processes to be used by the licensed establishments.

Art. 5. Authorization shall be given only for the irradiation of foodstuffs or groups of foodstuffs for which technical and scientific data obtained by national or international research establishments and duly approved by the National Nuclear Energy Commission are available, and from which there is confirmation of

(a) The harmlessness of the irradiated foodstuff for consumption;

(b) The extent of the effect of the irradiation on the principal nutrients in the foodstuff, as compared with those that occur through the processing of foodstuffs by conventional methods;

(c) The wholesomeness of the irradiated foodstuff and the effectiveness of the irradiation for the given objective.

Art. 6. It shall be incumbent on the National Commission for Food Regulations and standards of the Ministry of Health to draw up, on the basis of recommendations originating solely with the National Nuclear Energy Commission and of the scientific and technical data referred to in the previous Article, a Table of foodstuffs or groups of foodstuffs for which irradiation is authorized, indicating in each case the type and level of radiation energy that may be used, the nominal dose to be applied, the purpose of the irradiation, and any processing that must be carried out before, druing or after the irradiation to attain the desired objectives.

Art. 7. From each batch of irradiated foodstuffs samples shall be taken, in accordance with instruction issued by the technical competent body, to be placed at the disposal of the competent authorities for official analyses.

Special clause: The sample referred to in the present article shall be accompanied by a formal report signed by the person in charge of the food irradiation process, in which the following information shall be given:

a) The purpose of the irradiation,
b) The radiation source, energy and dose, and details of the ambient condition prevailing during the irradiation;
c) A description of any processing which the foodstuff may have undergone before, during and after the irradiation;
d) The type and nature of the packing material used for packaging the irradiated food; and
e) Conditions and duration of storage proposed for the irradiated food.

Art. 8. The irradiated foodstuff when displaced for sale or delivered for consumption, shall be marked on their packaging and on any labels attached at the place of sale or delivery for consumption: "Food processed by irradiation", and also bear the statement: "This product has been processed at an establishment approved by the National Nuclear Energy Commission".

Art. 9. The irradiated foodstuffs, when delivered for consumption, shall conform to the normal standards of identification and quality unless the National Commission of Food Regulations and Standards has approved a special standard of identification and quality for the irradiated foodstuff in question.

Art. 10. The use of additives in foodstuffs which are intended for irradiation or which have been irradiated shall be subject to prior authorization by the Commission referred to in the previous Article.

Art. 11. Any agriculture pesticide residues or other impurities present in foodstuffs intended for irradiation or already irradiated shall be within the limits fixed by the National Commission of Food Regulations and Standards of the Ministry of Health.

Art. 12. The provisions of this decree and other supplementary regulations shall apply, wherever appropriate, to imported irradiated foodstuffs.

Special Clause: Imported irradiated foodstuffs shall meet the requirements set forth in Article 6 and in the special clause of Article 7 of this Decree.

Art. 13. Irradiated foodstuffs intended for export may be prepared in conformity with the regulations in force in the country to which they are intended.

Art. 14. Failure to observe and comply with the provisions of this Decree and any supplementary regulations appended thereto constitute a breach of the public health regulation, making the violator liable to the penalties provided for under Decree Law No. 785 of 25 August, 1969.

Art. 15. The present Decree shall enter into force on the date of its publication, its disposition being annulled in case of the contrary.

Brasilia, 29 August 1973
The 152nd year of the independence
and the 85th of the Republic

Emilio G. Mestel
Mario Lemos
Antonio Dias Loite Jr.

APPENDIX 2

ISRAEL OFFICIAL GAZETTE COLLECTION OF REGULATIONS
2782 13 July, 1967.

PUBLIC HEALTH (RULES AS TO FOOD) ORDINANCE, 1935.

Regulations concerning the preservation of foodstuffs by irradiation

In exercise of the powers vested in me by section 3 of the Public Health (Rules as to food) Ordinance, 1935, I hereby make the following regulations:

1. Definitions

In these Regulations, "the Director" means the Director General of the Ministry of Health; "radiation" means gamma rays, x-rays, alpha particles, beta particles, high-speed electrons neutron and other nuclear particles, but does not include sound waves, radio waves and light waves, whether the light is visible or is infra-red or ultra-violet; "rad" means a unit of measurement of radiant energy, the absorption of which into one gramme of irradiated food releases 100 ergs of energy.

2. Foodstuffs permitted to be preserved by radiation

A person shall not, for the purpose of sale, irradiate any foodstuff with a view to preserving it, and shall not sell any foodstuff irradiated as aforesaid (such a foodstuff hereinafter referred to as "irradiated foodstuff"), unless it meets the following requirements;

1. It is a foodstuff specified in column 1 of the schedule.
2. It is, or has ben subjected to radiation of the class indicated opposite it in Column II of the schedule, up to the amount prescribed for it in column III of the schedule.
3. The Director has issued a written permit for it, containing directions as to the method of carrying out the irradiation.

3. Import of Irradiated Foodstuff

A person shall not, for the purpose of sale, import any irradiated foodstuff, and shall not sell any imported irradiated foodstuff, unless it meets the following requirements:

1. It is foodstuff specified in column I of the schedule;
2. The importer has produced to the customs authority a certificate from the competent authority of the exporting country, attesting, to the satisfaction of the Director.

a. that the class of radiation to which the foodstuff has been subjected is as stated in regulation (\2(2); and

b. that the method of radiation used conforms with the directions of the Director issued for that kind of foodstuff.

4. Marking of irradiated food

A person shall not sell any irradiated foodstuff unless the package thereof is marked with the label imprinted in clear and conspicuous letters with the words "Foodstuff Preserved by Radiation".

5. Citation

These Regulations shall be cited as the Public Health (Preservation of Foodstuffs by Radiation Regulations), 5927 - 1967.

SCHEDULE
(Regulation 2)

Column I Foodstuff up to	Column II Class of Radiation	Column III Amount of Radiation in Rads
Potatoes	Gamma Rays of Cobalt 6	15,000

Dr. R. Gjebin
Director-General
Ministry of Health

Israel Barzilai
Minister of Health

Approved
27th Sivan 5727
5th July, 1967.

EISENBERG and LAPIDOT

ISRAEL OFFICIAL GAZETTE - COLLECTION OF REGULATIONS
29 Tamuz 5728 2259 25 July, 1968

PUBLIC HEALTH (RULES AS TO FOOD) ORDINANCE, 1935
Regulations concerning the Preservation of foodstuffs by Radiation.

In exercise of the powers vested in me by Section 3 of the Public Health (Rules as to Food) Ordinance, 1935), I hereby make the following Regulations·

Correction 1. The Schedules of the Public Health of (Preservation of Foodstuffs by Radiation) Schedule Regulations, 5727 - 1967).

"Potatoes Gamma Rays of Cobalt-60 15000"
shall read:
"1. Onions Gamma Rays of Cobalt-60 10000
2. Potatoes Gamma Ravs of Cobalt-60 15000"

Approved
18 Tamuz 5728
(14 July 1968)

Dr. D. Brachot
Acting Director-General
Ministry of Health

ISREAL BARZILAI
Minister of Health

1. P. G. of 1935, Suppl. I No. 496, p. 56 (English Edition)
2. C. R. 5727-1967, p. 2792 (Hebrew Edition)

ISRAEL OFFICIAL GAZETTE - COLLECTION OF REGULATIONS
19 Tamuz 5733 3036 19 July 1973

PUBLIC HEALTH (RULES AS TO FOOD) ORDINANCE, 1935

Regulations concerning the Preservation of foodstuffs by Radiation

In exercise of the powers vested in me by section 3 of the Public Health (Rules as to food) Ordinance, 1935, I hereby make the following Regulations:

Correction 1. The Schedule of the Public Health of (Preservation of Foodstuffs by Schedule Radiations, 5727-19672), shall be ammended by adding after item 2:

Column I Foodstuff	Column II Class of Radiation	Column III Amount of Radiation in Rads up to
"3. Mixed Feed for Animals (Poultry)	Gamma Rays from Cobalt-60	1,500,000

2. These Regulations shall be cited as the Public Health (Preservations of Foodstuffs by Radiation) Regulation (Amended) 5733-1973.

Approved
29 Sivan 5733
(29 June 1973)

Dr. B. Pade
Director-General
Ministry of Health

VICTOR SHEM TOV
Minister of Health

1. P. G. of 1935, Suppl. I., No. 496, p.56 (English Edition)
2. C. E. 5727-1967, p. 2782; 5728-1968, p. 2259 (Hebrew Edition)

APPENDIX 3

AN EXAMPLE OF INFORMATION REQUIRED FOR A REQUEST FOR CLEARANCE OF IRRADIATED FOOD.

Full and detailed descriptions, particularly of all tests for wholesomeness made on the irradiated food should be made available to the evaluating and authorizing bodies before the marketing of such food is authorized.

Data provided from any source other than the petitioner himself could be taken into account in the evaluation.

a. Name and address of the petitioner.

b. Description of site of the irradiation plant.

c. Brief general description of the food to be irradiated and the technical effect the petitioners is attempting to establish (e.g. inhibition of sprouting).

d. Full information on the food to be irradiated, whether it is an unprocessed natural product of has been processed or manufactured, and, if this is the case, its composition in terms of carbohydrate, protein, fat, mineral salts, vitamins and water.

e. A description of other preservation methods that will be used on the food and of additive in it be included.

f. Nature of the pack, the gaseous environment within the pack and a full description of the material or the materials to be used for packaging with special reference to plasticizer or special additives.

g. Description of the proposed radiation source.

h. Nature and energy of the radiation.

i. Proposed mean dose with upper and lower levels.

j. Proposed mean dose rate, with upper and lower levels, and whether the dose will be continuous or delivered in portions; in the latter case with details of the discontinous delivery.

k. Description of proposed method of dosimetry.

l. Description of proposed safety measures to ensure that food intended to be irradiated is irradiated, irradiation will not be repeated and the build-up of radiation-resistant micro-organisms is prevented.

m. Description of the proposed checks on the efficacy of the safety measures.

n. Maximum and minimum intended periods between irradiation and consumption of food.

o. Proposed storage and transport conditions.

p. Information on whether the food will be stored and marketed in the packaging in which it was irradiated

q. Full and detailed description of results of tests for wholesomeness carried out on food that has been packaged, irradiated and stored as described in the petition and carried out on the irradiated food in the state (e.g cooked) in which it will be consumed, with special reference to:
   - induced or residual radioactivity
   - nutritional quality

- toxic effects, including mutagenic or carcinogenic effects
- microbiological effects

r. Details on the acceptability of the food

s. Proposed labelling.

t. Food contact surfaces for use with food during irradiation should be described.

DESIGN OF THE GAMMA IRRADIATION FACILITY OF SHESTCO

by

T. Friebe
Siemens AG Erlangen, Germany.

Abstract

The Gamma Irradiation Facility (GIF) of Sheda Science and Technology Complex (SHESTCO) is designed as a research and experimentation facility which on a pilot plant scale may be operated for industrial demonstration purposes.

The plant has a design capacity of 3.7×10^{16} Bq and will be equipped with an initial capacity of the irradiation source of 1.11×10^{16} Bq. It consists mainly of an irradiation room housing the irradiation source, a continuos transporting system for the goods, a hall for handling of the various materials to be irradiated and of different laboratories to perform the associated investigations of the envisaged research activities.

The presentation will cover the description of the design features of this plant.

Introduction

The irradiation technique is a widely known and used technology with main applications in the field of food preservation, seed mutation, sprout inhibition, sterile male technique of insects, sterilization of objects (mainly in the medical and pharmaceutical/cosmetic field) and at the polymerisation of plastics.

The Gamma Irradiation Facility of SHESTCO, located at Sheda near Abuja/FCT is a pilot plant which is planned to be operated to demonstrate the advantages of this technology and the feasibility of its introduction in the above mentioned fields of application in Nigeria.

Being a pilot plant, special emphasis is given to the versatility of the plant to suit the various modes of operation. Another main feature of this facility is the inclusion of different research laboratories to cover the various investigations and experiments related to the applications of the gamma irradiation techniques.

Design Concept

The design of the Gamma Irradiation Facility takes into account the different needs of the various research applications which require a wide dose range, a variety of techniques and tests of differently sized products. For food irradiation purposes the weight may range from a few kilograms to 500 kg and requiring irradiation doses from 40 to 10,000 Gy. On the other hand for example biological seed mutation experiments or sterile male techniques require irradiation doses from 10 to 5,000 Gy, samples normally sized between 100 and 5,000 ml. Higher irradiation doses are applied for the sterilization of objects (up to 25.000 Gy) and for the cross-linking of plastics with doses up to 100.000 Gy.

The continuous material throughput can be operated as well as the batch operation or a short irradiation of a sample. The transporting system is designed accordingly to allow these different types of operation. The irradiation source may be adapted as well to the different requirements.

The Gamma Irradiation Facility suits German Standards and International Atomic Agency (IAEA) and World Health Organisation (WHO) recommendations for safety of operation personnel and environmental protection.

The laboratories are arranged in a functional way and equipped in accordance with the various associated fields of investigation, being almost self-sufficient.

3 Plant Description

3.1 Irradiation Process Equipment

The building of the Gamma Irradiation Facilities consists of a hall with overall dimensions of approx. 48 m long, 40 m wide and a height of 12 m, which contains in its centre the irradiation room with the Gamma Irradiation Source and the Source Storage Pool. As irradiation source leak-tight, rod-type capsules of austenitic steel, containing Co 60 in form of pellets are used. There are approx. 40 source capsules sized approx. 450mm long and 11mm in diameter, arranged in stainless steel frames, each one holding up to 20 capsules and which in turn are placed in the source rack. During operation of the plant e.g. for irradiation purposes the source rack is lifted up into the irradiation room by means of the motor driven source lifting device. For shut down the source rack is let down into the storage pool to be covered by water for shielding purposes. The source has an initial irradiation capacity of 1.11 x 10^{16} Bq. If lower doses are required only one section of the source rack may be lifted up independently.

The construction of the irradiation room is a reinforced concrete structure with a wall thickness of about 1,8m for shielding purposes, thus assuring at the outer surface a dose rate of less than 2,5 μ Sv/h at maximum capacity of the source.

After determining the mode and time of irradiation, the products to be irradiated are filled in suitable containers which are stacked up on pallets. A fork lift places the pallets on the pallet conveyor, where registration and identification is performed. By means of the transfer station, two pallets are put in each cage of the overhead conveyor. Depending on irradiation time and mode of operation the overhead conveyor transports the materials within the cage to the irradiation room, where irradiation takes place at the different previously determined operation sequences. The following operating modes are considered in the design:

(i) 4 lane irradiation operation
(ii) 2 lane irradiation operation
(iii) irradiation at swiveling position
(iv) irradiation at steady position

and are achieved by different modes of transportation of the overhead conveyor around the irradiation source. The cycle time of the overhead conveyor can be adjusted as well. The movements of the conveyor cages around the irradiation source are controlled by the process control unit. After finishing the irradiation process, the cages leave, the irradiation room and are transported by the overhead conveyor to the transfer station, from where they are placed on the pallete conveyor and removed from there with the fork lift for storage in suitable storage containers.

For small volumes to be irradiated, a specially provided sample lift can be used independently of the overhead conveyor system. Refrigerated or deep frozen products can be irradiated as well, for which refrigerator and deep freezer storage boxes are provided for irradiated as well as for untreated products.

The incoming materials are stored at one side of the hall whereas the irradiated products are stored at the opposite side to avoid any mix up.

The access to the irradiation room is restricted and only possible during shut down, e.g. while the source rack is under water in the storage pool. The access openings are interlocked for this purpose and alarms and protection devices are provided to avoid any accident. The operation personnel is monitored with dosimeters to detect any exposition to radiation.

New source capsules is transported in a specially licensed shielding container which is lifted up by the transport container crane to the roof slab on top of the irradiation room. After removing the container plug at the irradiation room slab the shielding container is lowered into the source pool. The source capsules can then be removed from the shielding container under water with manipulators and placed into the source frame cases. Sufficient storage place is provided at the bottom of the storage pool for new as well as for spent source capsules.

The walls and the bottom of the storage pool are cladded with stainless steel plates; all elements in contact with the pool water and the cover of the source lift cage are also made of stainless steel.

The irradiation room is equipped with a ventilation system supplying fresh air and removing with the exhaust air radiolysis gas such as ozone and hydrogen. From the control room with the adjacent electrical equipment room located at the ground level, the process activities can be monitored.

Plant auxiliaries such as the CO_2 fire extinguishing system for the irradiation room, water treatment plant for the source pool water, compressed air system for instrumentation and control purposes and the workshop facilities for the maintenance of the equipment, complete the installation.

Materials to be irradiated can be delivered in any form of packing or as bulk material, requiring perhaps repacking to be performed during product identification and registration. Suitable storage containers and racks are provided in the storage area of the hall. Incoming and outgoing materials are ducked and registered at the hall entrance.

3.2 *Research laboratories*

The research laboratories are located at both side wings of the hall and the related offices are arranged close to them. They provide a broad range of support for comprehensive experimentation work.

At the physical-chemical laboratory general analysis can be performed. The function of the dosimetry laboratory covers the analysis of product dosimeters and registration of dose values. Two food laboratories, one for fish, seafood and meat and the other one for fruits, vegetables and dry products are provided for investigation of the untreated and irradiated products and for comparing results. A microbiological laboratory gives the necessary support for the food analysis as well as for medical, pharmaceutical and cosmetical products and their base products. A culture media room is designated for the preparation of culture media and nutrient solutions for the other laboratories. The irradiated food can be detected at the irradiation identification laboratory.

For mutation breeding experiments and for the sterile male technique experiments specific laboratories with the required equipment are provided.

The properties of the irradiated/untreated plastics can be determined and investigated in a special laboratory equipped with the appropriate installation for the analysis of a variety of parameters.

A photographic laboratory permits the fast and variable obtention of the desired photos to document the research results

CONCLUSION

The Plan View of the ground floor, first and second floor of the Gamma Irradiation Facility are shown in Figures 1, 2 and 3 respectively and the longitudinal and cross sections are shown in figures 4 and 5 respectively.

TECHNICAL DATA

Irradiation capacity:	1.11×10^{16} Bq (initial) 3.7×10^{16} Bq (extended)
Source:	40 Stainless Steel leak-tight capsules containing Co 60
Source lifting device	motor driven
Transporting System:	Overhead conveyor system
Operating modes:	Continuous, batch wise and stationary (rotating)
Shortest transfer cycle:	120 s
Type of products which can be irradiated:	various
Conveyor cage capacity	2 x 450 kg (2 x 1,44 m^3)
Irradiation contains:	0,12 m^3
Storage conditions:	ambient, refrigerated, deep frozen
Building dimensions overall:	48 m x 40 m x 12 m
Irradiation room:	15 m x 7 m x 5 m Shielded concrete structure
Source Storage Pool:	7,5 m x 1,5 m x 8 m
Pool cladding:	Stainless steel
Pool water:	Demineralized water
Sample elevator:	one

INFORMATION AND MEDIA MOBILIZATION FOR IRRADIATION TECHNOLOGY FOR NATIONAL DEVELOPMENT

by

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Director of Programmes,
FRCN, Abuja.

Introduction

Change in any society is a difficult phenomenon to contemplate. This is because of the fear of change. Many want change, but the trauma of being part of the change phenomenon is something else. That is why a great majority of the people are comfortable with the status quo. Many too have problem discarding established norms and values. Our cultural inhibitions, that are to a large extent pro-status quo, prevent the acceptance of change. Hence the local idiom "the enemy you know, is better than the devil you do not know". This is because many are afraid of change. The fear of change is compounded because in our society change does not necessarily mean progress or development. Development in our context here is "the deliberate engineering of both economic growth and social change".

Most programmes, laudable as they were, crumbled in our society because of lack of community participation. Community participation is a function of information mobilization. Community participation in this case is carrying the target beneficiaries along to appreciate, participate and relate with the programmes or the products that are participatory democratic model. Here in our own case we have Gamma Irradiation Plant. The objective is to introduce irradiation technology in Nigeria for our National Development. The main objectives are (as spelt out in your final announcement booklet):

i. To preserve food and agricultural products and consequently reduce losses, ensure food security and price stability particularly at off season;
ii. To provide an alternative to chemical methods used in the food industry;
iii. To introduce an alternative to existing methods in the sterilization and decontamination of medical and pharmaceutical products and packages;
iv. To promote the application of irradiation in cross-linking in the plastic, rubber and particle board industries and
v. To encourage private investments in the use of irradiation technology.

Laudable as all the above goals are, if they are packaged and not couriered to the target beneficiary, they are as dead as not existing. The ideas muted, researched into, but not disseminated, will lie gathering dust on the tables of the researchers. Posterity shall not forgive the muting of great ideas and experiment whose results the public cannot benefit from. When products are manufactured, they are packaged for consumers. In our own experience, many scientific products have been manufactured in our dear country. Those that are not lucky to reach the manufacturing plant lie dead rotten on the tables of our sundry researchers. Those that are manufactured with tears are never patented. And those that are lucky to be manufactured are not properly packaged. And finally, those that are lucky to be packaged hardly ever get to the consumers. The reason may be due to the ignorance of our people on the power of the media. Our people will prefer to go to Sokoto (town abroad) to look for solutions to their problems when the solution is in their Sokoto (pockets or at their disposal or at home or in their country). But the reality in our socio-political and economic developments is that a prophet is not acceptable in his domain. That is why we scamper abroad looking for consultants when experts abound in all disciplines in our country.

The question we should address our minds to now is how relevant is science innovation to information mobilization? This can be answered if we take a glance at the power of information mobilization.

The Awesome Power of Information Media in Mobilization

Field (1991) encapsulates vividly the power of the information media in mobilization.

> The mass media - Television, radio and the printed word have become one of the most dominant features of contemporary society ...

They shape our values, tell us what is going on at any given point in time, tell us what to wear, how to speak, how to belong, what to buy, what to consume and tone our tastes among others. In short, the media influence our attitudes and behaviour. Morris (1984) in his book God in a box says few can doubt the power of the media.

It is the capacity of the media, in influencing our thought, in shapening our imagination, in being part of our everyday lives, in dominating, exploiting and controlling our environment that makes the media to be an undisputed "Fourth Estate" in auto-cratic or democratic governments of the world.

In a nine o'clock Network News on 24th September, 1996, the Chief Press Secretary to the Head of State Chief David Attah - urged the media to be "in the vanguard of attitudinal transformation..."

United Nations MacBride Report sees communication as a right for the people. The people need to know themselves and the new technological and cultural developments that shape their lives.

Ball-Rokeach and Cantor (1986) stated:

> The mass media system, with its special information and communication resources is embedded in virtually every corner of social life, whether it be conflict, change, control, or societal integration.

Also, Field (1991) asserted that the British Broadcasting Company (the fore-runner of the BBC) was originally formed by industrialists who were keen on promoting sales of the components for radio receivers. The BBC was incorporated in the late twenties by the Royal Charter. Field affirmed that BBC was created in part, as a reaction to the perceived havoc of unrestrained, American, commercial competition. Media experts all over the world cannot but acknowledge that information media mobilization can be tailored towards wetting the appetites of consumers for a particular product.

The Media has a great influence on peoples lives to the point that consumers of media products use the media and the media use them or manipulate them to align their taste to the "teleguided" ends. In other words the information media has the capacity to mould or shape people's behaviour and change their tastes and preferences. The print, television in general and the radio in particular are transmitted to millions of people in a nick of time. And these millions of people, according to Field (1991) could be "persuaded of almost anything and could even be controlled" He continued by asserting that:

> The mass media were seen rather like social syringes - capable of injecting new ideas, ways of thinking and patterns of behaviour into an unresisting and unyielding society.

This sounds like the hypodermic needle approach theory in information management. Over the years the proponents of the media's influence as a "nexus of mediating factors" have not really succeeded in diminishing the octopian and radiating influence of the information media.

Sundry researches have shown that the information media for mobilization:

a. is potent
b. has power
c. has widespread influence
d. is persuasive
e. links virtually all major parts of the society
f. involved in virtually all aspects of daily life
g. clamours for change
h. integrates the populace
i. subjugates the whole population
j. guides or gives a sense of direction to the target audience
k. charges for a recognition of given value(s)
l. orchestrates everyday consciousness
m. is assessable
n. propagates an ideology
o. etc.

The long and short of all these are that "people look to the media for reassurance about behavioural changes they have already made". This view tallies with that of populist critics who argue "that media moguls have the power to change and mould society".

Today the media has shrinked our world into what Marshall McLuhan called "a global village". An event happening under our very eyes in Abuja can be viewed globally on CNN in a nick of an eye. Distance is no longer an obstacle.

In line with Field's (1991) assertion - the mass media assume:

> an ever increasing role in defining and interpreting the events going on around us and our place within them, so we become more dependent upon them for our understanding of social reality.

That is why "they set before the public a restricted agenda of important issues and problems". This is the accepted "moulding of public opinion" that most media experts cannot dispute.

A Rear Mirror View of the Role of Information Media over the Ages

The information media has played very significant roles either negatively or positively towards mind bending over the ages. Field (1991) opines:

> In the aftermath of the second World War, people wondered whether the impressive Nazi propaganda machine was largely responsible for ordinary men and women supporting a farcist state which condemned millions of its fellow citizens to the gas chamber.

The sceptism of the people towards the media not withstanding, the information media is without argument potent towards grassroot or general mobilization.

In Well's "The War of the World" accounts of thousands fleeing New York after a simulated news bulletin has become what most media gurus equate to be a modern media mythology.

In "A measure of uncertainty" quoted by Field (1991):

> One speaker at the Church of England's General Synod 15th February, 1990, debate on the influence of the media said "I don't care what anybody says. Nobody will convince one that children are not affected by it.

With this knowledge of the power of media, to stay aside and watch is to be blown helplessly by the wind of information media. To do something positive is to use the media towards a tailored end to the advantage of National Development. We have no other option today if we are not to allow the negative influence of the information media to erode the gains in our national development.

Williams (1988) sums up our dilemma:

> All the new technologies of communication have been abused, for political control (as in propaganda) or for commercial profit (as in advertising). We can protest against such uses, but unless we have a clear alternative version of human society we are not likely to make our protest effective.

Dare (1990) writing on "The Role of the Nigerian Mass Media in National Rural Development and Transformation" stated that:

> about three decades ago, media scholars and policy makers alike were almost unanimous that information constituted the critical variable in the calculus of national development.

In Schramm's Media and National Development (Heacock, 1977) UNESCO assigned the media a pivotal role in National Development, hence the concomitant development of the theory of development by communication.

In the areas of agricultural extension, local farmer's participation, credit, marketing, social services, project administration and training, etc, Dare's (1990) affirmation on information playing an important role in raising the productivity of farmers is relevant to all other human endeavours.

Here it should be pointed out that the observation of Schramm that:

Just as communication has been employed to raise the goals, spread the news of them and widen their acceptance ... it is (also) employed to raise the level of national accomplishment towards the goals.

In a nutshell, an in line with McBride's (1980) assertion:

Communication maintains and animates life. It is also the motor and expression of social activity and civilization...

One can conclusively state categorically with him that:

...Unless some basic structural changes are introduced, the potential benefits of technological and communication development will hardly be put at the disposal of the majority of mankind.

This categorical assertion is very true of Gamma Irradiation Plant in Sheda, Abuja.

Basic Introduction to effects of Science and Technology for National Development

Technology is daily developing. Technological growth and innovations are now the global trend. There is today technological progress in general. Today, it is increasingly becoming very difficult to forecast trends in technological developments. This is because there are diverse and sundry experiments taking place at the same time but different places all over our global village. It is even more difficult, at times to predict acceptability of a given technological development because of the negative effects on the beneficiary populace.

The world welcomed the growth of factories and industries least recognising the resultant pollutions and possible long related problems. After many years of industrial practice, the populace has to be inundated with the need for the setting up of environmental protection agencies.

Science or technological developments today has become an asset as well as liability for progress and development. As stated by McBride (1980).

Science and technology are constantly making such advances which may one day facilitate breaking down barriers between persons and nations. The trend is without doubt irreversible. But the consequences which can now be foreseen are not necessarily beneficial.

With this at the back of the mind of the recipient public of technological developments there is an urgent need to use the media for education, information and enlightenment towards the acceptance of a given technological breakthrough. As a result of this practical reality McBride (1980) continues:

It is therefore vital to determine how these technological developments can be of greatest benefit to all nations, within each nation, to each community and ultimately, to all men and women;

Many things are happening in our world all at the same time. The information media has successfully brought these happenings to the doorsteps of our diverse populace in the world. McBride (1980) is unanimous that technological progress is running ahead of man's capacity to interprete its implications - and direct it to its most desirable channels... While technological developments are in leaps and bounds, information media developments must run parri-pasu with the technological breakthrough.

Kurt Waldneim, the Former Secretary General of United Nations warning that:

new technologies, advancing by their own momentum or due to political pressures and economic requirements impose themselves before they can be assimilated...

is relevant to the role of information media in mobilizing the people towards accepting new trends in technological development. Here, it can be asserted that it is the information media that can successfully impose a given technological development on the people.

Today, distance is very irrelevant in information dissemination. Today, information disorder can be changed in favour of developing nations; today the people access to information in the areas of technological development can be improved; our scope is not to delve into the many ramifications of the information media but suffice to say that information media is vital towards letting the people know what is happening in the technological world.

Conclusively, the information media bring our basic issues that need to be known on a given area, it offers a wide prospect for the people to be carried along with technological developments; it makes the people aware of the problems, assets, liabilities and prospects of technological development; it brings about structural transformation without tears or pressure on the people; it creates a general awareness for them to accept technological innovations; etc.

One can go on and on but the basic question has to be asked. The question is what is the relevance of all these to Gamma Irradiation technological development in Nigeria?

Science & Technology and Information Media Mobilization in Nigeria

The media cannot operate without technology. Neither can technology flourish without the media. It is like the story of the egg and the hen. The question then is which one comes first? This can be a long and extensive argumentative essay.

Retrospectively one of the popular technological developments that attracted information media exposure was the agro-based technological breakthroughs in tractors, winnowing machines, harrowing machines, weeding machines etc. What a crowd of farmers were doing in group cooperative farming, was done under few hours by the magic of the farming machines. The attraction to this programme in innovation and popularity were made possible through the information media.

Another area of our focus is in the area of information dissemination. In those days, the only medium of communication within the realm of a compartmentalized village is only through the Town Crier. When the noise of the Town Crier rings through the shrill and solitary life of the village, the villagers are mobilized to gather at the village square! Today technology has made that method obsolete as a paid announcement or jingle on radio can mobilize hundreds, thousands, and even millions at the same time!. This too as effective and down-to the grassroot as it is could not have been accepted if this alternative approach which is better, faster and more effective is not properly sold to the recipient populace. Today farmers, cow fulanis and hunters are seen carrying their major link to the outside world of information media - the Radio.

Is it not possible to imagine what would have happened if technological breakthroughs in the area of medicine is not properly sold to the general public? If our public were not properly mobilized to accept Nivaquine, Chloroquine, Fansidar and the associated drugs as cures to malaria, they would have been happier to connect the malaria diseases to witchcraft or resort to their native concoctions.

Lastly, our collective forward movement in technological development can be a function of our capability in mobilizing ourselves in projecting a particular technological innovation as a viable alternative to others. These can be done through various means of communication. A given technological breakthrough can be piped to the public or target audience via the following samples:

1. Symbols - made by hand
2. Gestures - made by any part of the body
3. Numbers - on printed page/film/TV/Radio
4. Words - on printed page/film/TV/Radio
5. Pictures - on printed page/film/TV/Radio

Some, or all of the above can come in form of signs and words through body languages; or non-verbal languages; languages of the world which is today put at over 3,500; reading and writing; post and telephones; group and local media which include local newspapers, community radio, the mass media which include radio and television; satellites; computers; etc. All these are powerful information media that can transform the orientation of the recipient public. Each information medium has its own advantage or disadvantage in information dissemination. The onus lies with the packaging expert to use the right medium to send the right message to the receiver or a given target audience. The reality in our system is that there has always been either what I may call "information underload" or "information overload"; there has always been a system where information dissemination is equated to propaganda and distortion of facts; there has always been the selling of non-salable products; there has always been a consistent display of journalistic laziness as information that are not well-researched on are daily churned out of our information media. The result of all these is that today the information media is daily talking to skeptic non-receptive audience that can only tolerate the swallowing of the half-truths from our information media. The question then is what is the way forward for particularly the Gamma Irradiation Technology? The way out is the consistent packaging of the truth and nothing but the truth about the capabilities and capacities of Gamma Irradiation Technology to the masses of our people.

Conclusion

For a new technology such as the Gamma Irradiation Technology to be accepted, there must be the following among others:

1. Free flow of information from the Science and Technology Complex to the public.

2. Free flow of information from the consuming public to the Science and Technology Complex.

3. Avoiding information media distortion of technological development through periodic education of experts in the information media. This can come in form of workshops such as this, organising of study tours, periodic press briefings, press releases and so on.

4. Not allowing the technological development to alienate the people culturally. Here an extensive research can be conducted to marry the consuming public's culture with the technological development and breakthrough.

5. Not allowing external influence to diminish the gains of the local technology either by price variation, aesthetic appeal or in any way. Here it should be pointed out that this has been the bane of our local auto assembly plants. They have consistently been diminished by the high fly Japanese or Taiwanese technological breakthroughs in auto-industry developments.

The laudable objectives of Irradiation Technology for National Development in Nigeria have great attractions to our citizenry. Pursuing these objectives will be a mirage if the technological breakthrough that is about to happen in our time is not merged with appropriate information media mobilization strategies.

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TECHNICAL SESSION I
Discussion: Questions, Answers and Comments

Questions on the 1st Paper

Question 1 - Dr. S. P. Mallam CERT, A.B.U. Zaria.

Talking of the control of gamma irradiation equipment by NAFDAC to ensure that they pose no threat to health of operators and the general environment, is such an assignment part of the Decree establishing NAFDAC and is this not in conflict with the content of Decree 19 of 1995 vesting such power on the Nuclear Regulatory Authority?

Answer

We are not in anyway trying to usurp the responsibility of other Agencies. NAFDAC is only interested in collaborating with all organs of Government linked to the Irradiation Programme so as to protect public health.

Question 2 - G. A. Solabi, Nestle Foods Nigeria Plc.

Could you explain how regulations and codes of practice of radiation technology would be enforced without multiplicity of roles and possible conflict between the various agencies?

Answer

The different roles will be carried out without conflict through collaborative efforts.

Questions on the 2nd Paper

Question 1 - G. A. Solabi, Nestle Foods Nigeria Plc.

How do you guide against the existence of a case of multiple codes, regulations etc in the interest of industries?

Answer

A standard regulation will be developed through collaboration of all agencies and promulgated into law by Government for uniform application.

Questions on the 3rd Paper

Question 1 - Prof. J. I. Okogun NIPRD, Abuja.

Why are irradiated foods not allowed in the Federal Republic of Germany?

Answer

The reason is purely political and definitely not scientific since food already irradiated in the former East Germany prior to Reunification was allowed to be sold for two years following Reunification. It is thus part of the usual popular anti-nuclear campaign in Germany.

Question 2 - Prof. Shams Elegha CERD, A.B.U. Zaria.

What is the experience of GDR in the establishment of whether a food item has been irradiated by using either physical or chemical means?

Answer

Like mentioned earlier, irradiation at the appropriate dose, induces no changes in taste, odour or other qualities of food, thus making tests for irradiation rather difficult. It is an on-going study worldwide.

Questions on the 4th Paper

Question 1 - Dr. S. P. Mallam, CERT ABU, Zaria.

What is the relative cost per Ci of Co-60 and how does this compare with electron beams?

Answer

The cost depends on product and product volume as well as on local conditions. For relatively small volumes, an electron beam may be better but for large volumes and research purposes, radioactive sources are much preferred. Specific costs are difficult to give but I think a range of 100-150DM (US$60-100) per $100m^3$ is very likely.

Question 2 Dr. I. P. Farai FRPS, U.I, Ibadan.

All the safety interlock systems are electrically controlled. Does the SHESTCO design have an automatic return to safety position in case of power failure?

Answer

Yes. Special protections are incorporated. There is provision for the source to lower itself by gravity in case of power failure. Also, autonomous power generators are provided for the Complex.

Question 3 - Dr. G. O. Adejare, Plant Quarantine Services.

Is Germany using irradiation to check pests and diseases moving on the International Trade?

Answer

No

Questions on the 5th Paper

Question 1 - Dr. B. O. Ajagbonna NITR, Vom.

Which Listeria are you talking about? is it Listeria Monocytogenes?

Answer

It is Listeria Monocytogenes quite all right.

Question 2 - Dr. B. O. Ajagbonna NITR, Vom.

Is there a rise in temperature during irradiation?

Answer

Yes, there is a slight rise in temperature, but it is negligible.

Question 3 - Dr. I. P. Farai, FRPS, U. I, Ibadan.

I noticed that you used some radiation sources in your Institute. Did you at any time register those sources, and if so, with whom?

Answer

The facilities used were those at Vom which have been registered with the IAEA since 1982.

Chairman: They have to be registered here in Nigeria too.

Question 4 -

If the irradiation technology cannot eliminate toxins but only kills the pathogenic micro-organisms of what use is the technology then?

Answer

Good manufacturing practice requires that food should be irradiated before the toxins are produced.

Question 5 - Dr. S. O. Awonirin, Univ. of Agric, Makurdi.

From your work in ABU, what has been the experience regarding the effect of irradiation on vitamins in spices and poultry products, especially the B-vitamins.

Answer

It should be noted that the quantity of spices taken in food is normally small and that they also contain negligible amounts of vitamin nothing therefore is lost in terms of vitamin intake by irradiating spices. As for poultry products, at doses of 2-5kGy, the effect of Vitamin variation is just as low as that encountered with heat application through cooking in water. So there is no cause for alarm.

TECHNICAL SESSION 2

IRRADIATION TECHNOLOGY FOR NATIONAL DEVELOPMENT

i. Use of Irradiation for Post-Harvest Preservation of Crops.
by Dr. S. A. Adesuyi - Federal University of Technology, Akure.

ii. The Use of Ionizing Radiation in Reducing Post-Harvest Losses in Food Crops.
by Joseph Opadokun - Nigeria Stored Products Res. Institute, Ilorin.

iii. The Use of Gamma Irradiation in Root & Tuber Crops Improvement
by Dr. E. C. Nwachukwu - NRCRI Umudike, Umuahia.

iv. Problems Associated with Storage of Cocoa for Export
by O. L. Idowu - Cocoa Research Institute of Nigeria, Ibadan.

v. Biological Control of Tsetse Flies Using Nuclear Techniques in Nigeria
by Dr. B. O. Ajagbonna - NITR, FMST Vom, Jos.

vi. Grains Reserve Strategies
by Engr. A. Talabi - Strategic Grains Reserves, Abuja.

vii. Radiation Decontamination of Foods and Spices
by Dr. P. C. Onyenekwe- Institute for Agricultural Research, A.B.U, Zaria.

USE OF IRRADIATION FOR POST-HARVEST PRESERVATION OF CROPS WITH SPECIAL REFERENCE TO NIGERIA

by

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Federal University of Technology, Akure.

Abstract

The importance of post-harvest preservation of crops is highlighted in terms of making high quality foods available throughout the year, reducing losses, stabilising prices, supplying of agricultural raw materials to agro-allied industries and prevention of mycotoxins on food-stuffs. Also, storage losses, types and causes are discussed.

A comparison of irradiation as a preservation technique for crops with existing methods especially chemicals is carried out extensively. The use and prospects of irradiation for post-harvest preservation of crops is presented in the following perspectives.

(a) Irradiation used as a sole technique to control losses and remain as a possible substitute or standby for existing methods or as immediate replacement when several factors such as effectiveness, simplicity of application, cost of application, development of resistance etc. are considered.

(b) Used in combination with other prospective or existing method so as to bring about the effectiveness of both methods or enhance the efficiency of irradiation and the method on individual basis.

(c) Used as the only effective method available.

Finally, some recommendations are made to accelerate the adoption of irradiation technology for post-harvest preservation of crops in Nigeria.

Introduction

The importance of post-harvest preservation of crops can not be overemphasised especially in the effort to make food available to the masses. The purposes of post-harvest preservation of crops are to save both physical and quality losses of the crops from agents of deterioration and to ensure a steady supply of good quality agricultural products to the consumers all year round. Others are to reduce seasonal fluctuation in price, ensure a steady supply of raw materials to agro-allied industries based on such crops, and prevent contamination by microorganism, insects infestation, spoilage and danger to human health. It also encourages farmers to increase their production and export very high quality agricultural products that will compete favourably in the International market. This paper will be limited to major food crops only.

Grains mainly maize, rice, guinea corn and millet, grain legumes cowpea, soyabeans, and yam tuber, cassava, fruit and vegetables constitute the major food crops in Nigeria. Cocoa is a major agricultural export crop, earning substantial foreign exchange for Nigeria and many West African countries such as Ghana, Ivory Coast. Cocoa is also being used extensively by the cocoa processing industries in Nigeria.

FOOD PRODUCTION IN AFRICA AND NIGERIA

Figures of food production for 1991 in Africa and Nigeria taken from FAO 1992 yearbook (1) and 1994/95 World Cocoa Directory (2) are shown in table 1.

Even though the population of Nigeria is high compared to the rest of Africa, if this level of food production is supported by effective post-harvest preservation techniques, she should not be threatened by food shortage.

LOSSES IN STORAGE

The environment of high temperature and high humidity prevalent in the developing countries coupled with poor post-harvest preservation techniques prediscope harvested agricultural products to enormous losses. The losses could be in weight, food, quality, money, goodwill and seed. Losses of between 25 and 50 percent of harvested cereals and pulses have been reported in Latin America, aoout 30 percent of food stored in Africa and up to 50 percent in South East Asia (Hall, 1970). Edens and Peters (1962) have recorded maize losses of 25 percent while Adesuyi and Shode (1977) have found 24.7 percent maize loss in traditional storage for six months in Nigeria, Williams et al (1981) reported an increase in damage by insects to maize stored in cribs from 3.8 percent to 73.2 percent in six months. Food storage microorganisms mainly fungi, bacteria and yeasts cause deterioration such as loss in nutrient qualities, palatability and production of toxic substances in food. They also cause discolouration, abnormalities in growth, adverse flavour and odour of raw and manufactured products, heating and high temperatures and loss in weight. They destroy viability of seeds, packaging materials and produce toxic metabolites called mycotoxins. It had been reported that between 1.25 and 3.00 percent of grain was lost to mouldiness in a metal silo in Nigeria (Adesuyi, 1972).

As regards perishables such as fruits, vegetables, root and tuber especially yam tubers, the lack of any proper control of physical conditions, physiological process, pests and microorganisms lead to considerable storage losses. A loss of 10 -15 percent in weight in the first three months and losses approaching 50 percent after six months storage have been reported (Coursey, 1967, Adesuyi and Mackenzie, 1973).

Although, the food and Agriculture Organization (FAO) estimate of worldwide annual losses in store has been given as 10 percent of all stored grain, current losses of about 30 percent are apparently occurring throughout large areas of the world.

CAUSES OF LOSSES

The major factors involved in post-harvest losses of crops in the tropics are:

(a) Development of insects and mites on harvested crops
(b) Infection by and development of microorganisms mainly fungi and bacteria.
(c) Chemical changes,
(d) Exposure to extreme temperature and humidity.
(e) Feeding on stored food by rodents and birds.
(f) Mishandling by man adversely affecting the quality of stored food and causing loss through spillage.
(g) Use of poor containers and storage structure.

All these factors individually and collectively cause a lot of losses in stored food in the tropics.

PRESENT METHODS OF DISINFESTATION OF HARVESTED CROPS

Grain and grain legumes are handled and stored at present at small, medium and large scale levels. Disinfestation is mainly by use of insecticides. When grain or grain legume is stored unshelled or unthreshed, it is mixed with a persistent organophosphorus insecticide to control the insect pest e.g. pirimimiphos methyl 2% (Actellic dust or liquid formulation), tetrachloryinphos (Gardona) or Iodofenphos (Nuvanol) as admixture for eight to nine months. Any of these could also be with shelled or threshed grain and legumes. It should not however be consumed until the insecticide has broken down to a relatively safe level which may be about three months after application. The most commonly used persistent insecticide in Nigeria is pirimiphos methyl (Actellic) mainly at the small and medium scale levels (Adesuyi, 1973, 1976). If storage is for a long time, application may have to be repeated.

At the medium and large scale levels, storage of grains and grain legumes is either in bags in large stacks in big warehouses or loose in bulk in silos. At both levels and method of storage, insect control is by use of fumigants e.g phosphine fumigant that come in the trade names of Phostoxin, Detia, Gastoxin, Quickphos and Protex (Adesuyi and Cornes, 1966; Adesuyi 1966a and 1976). The fumigant leaves no residue because it is non-persistent insecticide. As a result, a fumigated product can be opened up after five days, aired for a day or two and it is fit for human consumption. Since it is nonpersistent, an effectively fumigated produce with 100% kill can be reinfested by insects soon after the fumigation. If such a produce is to be stored for a long period, post-fumigation protection has to be carried out. This is in the form of applying persistent insecticide such as pirimimiphos methyl or malathion dust to the exposed surfaces of the stored grains (Adesuyi 1969).

From the above, it is clear that insecticides of relatively high mammalian toxicities and persistence are used on stored grain and grain legumes even after fumigation. There are also cases of repeated application on the same grain. Deterioration through attack by microorganisms in stored grain is controlled by drying the grain and maintaining the moisture content at the level safe for storage, generally 13% or less for grains and legumes. The use of fungicide is not recommended on stored produce because of its high toxicity. However, some chemicals in form of mild antiseptic already cleared by Health Authorities can be used as preservatives. Cocoa is another product that will be considered in this paper. It is at present stored in very large quantities in bans in warehouses in readiness for export. It is fumigated under sheets with methyl bromide. (Riley and Simmons, 1967). The walls of the warehouse are sprayed with persistent contact insecticide so as to kill insects that escape the effect of fumigation and prevent reinfestation. Mouldiness is controlled on cocoa by drying to 7.0 percent or less. Pest control on stored cocoa is therefore through the use of persistent insecticide and fumigant.

The high losses of stored tubers, roots, fruits and vegetables are due to lack of proper control of physical conditions, physiological processes, pests and microorganisms. The present recommendation for yam is that it should be harvested and handled carefully to avoid damage, only undamaged tubers should be stored in open-sided shelves in a well-ventilated shed to protect the yams from rain and sunlight. (Adesuyi, 1975).

IMPORTANCE OF RADIATION IN FOOD PRESERVATION ESPECIALLY IN A DEVELOPING COUNTRY SUCH AS NIGERIA

Irradiation for post-harvest preservation of crops is used for control mainly of insects, microorganisms and inhibition of sprouting in tubers and some perishables e.g. Onions.

The following special features make food irradiation an appropriate technology for developing countries.

The process has been reported byBrynjolfsson (1978) to be energy-saving. The energy requirement for irradiation is much lower than for canning or freezing as shown in Table 2.

That the process is energy-saving over the conventional techniques for food preservation is a major asset especially now that energy costs are very high. Secondly, food irradiation employs the most economical type of packaging material and method. The rays penetrate bulky products and can be irradiated in various sizes. There is no need for expensive tin plates that are required in canning process or other specialised packaging materials as in vacuum packaging.

Irradiated foods maintain their freshness and other quality because they are not subjected to excessive heating during irradiation. Irradiation is not known to leave toxic chemical residues unlike many pesticides used on stored products. It does not therefore pose health hazards as it leaves no foreign residue.

The greatest potential of food irradiation is to help reduce world food losses substantially so as to increase food supply especially in areas that suffer high losses of up to 30-50 percent annually such as Nigeria. Irradiation prevents both internal and external sprouting in potatoes, onions and yam tubers. Cold storage of tubers which is the alternative method is not feasible under local household and marketing conditions. Irradiated foodstuffs generally e.g. tubers do not require special storage facilities. The tubers are stored in barns at ambient temperature. Irradiation is not known to produce chemical products that reduce quality.

Radiation can only benefit good quality foods. It should not be applied to inferior produce or used as a substitute for proper hygiene. It would only preserve the good quality that already exists.

Vas (1978) summarised the special features of irradiation thus:

(a) It does not increase the temperature of the food appreciably (1- 4°C at the maximum) and therefore can be applied even to frozen foods or viscous materials without changing the consistency of the product;

(b) Radiations can penetrate into the middle of even bulky goods, thus allowing for treatment in the ready-packaged state thereby preventing re-infestation or re-contamination by insects or microorganisms after treatment and securing destruction of insects or their eggs in the centre of a large fruit as required in plant quarantine or in the middle of grain kernels.

(c) The energy requirement of the process are low and by reducing the need for conventional energy carriers used in other processes, its application may contribute to the overall reduction of pollution caused by combustion products of traditional fuels;

(d) Irradiation does not impart chemical residues to the treated product and thus lowers the need for chemicals (fumigants, insecticides, preservatives etc) thereby contributing to a cleaner environment.

In addition to reduction of food losses, food irradiation creates new types of shelf-stable (at ambient temperature) convenience foods, produce better-quality (texture, flavour, nutrition) food products, improve microbiological safety and reduce the need for chemical additives such as nitrite, sodium chloride etc. However, like other physical food processing operations, for economic reasons, it cannot be applied on a small scale basis. Again its clearance for use is usually made conditional on extensive testing for safety of the irradiated products.

TECHNICAL FEASIBILITY

It had been reported by Amuh (1977), that mould growth could be inhibited on 2 months old. Cocoa beans, irradiated at a moisture content of 6.1% with doses of 0.5 KGy and above and stored at relative humidity of 95%. It was stored for one year. With the 9 month old cocoa beans, irradiation at a moisture content of 9.1%, the minimum inhibition dose was 5.0 KGy. The difference in the dose requirement was due to increase in radiation resistance of moulds with increased development age. If cocoa is irradiated early after processing relatively low doses would be required to control moulds on it. He reported that there was no significant change in protein, sugars, and alkaloids as a result of irradiation of cocoa beans up to a dose of 5.0 KGy. The yellow colour of the fat extracted from the cocoa gradually decreased above 0.5 KGy.

Effectiveness is highly increased when irradiation is combined with heat treatment. A combination of 80^0C heat treatment at high relative humidity (85%) with irradiation at 4.0 KGy was very effective in controlling Aspergillus flavus (Appiah et al 1980). So also, a combination of captain with 2.0KGy of gamma irradiation produces better fungicidal effect on A. niger than either treatment alone on apples. The combination therefore enhances the effectiveness.

The most serious problems in grain storage are insect infestation and mould infection. It has been found that irradiation treatment is effective in controlling the major insect pests on stored grains and cocoa by sterilizing them or by effecting complete mortality. Sitophilus oryzae (L) and Rhizopertha dominica (F) treated with doses above 25KGy consumed much less food than control after 5 weeks. The amount of damage caused by the live but sterile insects in bulk grain treated with gamma radiation would not be serious due to the reduction in their feeding brought about by the radiation. The weight loss would remain the same while that in unirradiated grain would greatly increase with time. Therefore the presence of live but sterile insects in irradiated bulk grain does not pose a threat of damage (Brower and Tilton 1973). It has been reported (Tilton et al 1966) that radiation doses of between 0.175KGy and 10KGy was not high enough to produce immediate mortality on Tribolium Confusum, Lasioderma

Serricorne, Rhizopertha dominica and Sitophilus Oryzae which are major insect pests of stored grains and cocoa. All four species were sterilized by gamma radiation in simple continuous dose of 0.25KGy or more. Tribolium Confusum, Tribolium Castaneum, Sitophilus oryzae, Ephestia sp. and Orzaephilus surinamensis can be successfully controlled by a dose between 0.20 and 0.30 KGy (Brower and Tilton 1973; Pointel and Sam 1969 and Hoedaya et al 1973). It is now clear that the major insect pests of grains and cocoa in storage can be controlled with 0.25 KGy. In general, a dose of 0.3-1.0KGy will kill insect pests in all life cycle stages. From the above, it is technically feasible to use irradiation as a sole technique in controlling both insect infestation and mould infection for post-harvest preservation of crops in Nigeria. It can remain as a substitute for existing chemical method or as immediate replacement.

Maqueen (1973) reported that the advantages of radiation over fumigation for controlling insect infestation are that the product can be treated after packaging regardless of the type of packaging used. Secondly, its ability to sterilise insect eggs laid inside kernels of grain, which can escape the action of chemical treatment. Thirdly, no toxic residue is left on the food when it is irradiated.

Fumigation, however, is the most convenient method for controlling insects infesting entire building such as flour mills. The disadvantages of use of insecticides are their potential toxicity to man if misused and development of insect resistance to them. He finally suggested that irradiation should be combined with insect-resistant packaging.

Investigations carried out in Nigeria on the use of irradiation technology for improvement of the preservation of yam tubers especially inhibition of sprouting showed that it can be successfully used to store yam tubers in the yam barn for eight months (Adesuyi and Mackenzie, 1973, Adesuyi, 1973, 1975, 1975b, 1976; Demeaux et al, 1982). After the series of studies, the following conclusions were made:

(a) An irradiation dose of 0.125KGy is effective on nine cultivars of yams tested in achieving acceptability, palatability and complete inhibition of sprouting without inducing adverse changes in physiological properties for eight months in storage.

(b) Timing of applying the irradiation treatment is as soon as the wounds have healed after harvest, during dormancy. They should thereafter be stored in the yam barn, i.e. ambient (no specialised storage environment) on open-sided shelves. Tubers treated at post-dormancy period require higher doses of radiation that may predispose them to rot in storage.

(c) The irradiation dose that is required to control rot in stored yam tubers will completely disintegrate yam tissues;

The chemical sprout inhibitors, maleichydrazide (MH-30), methyl ester of 1-naphthylacetic acid (MENA) and 2,3,5,6, tetrachloronitrobenzene (TCNB) investigated along with irradiation technique were not effective in inhibiting sprouting in stored yams. This is an example of where chemicals have failed but radiation technology has succeeded and radiation is the only method that is so far effective in inhibiting sprouting in stored yams for eight months. It can be adopted immediately (Adesuyi and Mackenzie 1973). It has been reported that the important insect pests of stored agricultural products have developed resistance against insecticides commonly in use e.g. Tribolium Castaneum resistant to malathion (Champ and Campbell-Brown 1970), Sitophilus zeamais to lindane (De Lima, 1972). Radiation techniques can be used where insect resistance to insecticides is found.

Apart from disinfestation of produce radiation should be applied where no other method is effective such as in the inhibition of sprouting in yam tuber stored under ambient conditions. It could also be used when there is shortage of insecticides to control insect pests for example. It can also be competitive with other existing preservation methods as its versatility has been proved.

It has been proved that irradiation is technically feasible on stored yam tuber, onions, grains, grain legumes and cocoa beans in Nigeria. However, there is need for more work to be done towards the adoption and acceptability which should be the next line of action in Nigeria. The requirements for adoption are as follows:

1. Irradiation technique must be found to be profitable.

The product should be relatively highly priced and the benefits of the radiation treatment will readily exceed the costs of the treatment

2. If irradiation will replace a less efficient method.
3. If it will contribute to product quality improvement.
4. If it will replace a less desirable process.
5. If it is effective where there is no other method and a real problem exists e.g. storage of yam tubers.
6. Where the product is available for processing throughout the year in sufficiently large quantities to keep radiation equipment busy. Alternatively, if different products are available at different period of the year for treatment. Grain, cocoa and yams are available in Nigeria at different periods in the year that can fully occupy the irradiation plant throughout the year.
7. If the maximum to minimum dose requirement are not critical so that large size packages can be processed.
8. If the clearance for the process is available or can be easily obtained at minimum expense.

Steps to be taken before commercialisation of the technique:

1. Extensive laboratory studies must be carried out.
2. Convincing and exhaustive wholesomeness tests must have been done.
3. Costing of the process to show profitability in order to attract industrialists.
4. Consumer trials and experience with storage and processing of products on a semi-industrial scale.
5. Having completed the above, a general introduction can be embarked upon.

CONSIDERATION IN COMMERCIALISATION OF IRRADIATION TECHNOLOGY

As in the case of new technology, it will either complement or entirely replace the existing technology for some products. This is usually resisted by the food industry because of their conservative and suspicious attitude. This is a very serious obstacle and can only be surmounted with glaring technological, economic or commercial advantages. However, irradiation technology faces additional problems of a high initial investment cost of the basic plant, an instinctive association of it with nuclear energy and radioactive fallouts in the minds of potential consumers. This last problem seriously affects food irradiation technology during clearance by the health authorities and acceptance by the consumer. A wide market for the irradiated food product has to be ensured due to the high initial investment. A careful analysis of the economics and technologies of the existing and the new technologies has to be made so as to know conclusively the superiority of the new over the existing technology. Information on the existing technology may be difficult to collect by Government or quasi-government organizations, so it is advisable for an independent body or organisation to handled it and to handle that of the new technology. Lapidot (1973) has discussed in detail the technological, agro-technical, economic, commercial and psychological factors involved in the introduction of irradiated products on a large scale. Our target should be to mount a successful acceptability campaign for irradiated products in Nigeria. Examples of worldwide approved irradiated foods and commodities are as follows:

Country	Product
Argentina	Spices, spinach, cocoa powder
Bangladesh	Potatoes, onions, dried fish, pulses, frozen seafood, frog legs.
Belgium	Spices, dehydrated vegetables, deep frozen foods, including seafood.
Brazil	Spices, dehydrated vegetables
Canada	Spices, potatoes, onions
Chile	Spices, dehydrated vegetables,

	onions, potatoes, chicken.
China	Potatoes, garlic, apples, spices, onions, Chinese sausage, Chinese wine.
Cuba	Spices, potatoes, onions, cocoa beans
Denmark	Spices
Finland	Spices
France	Spices, vegetable seasoning, poultry (frozen deboned chicken)
Hungary	Spices, onions, wine cork
India	Spices, onions, potatoes
Indonesia	Spices, tuber and root crops
Israel	Spices, potatoes, onions, grains
Japan	Potatoes
Korea Rep. of Netherlands	Garlic powder, potatoes, onions
Netherland	Spices, frozen products, poultry dehydrated vegetable, rice, egg powder, packaging materials
Norway	Spice
Pakistan	Potatoes, onions, garlic, spices
South Africa	Potatoes, onions, fruit, spices, meat, fish, chicken, processed products, vegetables
Spain	Potatoes, onions
Syria	Potatoes, onions, chicken, fruit, spices
Thailand	Onions, fermented pork sausages, potatoes
USSR	Potatoes, onions, cereals, fresh and dried fruits and vegetables, meat products, poultry grains.
USA	Spices, poultry, fruit
Yugoslavia	Spices, cereals, meat, poultry

Ref. Isotopes in everyday life. International Atomic Energy Agency, Vienna, Austria.

RECOMMENDATIONS:

1. A national committee on food irradiation programme should be set up to pursue the introduction and adoption of food irradiation in Nigeria. The existing members of AFRA set up by the Federal Government could from the nucleus of the committee. It should now include members from NAFDAC, Food Industries and more people involved in food irradiation.

2. With the present high cost of and scarcity of insecticides and fungicides, the use of irradiation may be found to be cheaper, more readily available and reliable.

3. In using it on any export crop especially cocoa, international cooperation and acceptance should be obtained before application so as not to jeopardise our national interest in international market.

4. There is need for more detailed work on the cost of irradiation application in Nigeria.

5. Considering the fact that agricultural production in small quantities is scattered all over the country, introduction of mobile irradiators for continuous operation with conveyor belts is recommended as fixed irradiators may not be feasible. It should be borne in mind that the higher the throughput of product irradiated, the lower is the cost per unit treated. The irradiator must be operated at near maximum throughput as much as possible. The best design for a specific purpose and environment must be worked out by the design Engineer and the plant owners for the highest economic results.

6. The newly acquired commercial scale Gamma Irradiation plant by the Science and Technology Complex (SHESTCO) should be used for treating products such as grains, apples, potatoes, mangoes and papaya (paw paw) grain legumes, cocoa, yam tubers, onions. Irradiation has been found to be effective in improving the storage of these products both in Nigeria and some other countries.

7. Knowledgeable independent bodies should be commissioned to carry out comparative studies of the existing techniques and irradiation technique on each product on a continuous basis so as to prove the superiority of one over the other.

8. Finally there is still a lot of research and development work to be done on irradiation preservation of food in Nigeria. Therefore facilities and financial grants should be made available to the research personnel to carry out more of these investigations on outstanding issues to enhance the clearance, introduction and acceptance of irradiated products in Nigeria.

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Table 1. Figures of Food Production for 1991 in Africa and Nigeria in 1,000 metric tonnes

Food Crop	Production: Africa	Production: Nigeria	Nigeria as % of Africa
Cereals	99,397	14,200	14.3
Yams	22,742	16,000	70.4
Cassava	68,931	20,000	29.0
Cocoyams	3,570	70	
(Taro) Potatoes	6,814	42	
Sweet Potatoes	6,473	35	
Pulses (grain legumes)	6,968	1,559	22.4
Vegetable & Melons	324	25	--
Cocoa	--	145	--

Table 2: Typical Energy Values Used for Processing of Food (KJ/KG)(BRYNJOLFSSON, 1978)

Radpasteurization with 2.5 KGy	21
Radappertization with 30 KGy	157
Heat appertization (heat sterilization)	918
Blast freezing chicken from 4.4^{0}C to -23.3^{0}C	7,552
Storing the product at -25^{0}C for 3.5 weeks (588h)	5,149
Refrigerated storage for 5.5 days at 0^{0}C	318
Refrigerated storage for 10.5 days at 0^{0}C	396
Cooking the whole thawed chicken at 93^{0}C	2,558

THE USE OF IONISING RADIATION IN REDUCING POST-HARVEST LOSSES IN FOOD CROPS: EXPERIENCE OF THE NIGERIAN STORED PRODUCTS RESEARCH INSTITUTE AND POTENTIALS FOR THE FUTURE

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Abstract

The paper highlights the magnitude, importance and consequences of post-harvest losses in agricultural crops in Nigeria. Some of the technologies recommended by the Nigerian Stored Products Research Institute (NSPRI) for controlling these losses and their limitations are discussed. The practical experience of the Institute in the use of ionising radiation to extend the shelf life of yam tubers is briefly discussed. Potentials of food irradiation for reducing postharvest losses in food crops already recognised but as yet unexplored are also discussed. Problems that need to be addressed before irradiation can be adopted as a technology for postharvest treatment of agricultural crops in Nigeria are also briefly discussed.

Introduction

Food is the most basic need of man which has to be satisfied to preserve life. Good feeding is essential to health and productive living. Only well fed, healthy people are in position to think and contribute meaningfully to economic development of a country.

Agricultural crops are the raw materials of agro-allied industries. These industries are growing in number and include food, beverage, textile, pharmaceutical, chemical and cosmetic industries. Industrialization is a major aspect of human development as it helps to diversify the economy, boost export trade, reduce imports, increase income of the people and the government and raise the standard of living of the people. In a developing country like Nigeria, development of agro-based industries offers special advantage in industrialisation because these industries use raw materials that can readily be produced in the country. Even industries that are not primarily agricultural still depend on supply of food to workers in such industries.

Agricultural crops are important in national and international trade as raw materials or as semi-processed products. Agriculture contributed a substantial proportion of Nigeria's Gross Domestic Product and was a major source of foreign exchange for the country until the early 1970s. Although its percentage contribution to the Gross Domestic Product has declined on account of petroleum, agriculture is still considered as the mainstay of the economy.

It is also noteworthy that more than 60% of the Nigerian population is involved in agriculture (FAO, 1988) producing huge quantities of various crops, as shown in Table 1. Agriculture is therefore a very vital aspect of the nation's economy and well-being.

Every responsible government all over the world aims at food self-sufficiency, for the security of the nation, which is also the pride of the nation. Self-sufficiency in food has two major components; growing enough food to feed the population and the food industries, and keeping what has been produced in good condition until it is needed. Great attention has been paid and is still being paid to increasing the quantity of food produced in Nigeria. It is gratifying to note that individuals and the government now know that great attention must also be paid to preserving what has been produced from spoilage if the goal of self-sufficiency is to be realized. Availability and utilization of tested, effective technologies is the answer to eliminating or reducing wastage in harvested crops. These technologies must be reviewed, modified or updated in the light of new discoveries in science and technology. Indeed, science and technology must continue to develop to provide man with 'safe' food in sufficient quantity. It is in this light that irradiation is a welcome addition to the technologies for food processing that will increase the shelf life and safety of food products.

POST-HARVEST LOSSES IN AGRICULTURAL CROPS

Magnitude and Consequences

All agricultural crops, whether of plant or animal origin, start deteriorating almost as soon as they are harvested. Deterioration may be rapid or slow depending on the nature of the crop and other factors which will be mentioned shortly. Deterioration leads to losses which have important consequences on food supply, the health, the economy and well-being of the nation. Post-harvest losses are still high throughout the world including Nigeria. Limited surveys carried out by NSPRI in the early 1980s estimate post-harvest losses to be about 10% for grains, 25% for roots and tubers and at least 30% for fruits and vegetables. An estimate of post-harvest losses in food and the monetary value of the losses is shown on Table 2.

It is certainly desirable, indeed imperative, that everything should be done to eliminate, or at least minimize, these losses in our harvested crops. Utilization of appropriate post-harvest technologies will contribute greatly towards this goal.

Advantages of Good Post-harvest Technologies

The advantage of utilization of suitable crop storage technology for agricultural crops include the following:

(a) Ensuring that high quality 'safe' flood is available to the citizens in sufficient quantities throughout the year for healthy and productive living.

(b) Ensuring that the nation has enough food in times of emergencies such as war, drought, flood, crop failure, e.t.c.

(c) Ensuring that high quality agricultural crops are available to the nation's agricultural industries.

(d) Preserving seed from season to season.

(e) Ensuring that high quality agricultural crops are available for national and international trade.

(f) Stabilizing prices of food throughout the year.

TECHNOLOGICAL APPROACH TO THE CONTROL OF POST-HARVEST LOSSES IN AGRICULTURAL CROPS

Development of effective technologies for a particular process depends on a thorough understanding of the problems surrounding the process, the methods available for solving the problems, the facilities available for solving the problems and the economics of the proposed technologies for solving the problems. With particular reference to post-harvest problems, development of effective technologies depends on understanding the nature of the crop, the factors causing or contributing to its deterioration and loss after harvest and the methods of controlling these factors under the prevailing environmental and socio-economic conditions in the country. The scientific and technical factors that cause or promote spoilage in harvested crops include:

(i) Physiological (metabolic) changes in the crop. The faster the metabolic changes taking place, the faster the rate of deterioration.

(ii) Chemical reactions taking place in the crop.

(iii) Physical factors such as mechanical damage.

(iv) Environmental factors particularly temperature and relative humidity.

(v) Biological factors, mainly the presence of micro-organisms, insects and rodents.

(vi) Engineering factors.

(vii) Duration of storage.

The technologies developed for post-harvest handling, storage and processing aim at eliminating or greatly minimizing the effects of the factors enumerated above in each crop to minimize spoilage. The relative importance of the various factors on the rate of spoilage varies from crop to crop and thus the technologies for storage may vary from crop to crop.

This paper concentrates on technologies presently used to control two major factors that contribute greatly to crop spoilage after harvest and which respond readily to manipulation by advances in technology; namely control of physiological processes and control of biological agents of deterioration.

TECHNOLOGIES FOR CONTROLLING PHYSIOLOGICAL CHANGES IN HARVESTED CROPS

Harvested crops are still living and metabolic changes associated with living continue, the most important of which is respiration. It is now known that the faster the rate of respiration, the faster the rate of deterioration of the crop. A major goal in reduction of losses in harvested crops is therefore to reduce the respiration rate of the crop to the minimum using suitable technologies.

Removal of Moisture from the crop:

This slows down the respiration rate considerably and thus prolongs the shelf life of the crop. It is the basis for the ease with which dry grains can be stored for long periods provided pests are excluded from the grain.

Cool Storage:

Cooling is perhaps the simplest and the most effective technology for reducing the rate of respiration and thus increasing the shelf life of perishable crops. It is by far the most effective technology for extending the shelf life of perishable crops. It has also been found to be very effective in suppressing sprouting and rotting in yam tubers and thus prolonging their shelf life.

However, use of cold storage for crops poses serious problems in Nigeria. Cold storage at regulated temperatures needed to achieve optimum shelf life requires mechanical refrigeration. This means high initial capital costs, often high cost of maintenance, the problem of power failure in Nigeria which may result in considerable loss to any user who stores under mechanical refrigeration unless he has a standby generator. Many rural areas in the country do not have electricity at all. Thus, mechanical refrigeration cannot at the moment be safely used for commercial storage of yam tubers or most fresh fruits and vegetables in Nigeria. However, the Institute recommends the use of evaporative coolers for commercial storage of fresh fruits and vegetables.

Controlled Atmosphere (CA) Storage:

This is an attractive technology for the control of respiration and thus extension of the shelf life of crops. It has been used to extend the shelf life of dry grains, fruits and vegetables. Controlled atmosphere technology has been successfully used for long-term storage of grains by NSPRI (Adesuyi et al, 1980; Williams et al, 1 980). However, inspite of its attractiveness and the excellent condition of grains stored using this technology, it has not yet been adopted for grain storage on a commercial scale in Nigeria largely because of the initial capital costs necessary to install the facility.

Use of Chemicals:

Chemicals have been experimented upon for suppressing growth in potatoes and onions to prolong their shelf life. Attempts have also been made to suppress sprouting in yam tubers by the use of chemicals. The only chemical which has shown some promise in suppressing sprouting in yam is gibberellic acid. Not all yam species respond favourably to its effect. Although required only in very small quantities, this chemical is now very expensive and cannot be considered to be economically feasible for the commercial storage of yams. More work is still being carried out on the use of chemicals to suppress sprouting in yam. Also some anti-microbial agents are currently used for post-harvest treatments of some fruits and vegetables to extend their shelf life.

TECHNOLOGIES FOR CONTROLLING BIOLOGICAL AGENTS OF DETERIORATION (PESTS)

The biological agents of deterioration of harvested crops, commonly referred to as pests, include micro-organisms, insects and rodents. Pests cause considerable damage to harvested crops. Their elimination or control constitutes a major aspect of crop storage technologies worldwide, especially in warm tropical countries.

It is now universally accepted that control of pests in crops is best carried out using the Integrated Pest Management (IPM) system which has been defined as:

> A pest management system that in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economic injury (FAO, 1967).

Components of the IPM include preventive methods, physical and mechanical methods, use of resistant varieties, biological control, use of electromagnetic radiation and use of chemicals.

Use of controlled atmospheres was mentioned earlier. The atmosphere used is deficient in oxygen and will therefore not support the respiration of aerobic organisms such as insects and rodents which infest the crop. If the crop is dry, the respiration of aerobic micro-organisms will also cease. This makes it possible to kill off aerobic organisms within minutes. It is an attractive technology that obviates the use of toxic chemicals and maintains dry grains in excellent conditions for years (Opadokun et al 1985).

Toxic chemicals have been extensively used for the control of pests of harvested crops over the years particularly in grains. They have several advantages over other methods of control. They achieve quick control, can be readily applied with little or no training over various surfaces and are generally readily available. Until recently, these chemicals were inexpensive. However, the use of toxic chemicals for pest control in food crops during storage raises some serious problems among which are:

a. Toxicity to users from toxic vapours or contact with the skin and eyes.
b. Toxicity to consumers of treated products due to high chemical residues.
c. Pollution of the environment with persistent pesticides
d. Tainting or discolouration of treated products
e. Widespread development of resistance by many pests to currently used pesticides.

Concern for public safety, public health and the environment has forced the international community to consider alternatives to the use of toxic chemicals for crop protection during storage. In fact, some of the chemicals formerly used in crop storage are no longer allowed on food crops by some countries. Ethylene dibromide, which has been widely used as a fumigant for insect control over the years, was banned by the US Environmental Protection Agency in 1984 (EPA, 1993). The use of methyl bromide (MB) once the mainstay of pest control in grains internationally, will no longer be allowed in the USA as from 31st December, 2000. This is because methyl bromide has been shown to have ozone-depleting property which is regarded as a serious environmental hazard. Ethylene oxide, another widely used fumigant in food ingredients, was banned by the European Union in 1991 (Dickman, 1991). The only other major fumigant now used for pest disinfestation internationally is phosphine. Reports of development of resistance to phosphine by many insect pests (Taylor et al 1986) raises alarm about the future of insect control in harvested crops with chemicals .

Beside, there are other problems peculiarly Nigerian in the use of toxic chemicals for pest control. These are unavailability of the right type of chemicals, widespread adulteration of what is available, misuse of chemicals and high cost of chemicals which, for the most part, are imported. For these and other reasons, alternatives to chemicals have to be found if pests are to be controlled in our harvested crops. Irradiation is one technology that is coming into prominence today for insect control during storage of agricultural crops.

FOOD IRRADIATION FOR REDUCING POST HARVEST LOSSES

The Process Itself:

Food irradiation is a physical process for the preservation of foods by use of ionizing radiation. Although this technology has been known for nearly 80 years, it is only within the last few decades that interest in food irradiation has revived and the potentials of the technology demonstrated through painstaking research, mainly in the developed countries. From research findings in recent years, it appears that food irradiation is an environmentally attractive post-harvest technique which is likely to become more and more important as a means of food preservation internationally. The potentials of ionizing radiation for food preservation include

a. Delay of senescence of living foods e.g. sprouting in yams and onions, delay of ripening in green bananas etc.
b. Inactivation of food spoilage micro-organisms
c. Control of insects in foods during storage
d. Sterilization of food

The process consists of exposing the food to the appropriate energy source (usually ^{60}Co) which gives ionizing gamma rays in such a way that a precise, predetermined dose is absorbed by the food being treated. The applied irradiation dose is measured in Kilograys (1 Gy = 1 J/kg).

PRACTICAL APPLICATIONS OF FOOD IRRADIATION RELEVANT TO CROP STORAGE AND PRESERVATION

Control of Sprouting and Germination:

Ionizing radiation has been used to inhibit sprouting in yam tubers, onions, garlic, ginger etc. The effective dose varies from 0.04 to 0.14 kGy depending on the crop and variety of the crop among other factors. Commercial irradiation of potatoes is now permitted by some countries. However, with some varieties of potatoes, irradiated potatoes darken on cooking. Also, irradiated potatoes are less resistant to rotting than non-irradiated potatoes.

Extending the Shelf Life of Fruit and Vegetables:

Exposure to low doses of gamma radiation (0.03 to 1. 0kGy) has been found to delay ripening or senescence of some fruits and vegetables and thus extend their shelf life. It has been found that the shelf life of mangoes can be extended by about one week and that of bananas by up to 2 two weeks by low dose irradiation (WHO, 1988).

Low dose irradiation also destroys some micro-organisms causing spoilage. Most food spoilage micro-organisms are killed at doses lower than 5kGy. However, only low doses should be used, otherwise the texture and the flavours may be adversely affected.

Low dose irradiation can destroy insects infesting fruits which could otherwise cause spoilage. The fruits that seem to be affected are citrus (fruit fly), mango (seed weevil, Sternochetus mangifera) and pawpaw (fruit fly). These insects can be controlled by irradiation with doses of 0.2 to 0.33 kGy. This is a particularly useful treatment in that fruit flies and seed weevil may lodge inside the seed of the fruit and cannot be controlled easily in any way other than killing the fruit itself. Fruits that have been irradiated and marketed successfully include mangoes, pawpaws and strawberries (WHO, 1988).

Disinfestation of Grains:

Irradiation at relatively low doses (0.5kGy) kills or sterilizes all the developmental stages of insects which infest grains, including eggs which are deposited inside the grain. Irradiation has been used for insect disinfestation of cocoa beans in Ghana (Amoaka -Atta, 1979) and reducing microbial population in cocoa beans at doses of 5kGy (Appiah, 1991).

Disinfestation of Dry Fish:

The major problem of dry fish storage is infestation with insects notably the hide beetle, Dermestes maculatus. Control of this infestation with residual insecticide as presently practised is not satisfactory because of toxic residues left on the treated fish. Irradiation appears to be the only acceptable method to control insect in dry fish, and is being used in Bangladesh
(Ahmed, 1990).

Control of Food Borne Diseases:

Irradiation, alone or in combination with other food processing methods can be used to control food borne diseases caused by micro-organisms such as Salmonella, Camphylobacter, Listeria, and Yersinia and parasitic organisms such as helminths. These food borne diseases adversely affect the health and productivity of populations world-wide and occur more commonly in foods of animal original such as red meat, poultry, pork and fish.

An irradiation dose of 2 to 7 kGy is generally sufficient to control these food borne pathogenic bacteria and helminths. It has been reported that meat, sea food and sausages have been sterilized by blanching, freezing and irradiation at 30 - 50 kGy for shelf stability for foods used in many manned space flights (Josephson, 1983).

FOOD IRRADIATION IN NSPRI

Work Already Done

Pioneering work on food irradiation was carried out in the Institute in the 1970s. The major work reported was on extending the shelf life of yam tubers with ionizing radiation. This work is reported in various journals.

The ionizing radiation source was a gamma irradiation unit with a sample chamber of 3.5 litres capacity. The yam species used was the white yam, Dioscorea rotundata Poir. The unbruised tubers were irradiated at doses ranging from 1 to 20 krad (0.01 to 0.2kGy) four weeks after harvest and initial curing. The irradiated yam tubers were then stored in the ventilated yam barn at ambient temperatures (27°C to 35° C) for eight months.

Adesuyi et al (1973, 1976, 1979) found that irradiation above 7.5 krad (0.075kGy) inhibited sprouting for eight months. Irradiation at dosages up to 15 krad (0.15kGy) resulted in lower degree of rotting than the control. The irradiation treatment also resulted in significant reduction in weight losses. All these lead to considerable extension in the shelf life of irradiated tubers up to at least eight months after treatment. Based on their findings, Adesuyi (1976) recommended that for optimum eating quality at the end of the storage life, yam should be irradiated at a dosage of 12.5 krad (0. 0125 kGy). Adesuyi's work suggests that irradiation is the most satisfactory method of suppressing sprouting of yam tubers in Nigeria. Other advantages of irradiation in extending the shelf life of yam tubers will be discussed shortly.

POTENTIAL OF FOOD IRRADIATION FOR REDUCING POST-HARVEST LOSSES IN CROPS RECOGNISED BY THE INSTITUTE.

Yam Storage

Although sprouting and rotting are generally regarded as the major problems in the storage of yam tubers, insects can sometimes contribute greatly to spoilage. One insect species that has been shown to cause considerable damage to yam tubers during storage is the yam tuber worm, Euzophrerodes vapidella described by Williams (1988). Infection by this insect on yam is not evident on the surface of the tuber which may in fact look very healthy. By the time the infection becomes evident, the tuber is totally destroyed. Since the infection is not evident on the outside, it cannot be controlled by chemicals. As yams cannot be safely stored at temperatures below 15°C, this insect cannot readily be controlled by cold storage either. Irradiation appears to be the easiest and most effective way of controlling this type of infestation. Thus, apart from suppressing sprouting and reducing rotting, irradiation will control insect infestation in yams thus ensuring maximum shelf life. This potential should be more thoroughly explored for this very important staple crop of Nigerians.

Suppressing Sprouting of Onions

Agbaji et al (1981) and Ogbadu (1981) found that gamma irradiation can be used to suppress sprouting in onions for up to seven months at the very low irradiation dosage of 0.05 to 0.15kGy. After irradiation, the onion can be stored in ambient conditions. This method of extending the shelf life of onions deserves further study for commercialising it.

Increasing the Shelf Life of Fruits and Vegetables

Pathogens are a major cause of spoilage in fresh fruits and vegetables. Insects are also occasionally important, low dose irradiation will reduce the microbial load in fruits and vegetables as mentioned earlier. Some insects which cause spoilage in fruits and vegetables actually develop inside the crop and their infestation is not evident on the outside of the fruit which may appear totally healthy. A notable example is the mango seed weevil, Sternochetus mangifera which causes considerable spoilage in some mango species. Such infections can not be controlled by chemicals as the infection is not evident on the surface and is deep seated. Heating the fruit to control the insect may actually destroy the fruit itself. Irradiation appears to be the best method of controlling this type of infestation.

One other potential of irradiation for extending the shelf life of fruits and vegetables is delaying ripening of some climacteric fruits such as bananas, plantains and mangoes. Although there are presently simpler and cheaper technologies for doing this than irradiation, future advances in irradiation research may make it possible to delay the ripening longer than can be accomplished by the present conventional methods.

Disinfestation of Grains

The two fumigants used for insect control in international trade in grains are methyl bromide and phosphine. Methyl bromide will not be available after the year 2000. Many insects have developed resistance to phosphine and it may be difficult to control these insects with phosphine in future. Obviously, alternatives to the use of chemicals as fumigants must be sought.

Controlled atmosphere storage technology is an attractive alternative but this is not yet adopted in Nigeria almost certainly because of high initial capital cost. Irradiation is a welcome addition although this also is a capital intensive technology. But as the use of toxic chemicals decreases, or is banned altogether and if the cost of irradiation also decreases, this technology will be found attractive for insect disinfestation in the future. Also, it may be difficult, if not impossible, to trade some grains in some countries if the grains are treated with toxic chemicals. They may have to be irradiated to control insect infestation.

Although not yet used in Nigeria, irradiation is currently being used for disinfestation of cocoa beans in Ghana (Appiah, 1988). Nigeria can benefit from such experience. The control of mouldiness in cocoa is a serious problem in the very humid parts of the country where the crop is grown and from where it is exported. Disinfestation by irradiation may well lead to substantial reduction in losses in this highly priced crop from which the country earns reasonable amount of foreign exchange.

Disinfestation of Dry Fish

Control of insect infestation on dry fish has been a problem for sometime. Because of the nature of the crop, residual insecticides on fish are not really advisable as the crop may be eaten anytime after treatment and the insecticides cannot be washed off readily. Although fumigants like phosphine may be used, even this is not satisfactory. Irradiation appears to be a really attractive option for disinfestation of this highly priced food commodity.

PROSPECTS OF FOOD IRRADIATION IN NIGERIA TO CONTROL POST-HARVEST LOSSES

Any food preservation technology will be utilized by people when the advantages outweigh its disadvantages from various considerations. These considerations include effectiveness, safety, public health, convenience and cost. It is appropriate to consider the advantages and disadvantages of food irradiation.

ADVANTAGES

Broad spectrum method for reducing post-harvest losses

Irradiation is a broad-spectrum method of reducing post-harvest losses in agricultural crops whether it be of plant or animal origin. It is a welcome addition to the technologies presently available for fumigation of grain before storage. Irradiation gives more uniform treatment than fumigation with presently known fumigants, it is less time consuming and leaves no toxic residues in the produce treated. As the major fumigants are withdrawn from use due to toxicity, environmental pollution or ineffectiveness due to development of resistance, disinfestation by irradiation will no doubt become more important for treating grains. For countries that have to trade in grains internationally, irradiation may be the only acceptable method for pest disinfestation in the near future.

As stated earlier, irradiation appears to be the best method of suppressing sprouting in yam tubers and thus extending its shelf life. Irradiation is expected to play increasingly important role in the extension of the shelf life of fruits and vegetables in future through delay in ripening and control of pathogens.

Controlling food-borne diseases

Irradiation is a very important method of controlling food borne diseases especially those transmitted through animal products. A meeting of the Task Force on The Use of Irradiation to Ensure Hygienic Quality of Food in Vienna in July 1986 came to the following conclusion:

> "At present, and in the foreseeable future, no technology is available to produce raw foods of animal origin, particularly poultry and pork, in which the absence of certain pathogenic micro-organisms and parasites such as Salmonella, Camphylobacter, Trichinella, Toxoplasma etc. can be guaranteed. Where such foods are important in the epidemiology of food borne diseases, irradiation decontamination/dis-infestation must be seriously considered" (WHO, 1986)

Irradiation is thus a very important method of increasing the microbiological safety and shelf life of foods.

Hygienic Packaging is possible through the use of irradiation

Most foods can be irradiated in the final packaging including packages that cannot withstand heat. This is of great advantage in preventing recontamination of irradiated food. Irradiation is particularly suitable for technical treatment of hermetically packaged food without the risk of recontamination. Most modern packaging materials are resistant to irradiation (Kilcast, 1995).

Increase in International Trade in Foods

Irradiation has potentials to increase world trade in fresh foods. Many advanced countries demand high quality fresh fruits, vegetables, fish and meat and are prepared to pay for them. In order that these crops may arrive at their destinations in healthy conditions from the exporting countries, treatment with ionizing radiation, alone or in combination with other treatments, will increase their safety and shelf life for international trade.

Quarantine Treatment

Irradiation is a very good treatment for plant products for quarantine purposes. With the banning of ethylene dibromide and ethylene oxide and the impending withdrawal of methyl bromide from the market by the year 2000, irradiation offers the most viable alternative to meet plant quarantine requirements against some insects.

DISADVANTAGES

Consumer Acceptance of Irradiated Foods

The first requirement of any substance to be considered as food is its microbiological and chemical safety for consumption. There is still fear among large sections of the population about the safety of irradiated foods. It is feared that because irradiation is associated with nuclear technology, irradiated food may in fact be radioactive. There is also concern among potential consumers that irradiation may result in the generation of radiolytic compounds of unknown toxicity in addition to development of radiation resistant strains of micro-organisms. In spite of its obvious technical advantages over other technologies for food preservation and processing for certain foods, this technology is not yet widely accepted worldwide mainly because of this fear. And irradiation cannot be a marketing success unless it can be accepted by consumers.

However, it seems this fear is misplaced in the face of overwhelming available scientific evidence. On the safety of irradiated foods, one can only reiterate the conclusion reached by the joint FAO/IAEA/WHO. Expert Committee on the Technical Basis for Legislation on Irradiated Food at its Geneva meeting in 1980 when it was presented with abundant evidence from research data:

> "The irradiation of any food commodity up to an overall average dose of 10kGy presents no toxicological hazards, hence toxicological testing of foods so treated is no longer required. Irradiation of food up to a dose of 10kGy introduces no special nutritional or microbiological problems."

The most recent Expert consultation in 1992 also affirmed this conclusion (WHO, 1994). These conclusions and recommendations were elaborated into an international standard by the Codex Alimentarius Commission in 1983 and passed to all its members for acceptance in 1984.

On consumer acceptance of irradiated foods, it is worthwhile pointing out that recent surveys carried out in some developed countries suggest that consumers will accept irradiated food if they can be persuaded about its safety and appreciate the benefits of irradiation (O' Connor 1989). However many people, even in the developed countries, are still ignorant of this technology.

Knowledge of food irradiation and its potentials to the consumers is still scanty in Nigeria and probably limited to researchers in this field. The reaction of a few people outside researchers in the field on this issue has been hostile. Education of the public is crucial to the adoption of irradiation as a post-harvest technique in Nigeria.

Technical Limitations of Food Irradiation

While food irradiation solves some specific problems of food losses, it is not applicable to all foods. Dairy products such as milk and butter develop off flavours when treated by irradiation. Also at the low irradiation recommended for treating foods, irradiation will not destroy all microorganisms or their toxins. Low-dose irradiation will not destroy all bacterial spores or bacterial toxins. Thus, foods prone to contamination by such micro-organisms or toxins must be handled in accordance with good manufacturing practices prior to and after irradiation processing.

Economics of Food Irradiation

Before irradiation can be accepted as a technology for food preservation and processing, it should be as economical or more economical than other competing technologies. Food irradiating processing requires heavy investment to set up. This includes the cost of infrastructures such as land, building, water, electricity as well as the cost of irradiation plant and accessories. The source must be installed in a shielded cell specially designed to prevent exposure of personnel to radiation, these costs run into millions of dollars. Irradiation also needs highly trained personnel to operate it as well as regulatory system to ensure that the process is carried out correctly. Although it is reported that irradiation has low operating cost, the initial capital cost may be prohibitive for many developing countries and will no doubt limit the use of this technology for sometime whatever the technical advantages.

However, it has been observed that the number of countries that use irradiation for food processing commercially has been increasing in recent years; 19 in 1987 and 28 in 1994 (Loaharanu, 1995). Some developing countries have joined other developing countries in installing irradiation plants as shown in Table 3.

As the use of chemicals in food preservation gets reduced as a result of prohibition, development of resistance or for some other reasons, irradiation may become inevitable for crop protection for some crops after harvest in future. Further developments in science and technology may also greatly reduce the cost of irradiation and make it more competitive with other means of food preservation in the not-too-distant future.

Detection of Irradiated Food

Many opponents of food irradiation insist that in order to protect consumers from the hazards of food irradiation, reliable methods are needed to detect what foods are irradiated, and at what levels. It is a fact that abuses in the use of irradiation are possible and can have disastrous effects. Reliable methods of detection will minimize this.

However, inspite of many years of research, there is as yet no simple method of detecting whether food has been irradiated or not. Three methods have been recently developed for control purposes but these are by no means simple. They are Electron Spin Resonance (ESR), thermoluminiscence (TL) and detection of lipid breakdown volatiles (e.g akylcyclobutanones and hydrocarbons). Even these are applicable only to certain categories of foods. The ESR is currently limited to foods containing bone. The TL is applicable mainly to dried products while detection of lipid breakdown products is limited to fat-containing foods (Kilcast, 1995). The three methods are capital intensive and require a great deal of expertise. More research is needed to develop detection techniques that are specific to irradiation and that can be routinely carried out with modest investment. Other potential detection methods are shown on Table 4.

Nature of Nigerian Agriculture

Small scale farmers still constitute the bulk of the farming population in Nigeria producing over 80% of the total crops grown in the country. The individual farmer produces small quantities of produce and store part of what is produced on the farm. If post-harvest losses are to be greatly reduced in the country, the small-scale farmers must be given priority attention and technologies for crop storage must be those they can readily use on the farm.

The Federal Government of Nigeria recognised this and has given special attention to these farmers, especially over the last few years. The Federal Government gave a special mandate to NSPRI in 1989 to construct and install small scale storage facilities for on-farm storage of crops throughout the country and to train a core of extension workers on the use of these facilities for storing their crops on the farm. This mandate was executed between 1990 and 1994. At the moment, irradiation can not yet be considered for on-farm storage of crops in Nigeria.

It has been observed (WHO, 1988) that food irradiation is economically feasible only when there is a fairly large quantity of produce to be processed. It is not economical for small-scale storage. It is possible that farmers may be encouraged to organise themselves into cooperatives to benefit from irradiation. Further, small-scale, mobile, multi-purpose irradiation facilities may become available in future. If the safety of such machines can be guaranteed and the equipment can be made affordable, this may be worth considering in future even on the farm. Otherwise, irradiation may have to be limited to central storage at central depots and at the ports where large quantities of crops such as cocoa are exported.

On the irradiation of fruits and vegetables, a major requirement is the adoption of a good post-harvest system that involves good manufacturing practice from harvest to consumption.

The Situation of Food Irradiation Research in Nigeria

Reasonable amount of work has been done on food irradiation in Nigeria mainly on yams and onions. Because of the heavy capital investment needed, not much work is being done on food irradiation since the pioneering work in 1970s. Nigerian researchers need to carry out more studies to understand this technology better, investigate various problems surrounding the technology under Nigerian conditions and be in a position to answer nagging questions from potential users of this technology as well as consumers. It is hoped that this workshop will serve as a forum to launch a programme of extensive research in food irradiation in Nigeria in the near future.

CONCLUSION

After nearly 40 years of research, it has now been established that irradiation is a valuable physical food processing technique that is a welcome addition to technologies available to reduce post-harvest losses in agricultural, particularly food crops, world-wide. For some food commodities like yams and dry fish, irradiation is about the only method that can truly extend their shelf life. For commodities like grains, irradiation may replace other methods of disinfestation to ensure safety in the near future. For some fresh fruits and vegetables, this technology promises to become more important in future for extension of shelf life.

Fears about the safety of irradiated food appears misplaced in the face of overwhelming evidence from extensive research findings to the contrary. However, education of the Nigerian public is crucial to the adoption of this technology in the country, while further research continues on making the technology affordable. International community should play an important role in supporting research and education in Nigeria to make consumers accept this promising technology for reduction of post harvest losses in our food crops.

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TABLE 1: ANNUAL PRODUCTION OF MAJOR CROPS IN NIGERIA (1991 - 1993)

	ANNUAL PRODUCTION (1000MT)		
CROP	1991	1992	1993
Maize	1900	1700	2300
Millet	3497	3200	3800
Rice (Paddy)	3185	3453	3400
Sorghum	4346	4100	4800
Cocoa beans	110	135	140
Pulses	441	508	508
Cassava	20000	21320	21000
Yams	15603	18500	20000
Cocoa beans	110	135	140
Tomato	380	390	400
Banana	1050	1050	1050
Citrus	2100	2150	2200
Green Pepper	850	880	900
Mangoes	500	500	500
Pawpaw	500	500	500
Pineapples	800	800	800
Plantain	1314	1454	1400

Source: FAO (1994).

TABLE 2: POST-HARVEST LOSSES IN SELECTED CROPS IN NIGERIA

CROP				POST-HARVEST LOSSES	
	1993 ANNUAL PRODUCTION (1000MT)	ESTIMATED COST PER TON (N)	%	ESTIMATED QUANTITY (1000MT)	MONETARY VALUE (NM)
Maize	2300	10000	10	230	2300
Millet	3800	10000	10	380	3800
Rice (Paddy)	3185	12000	5	159.3	1593
Sorghum	4800	10000	10	480	4800
	14085			1249.3	
Yams	20000	5000	20	4000	20000
Tomato	400	20000	30	120	2400
Banana	1050	10000	30	315	3150
Plantain	1400	10000	30	420	4200
Total losses					**42243**

*FAO (1994)

TABLE 3: COUNTRIES WITH COMMERCIAL FOOD IRRADIATION AS AT JANUARY, 1994.

COUNTRY	LOCATION	PRODUCTS
Argentina	Buenos Aires (1985)	Spices, spinach, cocoa
Bangladesh	Chittagong (1983)	Potatoes, onions, dried fish
Belgium	Fleurus (1981)	Spices, dehydrated vegetables, deep frozen foods
Brazil	Sao Paulo (1985)	Spices, dehydrated vegetables
Canada	Laval (1985)	Spices
Chile	Santiago (1983)	Spices, dehydrated vegetables, onions, potatoes, poultry, meat
China	(10 centres between 1978 and 1991)	Spices, vegetable seasonings, chinese sausage, garlic, apple, potatoes, onions, dehydrated vegetables, tomatoes.
Croatia	Zagreb (1985)	Spices, rich, food ingredients.
Czech Republic	Prague (1985)	Spices, dry food ingredients.
Cuba	Havana (1987)	Potatoes, onion, beans
Denmark	Riso 91986)	Spices
Finland	Ilocatsi (1986)	Spices
France	8 centres (1982-1992)	Spices, vegetable seasonings, poultry, dried fruits, forzen frog legs, shrimp
Hungary	Budapest (1992)	Spices, onions, wine cork, enzyme.
Indonesia	2 centres (1985, 1992)	Spices
Iran	Tehran (1991)	Spices
Israel	Yavne (1986)	Spices, condiments, dry ingredients
Japan	Hokkaido (1973)	Potatoes
Korea, Rep.	Seoul (1988)	Garlic powder, spices and condiments
Mexico	Mexico city (1988)	Spices and dry food ingredients
Netherlands	Ede (1981)	Spices, frozen products, poultry, dehydrated vegetables, rice, egg powder, packaging material
Norway	Kjella (1982)	Spices
Phillipines	Quezon city (1989)	Not specified
Poland	3 centres (1984-1991)	Not specified
South Africa	6 centres (1968-1986)	Potatoes, onion, fruits, spice, meat, fish, chicken
Thailand	2 centres (1971, 1989)	Potatoes, pork sausages, enzymes, spices.
Ukraine	Odessa (1983)	Grain
United Kingdom	Swindon (1991)	Spices
United States of America	6 centres (1980-1993)	Spices, strawberries, poultry, fruits, vegetables
Yugoslavia	Belgrade (1986)	Spices

FACILITIES UNDER CONSTRUCTION

Algeria	Mascara	Potatoes
Cote D'Ivoire	Abidjan	Yams, cocoa bean
	Bombay	Spices
India	Nasik	Onion
Vietnam	Hanoi (1991)	Onion, potatoes, seafood, spices, rice

* Adapted from Loaharanu (1995)

TABLE 4: POTENTIAL METHODS OF DETECTING IRRADIATED FOODS

FOOD	TECHNIQUE
Chicken	ESR, Lipid derived volatiles
Citrus and other fruits	Inhibition of seed germination
Herbs, spices, dehydrated vegetables	Thermoluminiscence, Chemiluminiscence, Viscometry
Potatoes	Electrical impedance
Strawberries	Electron Spin Resonance (ESR)

* Adapted from Delincee (1991).

THE USE OF GAMMA IRRADIATION IN ROOT AND TUBER CROPS IMPROVEMENT BY MUTATION INDUCTION

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Abstract

Root and tuber crops, notably, the yams and cassava are difficult to improve by hybridization and selection because of problems associated with flowering and seed set. It has been shown that they could be improved genetically through mutation induction, by gamma irradiation.

In the white guinea yam, a preliminary work to develop methodology for mutation induction and isolation has been concluded and a large population of irradiated white yam seedlings has been established in the field for screening for dwarfiness, high yield and resistance to major pests and diseases.

In the cassava, 14 cassava mutant lines have been isolated for low HCN contents from irradiated high HCN containing but very high yielding cassava varieties and 22 lines have also been selected for high dry matter content.

Introduction

Gamma irradiation has found useful application in the preservation of food and agricultural products for the industry, in sterilizing and decontamination of medical and pharmaceutical products and packages. To an agricultural crop scientist, gamma irradiation has found use in another way and purpose. It is being used extensively to produce high yielding and disease resistant varieties through mutation in plant.

The root and tuber crops, notably the yams, cassava and the cocoyams has over the years been propagated vegetatively through the segmentation of their stems, tubers, corms or cormels (Onwueme, 1978). Because of this, they have lost the ability for efficient sexual reproduction (Ammirato, 1984). This condition has made the genetic improvement of the crops by hybridization and selection very difficult. In the D. rotundata for example, many good and important cultivars have never been known to flower (Sadik and Okereke, 1975). The aim of crop breeding (selection) is to generate new productive commercial varieties. To do this, the breeder creates new lines (variations) and selects materials corresponding to the breeding objectives.

However, because of the flowering and hybridization problems as well as limited genetic variability available in the root and tuber crops germplasm, it becomes imperative to seek and utilize other asily available genetic improvement technologies to supplement hybridization.

Induced mutations by gamma irradiation have been used for breeding purposes in several vegetatively propagated plants (Ancora and Sonnino, 1987) and up to date, several commercial varieties from diverse crop species have been developed and released through mutation induction (Gustafsson, 1947, Mackey, 1956, Micke, et al, 1985 and 1987, Wang, 1991). It's potential in improving tropical root and tuber crops genetically has been recognized by the International Atomic Energy Agency, Vienna (IAEA, 1987).

When to Use Mutation Induction

Mutation induction can alter any trait and may be used by the breeder for any purpose or objective. However, there are conditions or situation where induced mutation can be applied as a tool for crop improvement. These situations include a condition when a well adopted good variety or cultivar requires improvement in one or two deficient characters leaving the rest of the genome essentially untouched. Also, mutation induction can be used to improve genetically vegetatively propagated crop species which cannot be crossed easily and particularly where flowering and seed set is a problem.

Another area where mutation induction can be used is where a trait or particular characteristic is lacking in the germplasm and therefore needs to be induced. Mutation induction is also used re-creating increased genetic variability in situations where there is narrow genetic variability for the characteristic being sought.

Most of the areas enumerated where improvement may be achieved by induced mutation exist in the root and tuber crops thus supporting the interest in their improvement through gamma irradiation.

Breeding Objectives for the Yams and Cassava

Success in any breeding programme starts with the identification of sets of achievable objectives and the development of appropriate breeding procedure to achieve the objectives. Thus, the objectives breeding yams and cassava are:-

(i) To produce yams with
- (a) High yield (tuber);
- (b) High dry matter content;
- (c) Erect dwarf shrubby vegetation that may not require staking for high yield and suitable for inter-crop.
- (d) Resistance to pests, nematode and yam beetle.
- (e) Resistance to diseases.

(ii) To produce cassava with
- (a) High yield
- (b) High dry matter content
- (c) High starch content
- (d) Low hydrogen cyanide (HCN) content
- (e) Hairy young leaves associated with resistance to cassava mealybug.
- (f) Resistance to cassava bacterial blight, CBB, ACMV, CAD.

What Has Been Done:

Yams (D. rotundata)

A preliminary ground work for mutation induction by gamma irradiation has been done using the following yam plant parts: mini-tubers, yam true seeds and in-vitro growing yam plantlets. The first activity was the determination of the radiosensitivity range for the various types of plant parts (Table 1). Presently, a large population of irradiated white yam has been established in the field for screening for dwarfiness, high yield and suitability for inter-crop.

Cassava:

The gamma radiosensitivity range for various cassava plant parts has been determined (stem cuttings 20-30Gy, cassava plantlets growing in-vitro, 20-25 Gy) (Table 1). One of the objectives of cassava breeding programme is the production of cassava lines with low cyanogenic levels. Most of the very high yielding cassava varieties are high in HCN contents. None of the low HCN containing cassava varieties developed are high yielding, comparable to high HCN conforming ones. Mutation breeding usually aims at changing one or two heritable characters of usually a well-adapted, unique and popular variety, (Micke, et al, 1987), and thus suited for cynogenesis breeding.

Thus, it is a matter of changing the gene for high HCN content to low HCN of the high yielding varieties without affecting their yield potentials. Fortunately, characters that can easily be bred by mutation induction are characters controlled by recessive genes and such characters in cassava e.g low cyanogenic content, high dry matter and starch contents and quality are controlled by minor recessive genes and can easily be introduced into a variety without loosing the general characteristics of the variety.

To induce low cyanogenic levels in cassava, by mutation induction, three locally adapted and high yielding varieties, TMS 30572, NR 8817 and NR 84111 were exposed to 20, 25 and 30Gy gamma radiation. From the irradiated cassava population at MV_2 (second mutated vegetative phase), 14 cassava mutant lines were selected for low HCN (Table 2) contents and 22 lines were selected for high dry matter content. These lines are being tested in replicated yield trials.

CONCLUSION

Mutation breeding by gamma irradiation is going to play a major role in varietal development in the root and tuber crops more especially, in the yams where hybridisation is difficult. The major objective of breeding is yam development through the creation of new yam lines that are dwarfy, possess erect vegetation, may not require staking and suitable for inter-crop. These characteristics are not available in the Nigerian yam germplasm. Therefore the option left is to induce those character by gamma irradiation.

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TABLE 1: The gamma radiosensitivity range and plant material used for the induction of mutations in yam (D. rotundata) in cassava.

PLANT MATERIAL TREATED	GAMMA DOSE RANGE (Gy)
<u>Yam:</u>	
Mini-tuber	20 - 40
Plantlets (in-vitro)	25 - 30
<u>Cassava:</u>	
Stem cuttings	20 - 30
Plantlets (in-vitro)	20 - 30

TABLE 2: Cassava mutant lines selected for low hydrogen cyanide content in the root tuber flesh

Mutant line	HCN Score	HCN Content (ppm)	% Dry Matter	% Starch content
30572/30/002 (2)	4	25-40	31.10	19.30
30572/30/004 (1)	3	15-25	31.20	25.00
30572/30/005 (5)	4	25-40	30.00	20.80
30572/30/007 (4)	3	15-25	37.00	24.10
30572/30/007 (8)	3	15-25	34.00	19.30
30572/30/072 (6)	3	15-25	40.00	15.00
30572/30/008 (8)	3	15-25	33.80	22.30
30572/20/010 (1)	3	15-25	15.40	15.20
30572/20/010 (2)	4	25-40	32.40	12.20
30572-Control	-	-	35.00	12.20
8817/30/004 (2)	3	15-25	34.40	21.30
8817/25/009 (3)	4	25-40	24.50	11.60
8817/20/003 (5)	3	15-25	28.50	13.50
8817-Control	-	-	28.00	23.60
81111/25/[illegible] (6)	2	10-15	34.00	20.50
[illegible]/20/[illegible]	2	[illegible]	36.30	22.30
[illegible]		-	[illegible]	[illegible]

TABLE 3: Cassava mutant lines selected for high dry matter (DM) content

Mutant Line	DM (%)	Starch Content(%)	HCN Rating
30572/30/001 (6)	42.00	28.00	M
30572/30/003 (3)	40.00	23.60	M
30572/30/007 (7)	40.00	15.00	L
30572/25/004 (3)	40.00	22.00	M
30572/25/002 (3)	40.40	20.60	M
30572-Control	35.00	22.00	L
8817/25/002 (3)	31.90	18.30	M
8817-Control	28.00	16.30	L
84111/30/008 (2)	40.00	17.50	M
84111/25/001 (1)	40.80	20.00	M
84111/20/001 (7)	40.00	24.60	M
84111/20/003 (7)	40.00	21.30	M
84111/20/006 (4)	40.00	24.60	L
84111/20/006 (9)	40.30	19.90	M
84111/20/007 (3)	40.40	24.30	M
84111/20/009 (1)	42.30	22.60	M
84111/20/009 (4)	40.30	20.00	M
84111/20/010 (2)	41.30	23.20	M
84111/20/010 (3)	41.30	21.30	M
84111/20/011 (1)	41.30	21.50	M
84111/20/011 (5)	40.80	21.30	M
84111/20/011 (6)	40.90	23.00	M
84111/20/011 (8)	40.80	20.10	M
84111/20/011 (10)	42.70	22.70	M
84111-Control	36.10	23.60	M

PROBLEMS ASSOCIATED WITH STORAGE OF COCOA FOR EXPORT

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Abstract

Between cocoa farmsteads and Nigerian ports of shipment, fermented dried and bagged cocoa beans (seeds) meant for export are usually kept in stores of varying designs and capacities. Some inadequacies in these storage facilities, especially poor-ventilation and sometimes leakage in small stores and sub-standard warehouses, as well as the use of old jute bags often aggravate the familiar problems of deterioration associated with cocoa consignments awaiting shipment. Such problems include fungal infection, insect/rodent infestation and contamination of stored cocoa produce with pesticide residues. All these result in fall of the original high grade of export-cocoa and inevitable loss of revenue to Nigerian exporters, by the time the consignments of produce get to the importing countries. Methods of minimising these losses including the probable use of irradiation technology are suggested and discussed.

Introduction

In the last five years, about two hundred thousand tons of dry and fermented cocoa beans were produced annually, in Nigeria. Out of these, about 130,000 tons consisting of Grade I and II cocoa were exported to Europe and the United States of America each year. According to international standards exported cocoa consignments should maintain the following grading standard, among many others, by the time they get to the importing countries.

i.	Average Bean Weight:	about 1.0 gramme
ii.	Moisture content:-	6 - 7%
iii.	Mouldiness:	3 - 4%
iv.	Slaty/flat bean contents	3 - 8%
v.	Insect damaged/Germinated bean content	3 - 6%
vi.	Free Fatty Acid (FFA):	less than 1%
vii.	Pesticide residues:	Very low; 0.01 - 1.0gm/kg cocoa bean depending on the Pesticide used
viii	Foreign bodies (stones, animal dungs, urine etc.).	Preferably Nil.
ix.	Bag type and condition:-	New and undamaged jute bags.

To meet the standards listed above, fresh mature cocoa pods and beans are passed through various stages (harvesting, extraction, fermentation, sun-drying/air-drying, sorting, bagging and storage) of primary processing. In Nigeria, these various stages of primary processing are carried out manually and predominantly by peasant farmers, the Licenced Buying Agents (LBA) and their middlemen. The dexterity with which the various category of handlers conduct the different stages of primary processing determines the quality of cocoa beans produced. Along the line, varying quantities of exportable cocoa beans produced are kept in containers and stores of different types of materials, sizes and construction, which often contribute to the familiar problems of mouldiness, insect/rodent infestation, and contamination associated with exportable cocoa. For example, in the farm, village or even township, cocoa beans undergoing primary processing could be kept in baskets, earthenwares, plastic containers, and old jute bags or stored in very small and often poorly ventilated rooms. Even after selling to the LBA, bagged cocoa may be stored in fairly big but improvised stores with leaking roofs, with cracks and crevices on their floors and in their walls - all of which facilitate insect/rodent infestations and mouldiness of the cocoa beans, with consequent deterioration in quality of affected produce. Invariably, cocoa farmers and traders in their bid to make brisk business with overenthusiastic but less experienced exporters, pay less attention to the lapses highlighted above at the expense of the overall quality of the produce meant for export. In some years with prolonged wet season, inclement weather also aggravates these problems as shown later in this presentation.

PROBLEMS

As noted above, the five major problems associated with cocoa meant for export are mouldiness, insect infestation, moisture absorption, pesticide/rodent-related contamination and substandard or deficient storage facilities.

Mouldiness

In commercial cocoa mouldiness is the detectable presence of fungal mycelium or fruiting bodies on, or inside the cotyledons of the cocoa beans (seed). Oyeniran (1980) recorded over thirty fungal species at four different stages of processing and handling of cocoa beans as follows:

Fresh Seed Extraction Stage

During pod-breaking and fresh-seed extraction stage, the most prominent mould fungi are Botryodiplodia theobromae and Macrophoma species which are weekly parasitic or saprophytic. These are usually found on beans extracted from diseased cocoa pods (Blackpod and Dry-rot diseases) or pods damaged in the cocoa farm by pod-boring insects and rodents. Infected fresh beans are usually black or dark black or dark brown, and are therefore easy to identify. However, thrifty and less experienced handlers often bulk these infected beans with healthy ones for fermentation, and thereby promote cross infection of the healthy ones. This practice is detrimental to the quality of the produce obtained thereafter particularly when fermentation is done under cool weather.

Fermentation Stage

The most important mould spp. during fermentation are Aspergillus fumigatus and Mucor pusillus, which are thermophilic fungi. Prolonged fermentation (more than five days) without mixing the beans intermittently in the fermentation container, promotes internal penetration and mouldiness of the beans by these fungi. Very wet and cool weather, by prolonging the period of fermentation, could aggravate the intensity of fermentation mouldiness. Indoor facilities (small room or store) which, usually, in warmer than the open yard/shed environment, could reduce the problem during prolonged very wet season with cool weather.

Drying Stage

Mouldiness also occurs during drying of fermented beans and this could be caused by Aspergillus flavus. A. tamarii, A. niger and Rhizopus arrhizus. The rate of drying affects the rate at which moisture content of beans decreases, and this in turn determines the rate of and intensity of mouldiness. Slow - drying favours mouldiness whereas rapid drying within 4 - 5 days, to the appropriate moisture content of see 5 to 6.7% confers extra protection from those mould-fungi carried over from the fermentation stage. Again, this problem could be aggravated in years with prolonged wet and cool weather. It is more pronounced in Cross River and Akwa Ibom States where rainfall is much heavier and prolonged than in other cocoa producing areas of Nigeria. The use of artificial air-drying equipment could minimise deterioration at this stage of primary processing.

Mouldiness in the Store:

Xerophytic moulds such as Aspergillus chevalier A. ruber and A. penicillocides may also cause mouldiness in cocoa stored in very humid stores and warehouses. Dry cocoa beans, because they are hygroscopic, would absorb moisture from its immediate environment, when stored under very humid conditions. The amount of moisture absorbed and the level of internal mouldiness of the beans usually increase with ambient Relative Humidity (RH). Oyeniran (1979) showed that at store RH of 65 - 75%, moisture content of stored cocoa beans ranged from 6.4 - 7%, while internal mouldiness ranged between 0 - 3%. Whereas, at RH of 81 - 98% moisture content of beans increased rapidly from 8.5% - 17.6%, while internal mouldiness peaked from 15 - 95.5%. Any store or warehouse whose design and management encourage high build up of ambient relative humidity above 75%, are therefore undesirable. Peripheral bags in stacks of cocoa are more susceptible to high ambient moisture than those inside the stack. Arrangement of cocoa bags on wooden platforms off the concrete floor of the store or warehouse, and away from the wall will give room for free circulation of air. Adequate ventilation facilities during storage and mending of store wall and roof defects before the onset of rains and before stocking the stores would also minimise storage mouldiness.

Insect and Rodent Pest Problems:

Most of the moths and beetles which affect the quality of cocoa produce are stored product insect pests. The most important among them are, the cigarette beetle, Lasioderma Zorricorne, the Tropical warehouse moth, Ephestia cautella, the Rust-Red flower beetle, Tribolium castaneum, the Flat-grain beetle, Crypto-lestes sp and the mould feeders. Ahasverus advena, and Carpoptailus species. (Cornes Majule 1980).

These storage insect pests affect cocoa beans in the following ways:

(i) They bore holes into, and break cocoa beans.

(ii) They feed on cocoa beans content and cause weight loss.

(iii) They live their waste products (frass and webs) behind and adulterate the produce.

(iv) High insect infestation causes increase in temperature and moisture content which predispose the cocoa beans to mouldiness, and increase the production of free fatty acid.

(v) Insect infestation makes cleaning and separation of extraneous materials difficult.

(vi) Presence of insects or their body parts in processed cocoa products is unacceptable to consumers and causes depreciation of such products.

Insect pests infestations start during sun drying especially under very dull weather when the rate of sundrying is slow. It occurs also during storage, particularly in substandard stores where ventilation is poor, the standard of store-hygiene is low, and roof-leakage and wetting of store floor or walls occur. During slow sun drying especially under very dull weather when the rate of sundrying is slow. It occurs also during storage, particularly in substandard stores where ventilation is poor, the standard of store-hygiene is low, and roof-leakage and wetting of store floor or walls occur. During slow sundrying, infestation occurs from reservoir of storage insect pests concealed in crevices of damaged concrete drying floors, mats and tarpaulins used for spreading or covering the beans. Insect pests also hide in baskets and old bags used for conveying beans in and out of stores during drying and inside cocoa stores, which in the farmsteads and villages, are invariably small, dark and poorly ventilated rooms. Storage moths and beetles thrive well under these conditions. So also do domestic rodents, particularly house rats which not only feed on dry cocoa beans but contaminate them with their dungs and urine which adversely affect the quality of beans. To minimise losses arising from insect and rodent damages, high farm and store hygiene should be maintained. Furthermore, at the beginning of the dry season (i.e. the peak period for buying and selling cocoa produce) crevices and patches in the drying concrete floor should be patched with cement in order to dislodge and eradicate reservoirs of storage insect pests which survived the previous season. So also should crevices and holes in the walls of stores be patched. The drying mats, baskets, old cocoa bags, tarpaulin sheets and walls of storage rooms and warehouses should also be disinfected by beating, sweeping or spraying with recommended insecticides and the stores/warehouses swept clean before new consignments of bagged cocoa are stored in them. The efficiency with which the above operations are executed would go a long way to determine the level of infestation of in-coming fresh cocoa produce. However, overuse or misuse of emusifiable concentrate formulation of pesticides for store disinfestation by over-zealous farmers and Licensed Buying Agents should be discouraged because this may result in tainting and off flavour of cocoa produce arising from pesticide residues. Pre-shipment disinfestation of produce in a standard warehouse is usually one with gaseous insecticides such as Phosphine (from Aluminum phosphide) and methyl bromide. The fumigation is also usually carried out by trained personnel of the State and Federal Produce Inspection Services. However, appropriate preventive measures against gas poisoning, especially post treatment aeration of fumigated warehouse must be taken always.

IONIZING RADIATIONS AND STORED PRODUCT INSECTS

Two major constraints to the use of Methyl bromide and Phosphine gases are:

1) the world-wide campaign against the use of Methyl bromide because of its adverse ozone-layer effect and

2) the potential development of resistance to phosphine by stored product insect pests. One way of forestalling these problems is by exploitation of irradiation technology for disinfestation of cocoa consignments meant for export.

In Nigeria, Daramola and Taylor (1975), Ivibjaro (1977) and Akingbohungbe (1993) showed that the kola weevils Balanograstris kolae and Sophrorhinus sp can be controlled by irradiating infested kola nuts with gamma rays at a dose of 0.1 KGy which killed both the eggs and larvae, and at a dose of 0.02 KGy which sterilised the adult. Their work also showed radiation treatments had no adverse effects on taste and acceptability of treated nuts by consumers. Akingbohungbe 1993 also studied the effect of gamma irradiation on Colosobruchus maculatus in stored cowpeas, L. serricorne in maize, and Dermestes spp in smoked fish and found that at low dosages of irradiation (0.2 - 1.0KGy) the various produce were successfully disinfested of mature and immature stages of storage insect pests. He found also that the food values of the treated grains and smoked fish were not adversely effected. A recent report of IAEA/FAO Research Coordination Meeting on the application of Irradiation Techniques for Food Processing in Africa showed that food irradiation is becoming widely accepted as a disinfestation technique in several developed countries and some developing countries. The report also highlighted the results of studies on disinfestation of cocoa beans by irradiation technique in Nigeria and Ghana where it was shown that cocoa beans could be protected in storage from cigarette beetle, L. serricorne, the Tropical Ware-House moth,
C. caurella and the rice-moth Cocyra cephalonica, using gamma rays with a dose-range of 0.2 - 0.5 KGy. Oyeniran (1979) also suggested the use of irradiation along with other methods for control of moulds in dry produce such as, cocoa beans and grains.

CONCLUSION

From the fore-going, it is suggested that irradiation technique could be safely exploited for disinfestation of agricultural commodities, particularly cocoa beans, coffee beans and kolanuts while improving their qualities and enhancing their market values. Also, the adoption of this technique on commercial scale for disinfestation of produce would minimise pesticide usage, pesticide - related contamination of produce and at the same time enhance safety of workers and the environment. It is on this basis that I advocate the installation of an irradiation complex at the main Nigerian seaport in order to facilitate pre-shipment disinfestation for export commodities, enhance quality improvement as well as ensure effective quarantine of imported planting or food materials. To minimise the usually very high cost of establishing this facility in our country, the Federal Government of Nigeria could approach donor countries for assistance, through the appropriate agencies especially the International Atomic Energy and the Food and Agricultural Organisation.

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BIOLOGICAL CONTROL OF TSETSE FLIES USING NUCLEAR TECHNIQUES IN NIGERIA

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Abstract

Biological Control of tsetse flies using the Sterile Insect Technique (BICOT) is involved in the eradication and control of tsetse flies (Glossina palpalis palpalis and G. tachinoides) using gamma radiation from Caesium 137 or Cobalt 60 sources supplied by IAEA. Laboratory reared male tsetse flies were treated with 0.12KGy dose to introduce dominant lethality to the flies while allowing for good survival.

All radiated male flies compete favourably with wild flies in the field. This paper highlights the important methods used by the project in achieving the eradication of this species of tsetse in an agriculturally viable subhumid area of Plateau State, Nigeria.

Introduction

Principle of Sterile Insect Technique (SIT)

When sufficient number of sterile males are released so that they can disperse and compete with the males of the natural population, they reduce the natural rate of increase to less than one fold generation, thus reducing the population to zero within a predictable length of time. This method is most efficient in controlling insect pests whose population are normally at a low level, on the decline or have been markedly reduced by suppression by the use of chemical, biological or other techniques. The use of SIT presupposes a knowledge of the insects ecology, population dynamics as well as complete isolation of the target area. Among the major requirements are a) Insectaries for mass production of the male insects; b) radiation of the male flies such that the flies can compete with the natural population flies i.e. the male flies must have low fertility, high survival and maximum competitiveness

Advantages of the SIT

In areas where the SIT could be used, this method avoids contamination of the environment and selectively attacks one Glossina specie, resulting in a minimum destruction to the ecosystem. If an integrated use of the insecticide is indispensable, this advantage may be lessened but the contamination of the environment is nevertheless considerably lower than would have been encountered in a programme based entirely on chemical control. SIT is more efficient because it is target specific. Since Glossina have low reproductive potential and a low rate of increase per generation, thus fewer flies would be required during the control programme.

When the population is low, the chances for eliminating them using the SIT is better enhanced and it becomes cheaper. The possibilities of Glossina developing resistance to insecticide is rare, if it occurs, it is not likely with sterile male flies. The SIT alone may be the method of choice where the disadvantages of the chemical or other control methods such as game elimination or bush clearance must be avoided.

Tsetse and Trypanosomiasis

Tsetse transmitted Trypanosomiasis poses severe constraints to man and livestock production in about 10 million sq km of Africa. Yearly losses of up to $0.6-1.2 billion has been estimated due to these disease (FAO 1995). It is one of the most significant single factor in Africa's deteriorating food production situation. Specifically, it limits animal production in the humid and subhumid Zone of Africa In Nigeria, tsetse inhabits approximately 80% of the land mass (737,338 sq. km) where eleven species are known to occur (Onyiah 1982).

Major method which has been used against tsetse fly has been the application of the insecticide. However, due to the rise in the price of chemicals and cost of operation, the pollution of the non-target fauna such as fish, insects and man etc , and the justifiable campaign by environmentalists to limit pesticides because of the undesirable side effect on non target species that biological control becomes an attractive complement in the integrated control of tsetse.

The biological control of insects by genetic means, using the Sterile Insect Technique (SIT) has slowly developed during the past forty years as useful method for the eradication of major insect pests such as screwworm, Cochliomyia hominivorax Mediterranean fruit fly. Ceratitis capitata (Weid) melon fly, Dacus cucubitae mexican fruit fly and the pink bollworm, Pectinophora gossypiella. Generally, the principle, theory, requirements, advantages and problems associated with the application of SIT to insect control practices have been adequately documented by Knipling (1955) who conceived the unique idea. Therefore, only a brief mention will be made in this paper of the factors that support or influence the use of SIT in tsetse control.

SIT is applicable to tsetse because of its low reproductive potential. The method is based on the sterilising action of irradiation particularly gamma rays on the reproductive system of the tsetse, thus breaking chromozone of cells undergoing division. Males subjected to radiation treatment have damaged spermatozoa which are unable to fertilise a ripe ovum. The principle of the technique therefore is that females mated to irradiated males loses the power to reproduce for ever. In order to exterminate the natural population during the SIT programme, overflooding of infected area is done with laboratory bred irradiated males.

BICOT PROJECT

Biological control of tsetse flies using the sterile insect technique (BICOT) is a bilateral project between the Federal Government of Nigerian (FGN) and the International Atomic Energy Agency (IAEA). The FGN is represented by the Nigerian Institute for Trypanosomiasis Research (NITR) and the Federal Department of Pest Control (FDPCS). The project became operational in 1979.

MATERIALS AND METHODS

FIELD OPERATIONS

Release area

The target area is situated at 250 km south of Jos, Plateau State in the agricultural land drained by the Feferuwa Akuni river systems, measuring 1,500 sq km. This catchment area lies within the southern guinea savannah vegetation (fig. 1). The project area is within the 9,000 km Plateau Agricultural Development Project (PADP) an important World Bank assisted project (BICOT 1983). Both G. palpalis palpalis and G tachinoides subjected to control by SIT are important vectors of human and animal trypanosomiasis. Regular surveys by NITR and FDPCS showed that human and animal trypanosomiasis is common among the people and cattle within the project area.

Mode of Operation

The plan of eradication is by the integration of removal trapping, sterile male release and the use of impregnated screens in areas of marginal tsetse density as barriers The entire SIT area is surrounded by impregnated screen placed at 100 metres to act as barriers against reinvasion of flies into the target area. Where riverine vegetation is exceptionally dense and wide, screens are placed on both flanks of the river, in openings within the vegetation to intercept flies moving along the ecotones. Impregnation of the screen target was done in a solution of 0.05% Deltamethrin

(DECIS 25gm/Lt.). Ground spraying was discontinued to save cost and due to the effectiveness of the impregnated screens. Flooding ratio of 10:1 sterile laboratory released males to field flies was maintained for the eradication.

Physiological impact of SIT

During the monthly monitoring done in the field female flies caught are dissected, ovarian development examined and then the impact of the sterile males on each female can be assessed. Thus, the degree of sterility from females with abnormal reproductive developments: abortions, degenerated eggs in utero and obstruction of the common oviduct could be confirmed. (Van der Vloedt & Barnor 1984).

LABORATORY OPERATION

Tsetse rearing

The laboratory rearing of tsetse flies is done using both the in vitro using locally collected blood from the abattoir as food source and in vivo using rabbits or guinea pigs. Presently, all the flies are fed exclusively by the in vitro method. At the peak of production, the colony had more than 180,000 producing female flies in the project producing excess of more than 14,000 sterile virgin males were supplied to the field weekly. Climatic environment was regulated at 24±1 °C and 75±5% temperature and relative humidity respectively (Ajagbonna 1985). All flies earmarked for the field release are marked according to release site so that they can be identified during recapture. Recapture was done to record the survival of the released flies, flooding ratio, rate of dispersal and reproductive abnormalities in the females that mate with the sterile males.

Computerisation of data

To facilitate the daily monitoring of colony performance, and sterile male output, all colony data were computerised and weekly performance is produced showing the performance of each unit of the colony. Corrections are made quickly to forestall major set backs. Field data are also routinely stored, several programmes were developed to monitor the effect of sterile males on wild tsetse population. The processing of a large number of field data enabled the project to evaluate the impact of its activity more efficiently (Feldmann et al, 1987).

Sterilisation and transportation of males to the field

Sterilisation of young male flies is done using Caesium -135 and Cobalt-60 Gamma sources. Because of the prevalence of trypanosomiasis, releases are made of adult sterilised males that have taken at least the first bloodmeal from the laboratory. Males are sterilised with a sub lethal dose of 0.12 KGy dose in a normal atmosphere to limit damage to somatic cells and gonads, and ensure good survival.

Transportation of flies to the field is done in a wooden box padded with foam and covered with wet towel to increase humidity in the container, temperature was maintained by putting an ice pack in each release box. Thermometers are inserted into the container to enable the temperature to be recorded during transportation of the flies from the laboratory to the field.

RADIATION SOURCE

Cobalt Source

Gamma cell 220 Cobalt-60 Source is used in the project for tsetse fly and collected blood. It is one of the most popular high dose research irradiator (fig 2). They are being used in a wide range of studies in the field of medical product sterilisation, biological and genetic effects, food preservation, growth stimulation, chemistry, pollution, irradiation on materials, sterile male technique and the irradiation of semiconductors The prominent feature of the source consist of a steel encased shield, with a total weight of 3765K.gm. It has a high exposure rate of up to 2.0 x 10^6 Roetgens/hr when loaded with 24000 curies (0.888PBq) of Cobalt 60. The total available space for irradiation is 3610 cm^3. The source is fitted with a digital timer 0 .1 TO 999.9 in seconds, minutes or hours as required. The radiation chamber moves out of the radiation field after a preset intervals. It has a wide range of accessories for high and low temperature experiments, gas flow, stirring of solutions etc while irradiating. Cobalt-60 source was preferred over the Caesium-135 because of its high output of gamma rays, thus reducing the time of exposure and the work load.

DISCUSSIONS AND CONCLUSIONS

The population of Glossina palpalis palpalis, G. tachinoides present in the target area decreased constantly with the combined use of traps, SIT and impregnated screens.

In an experiment to study the effect of long term removal trapping on Glossina population it was found that traps removed a high number (90%) of flies from the area under study but few flies were always caught showing that traps cannot lead to tsetse fly eradication.

Losses of up to 66% of the screen were recorded in area of high human activity. Reasons are theft, fires and flooding.

It was observed from the experience of the project field staff that the number of sterile males to be released were reduced by reducing the population of flies in the high density spots by traps with or without impregnated screens.

For the eradication or control phase more than 1.5 million laboratory bred sterile males were released to the field. Transportation losses of the flies from the laboratory to the field during the project operation were less than two percent. This good performance was due to stringent supervision and care.

Eradication or control of the target species G. palpalis palpalis was demonstrated in the 1,500sq km area chosen within the third year of releases G. tachinoides another specie later subjected to SIT was highly reduced in the target area. Proof of eradication was shown by the release of sterile virgin females to the target area. 2,000 sterile virgin females were released. Up to 20.6% of these flies were recaptured 3-8 days post release. Result showed that all recaptured females were virgin, thus demonstrating the absence of wild males. The success achieved so far, has led to the proposed expansion to cover a wider area of 12,000 sq km for tsetse control using SIT method. The FGN of Nigeria has approached IAEA for donor countries to support Nigeria in combating the menace of tsetse and trypanosomiasis using SIT, in the new proposed area.

During the operation, set backs were experienced at some stages due to disease outbreaks in the host animal colony use as blood source, this led to low productivity of the flies. Other problem associated with the production of tsetse flies include, frequent breakdowns of essential equipment such as Cobalt 60 source were experienced during the operation, experts on the source brought by IAEA repaired it as short notice.

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GRAINS RESERVE STRATEGIES

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Abstract

This paper discusses the eminent position of food as an economic and nutritional commodity and the need for its year-round ready availability inspite of the seasonality of its production.

Food security and its international political dimensions are examined. The National Grain Reserve Scheme vis-a-vis policy implementation strategies, constraints and future perspectives are analysed.

The paper concludes that it is desirable for Nigeria to maintain an adequate Food Reserve Stock, irrespective of the prevailing level of self-sufficiency, in order to provide food security for its citizens and maintain its leading role in the West African sub-region.

Introduction

According to the current Food and Agriculture Organization's estimate, by the year 2000 more than half of the world's population would live in urban cities. It further estimated that the present world population of 5.billion will increase by three billion by the year 2030. This presupposes a decrease in the availability of arable land, heightening the need to intensify agricultural production and making greater demands on finite natural resources. (African Farming October, 1 995)

Currently, more than 200 million of Africa's 700 million people are confronted with starvation precipitated by civil wars, political and economic instability, inadequate farming system, protracted drought, rapid changing weather patterns and poor harvest. It is further reported that the 1995 global cereal production of 1.902 million ton, was 2.6 percent less than 1994 and well below the trend for a third consecutive year. The report in addition confirm a tight cereal supply/demand situation in 1995/96. Based on this outlook, the food supply situation in many countries is precarious.(African Farming October, 1995).

In Nigeria, records available indicated that between 1986-1992, an annual growth rate in the critically important components in the dietry requirement of most of her people was recorded (Financing Crop Storage 1995). The FAO, however in her current Food Security index classified Nigeria among the 44 countries of the World with low food security. The consequence of this growth rate is that an increase in food production/supply does not necessarily result in an adequate food security.

In 1985, Zimbabwe had a stockpile of small grains (sorghum and millet) and much greater stocks of maize, but the government had to provide drought relief feeding for 500,000 people in other regions of the country where the harvest was grossly inadequate. In effect the country achieved a national food self-sufficiency but household food security remain a major course of concern.(S.C. Muchena.1989)

FOOD RESERVE SCHEMES

Cereal such as rice, wheat, maize, sorghum and millet are very important dietary components of most people in many countries of the world. Depending on each country region of the world, one or a combination of these cereals is very important in the dietary component of the people living there. Consequently this cereal or a combination of these cereals form the main thrust of the food reserve scheme. For example in S.E. Asia, where 90% of the world's rice is grown. In Indonesia rice is the main thrust of her food reserve scheme. Paul Hindmarsh et al (1988). In Zimbabwe, due to protracted drought, small grains such as sorghum and millet which are relatively drought tolerant were introduced to supplement maize for household food security (GASGA 1978).

Cereal production is usually restricted to one but in exceptional cases to two or three harvests a year. Food Reserve Scheme is used to even out fluctuations between supply and demand, whether these are intra-year, demand induced, weather induced or due to transport delay. According to Paul Hindmarsh et.al (1988), Food Reserve Scheme is a function of the variability of these factors and the level of protection from the effects of fluctuation that is desired. In addition, Food Reserve Schemes have considerable associated costs and development efforts are applied to reduce these costs to a minimum consistent with an acceptable level of food security. The following fundamental problems are however evident in many countries:-

(i) Unclear Marketing and Storage objectives;
(ii) Target Stock levels, procurement and release rules are inadequately defined or not defined at all;
(iii) Inadequate relationships between transport and storage
(iv) Poor motivation and underpayment of staff;
(v) Opportunities for disposal of surpluses may not be fully recognised;
(vi) Facilities (warehouse) may not meet distribution needs in terms of locations, capacity and design.

Food Reserve Schemes are extremely expensive due to interest costs and quantitative and qualitative losses. They should ideally be considered relative to other initiatives for food security enhancement which may be less visible but more cost effective. The cost of food reserve schemes can be minimised by limiting the size of the stocks stored. This requires that the size of the stocks needed be rationally and critically addressed both publicly and privately and in real world perspective, (Paul Hindmarsh et.al,1988).

In the early 1980s, in many tropical countries, food reserve scheme was based on the concept of encouraging local production through guaranteed purchasing, inter-regional trade bans, seasonal pricing and, to satisfy consumers by subsidising sales. The following scenario emerged from this:

(i) the production of surpluses for which no market had been identified;
(ii) production of surpluses in areas distant from consumers with the consequent high transport costs for both inputs and production;
(iii) low quality stocks because of guaranteed purchasing without inbound quality control, (Paul Hindmarsh et.al, 1989).

Also in the early 1980, the government of Indonesia made a major decision to stop importing rice and become self-sufficient in rice production. The responsibility of implementing this major policy decision was saddled on BULOG, a parastatal organisation with considerable autonomy it created to run its Food Reserve Scheme (D.J.B.Calverley 1988). In Zimbabwe the thrust of the country's food reserve initiatives was implemented by the Grains Marketing Board -also a Parastatal with considerable autonomy -ODNRI(1989). The establishment of this Parastatal by the government of these countries was to enable the countries to achieve a high degree of food security at a minimum cost (D.J.B. Calverley 1989).

In Indonesia, it was observed that the nearer the domestic rice production approaches the national demand, the smaller will be the carry over stock levels needed for any appreciate level of food security. It was however noted in 1983 that a 2 million tonne carry over gave 69% confidence in their Strategic Grain Reserve Scheme. But with a higher production trend in 1985/86, 1.5million tonnes of rice with increased procurement gave 97% confidence. D.J.B. Caverley (1989) is of the opinion that the basis for direct transfer of the BULOG Model to any African country does not exist in these countries. This he attributes to weaker database and institutional framework. However, he recognised that the new and recent initiatives towards regional cooperation in food security need support and offer scope for an application of a model on a regional basis.

NATIONAL GRAIN RESERVE SCHEME

Consequent on the vagaries of changing global weather patterns, massive grain crop failures, pest problems, protracted drought and poor harvest, the ensuring broader concept of food security such as adequate stocks of food, a stable supply of basic foodstuffs at any given time, access of everyone to supplies and quality of stock can no longer be guaranteed by many countries of the developing world. In view of the expensive nature of this concept, the responsibility of guaranteeing this becomes that of the national government in establishing a Strategic Reserve Stocks - (GASGA 1978).

GRAIN STORAGE POLICY

In Nigeria, the benefits of the increase in the annual growth rate in food production between 1986-1991 have not been evident Table I: (Important Dietary Component of Nigeria)

CROPS	ANNUAL GROWTH RATE IN % 1986- 1991
Cassava	36.3
Yam	24.37 .
Cowpea	14.25
Maize	1.68
Sorghum	9.74
Rice	7.86

(Source: Financing of National Crop Storage Programme,1995) in the country. This has been attributed partly to the high level of food losses occurring right from the farm shortly after harvest and throughout the food distribution chains and partly due to lack of an adequate storage, preservation, processing and packaging technologies - Food Reserve Strategies (the Financing of the National Crop Storage Programme 1995). In a bid to stem this unsavory situation, the Federal Government in 1988, adopted a comprehensive package of policy instrument expected to consolidate the gains of agricultural development and production. One of such policy instrument is the National Food Security Programme. The major objectives of this policy are:

(i) *To ensure a higher food security for the country by deploying efficient food storage technologies;*

(ii) To reduce inter and intra seasonal variations in food availability, stabilize food prices and minimize drastically the food losses occuring at all levels of post-harvest produce management. In the realisation of these objectives, the Federal Government adopted a three-pong approach in which definite roles were designated to the three-tiers of government and the private sector. The defined assignments for the three-tier government and private sector according to FNCSP 1995, are as follows:

(i) On-Farm Storage Programme

Under this arrangement, 85% of the total grains and pulses produced in the country would be handled by the private sector. This include, the small, medium and large scale farmers and entrepreneurs. To effectively implement this programme and provide it with the necessary technological base, Federal Ministry of Agriculture in conjunction with The Nigerian Stored Products Reserve Institute and other relevant national and international agencies developed a programme of improving indigenous "On-farm" storage structures and introducing new storage technologies to small scale farmers through the appropriate state storage extension services.

(ii) Buffer Stock Storage Programme

In the implementation of this Programme, the state government are to hold 10% of the total grains and pulses production- they take on the responsibility of maintaining the buffer stocks for staple grains in their areas. It is expected that grains will be purchased from farmers during periods of surplus in the market and release during periods of scarcity thus ensuring the availability of staple food at all times. This will also guarantee price stability to both producers and consumers.

(iii) Strategic Grains Reserve Programme
In this programme, the Federal Government is expected to store 5% of the total grains and pulses produced in the country. The programme is aimed at forestalling scarcities in the event of massive crop failures, national calamities, pest infestation and man-induced disaster (Talabi, AE 1996). In the realisation of the objective of storing 5% of the total grains and pulses production in the country, metal grain silos of 25,000MT capacity have been constructed at several locations within the country. This is essentially for bulk storage but with provision for bagging of grains for delivery purposes (Talabi, A.E. 1996 and FNCSP 1995).

OPERATIONS, MANAGEMENT AND IMPLEMENTATION CONSTRAINTS

(i) Stored food grains are biological in nature with a high propensity for quality deterioration and weight losses. The operation and management problems of stored grains in metallic silos, coupled with the colossal capital investment in grain silo construction and stocking by the Federal Government requires a quick responsive management that will be capable of taking timely actions on matters related to plant maintenance and grain quality sustenance at all times. Of more importance is the fact that the sensitive nature of food security as it affects political and social stability leaves no room for management failures.

(ii) Acceptable Grain Marketing Standards are yet to be adopted, ratified and enforced to promote grain trade in Nigeria. The current system of delivery of grains to the existing SGR Grains silos is highly centralised and leaves no room for direct participation of farmers in the neighbourhood of the silo complexes, even where they are prepared to comply with the specifications and operational procedures of the SGR Silo System.

(iii) There is no acceptable distribution system to ensure that grains distributed from the SGR Storage Stock actually get to every interested member of the public or the intended consumers.

(iv) Another serious set back to the smooth execution of the SGR Programme is under-funding which is due to conflicting opinions of the funding agents viz the National Planning Commission, Federal Ministry of Finance and even the implementing agency. The Federal Ministry of Agriculture, i.e. on what should be the modus operandi for the scheme, e.g. who pays for the shortfall in grain revenue in the operations of a revolving grain fund, when grains are directed to be released to the public at subsidised rates?

(v) Excessive bureaucracy and delays on matters requiring urgent attention makes the present civil service oriented management of the SGR Programme unsuitable for a National Food Security Programme. The implication on the Strategic Grains Reserve (SGR) silo management is that funds cannot be utilised soon after approvals have been given. It takes almost a whole month to collect the Authority to Incur Expenditures (AIEs) to pay for an approved expenditure, and about another two months for the cash backing from the treasury office to be ready, before the money can be utilised to execute approved remedial works at the silo complexes, most of which usually need fast responses, either on the silo structures or to treat infested grain stock.

(vi) Eventually, things which require urgent attention are done far behind schedule, thus resulting in avoidable loss of time and materials, which is highly detrimental to good management of large grain stock (Talabi, A. E.1996).

CHALLENGES ON FURTHER STORAGE NEEDS FOR FOOD SECURITY OPERATION

Storage in the context of food security is often times synonymous with grain storage. This is traceable to a number of factors.

Firstly, food is highly perishable and its storability or the ease with which it can be prepared for extended storage is a major factor in determining foods to be held in a reserve stock. Grains contain less water per unit weight and can easily be dried to moisture contents at equilibrium with ambient conditions for extended storage without deterioration. Grains have therefore traditionally been the choice foods for reserve storage - even in biblical times and long before then.

Secondly, the climatic conditions in many food self-sufficient nations particularly in the developed countries is highly suitable for grain production. Producing crops for which a country has a high productive advantage helps keep the costs down and the profits up.

Thirdly, although most foods contain to a varying degree all the essential nutrients for a healthy and strong body, carbohydrates, proteins and fats are usually the pre-dominant ones with the others only present in minute traces. In grains, the level of protein is higher than in roots and tubers and fruits and vegetables and therefore closer to providing a one-food balanced diet than foods in the other categories.

However, the diet regimes of many Nigerians, and in fact West Africans, accord Roots and Tubers high significance. And a universally acceptable Food Security Programme (scheme) must take cognisance of this. Future efforts will centre around expanding the scope of the National Food Security Programme to include Roots and Tubers like yam and favourite processed form of cassava like gari.

Since bulk of roots and tuber crops is water, they contain less nutrient elements per unit weight and are more difficult to transport. And yam, for example, sprouts if stored under ambient conditions thereby loosing much of its food content.

It will interest this gathering that a preliminary comparative analysis done in the Ministry of Agriculture on adopting an irradiation based system for yam preservation under a National buffer stock programme for the commodity revealed that it would cost just 10% of what it would cost in adopting a refrigeration based system. Let me then state that we look forward to the validation of this preliminary finding with the irradiation facility SHESTCO is acquiring. It should also be mentioned, that a recently concluded "National Workshop on Strategic Grains Storage Programme Nucleus for National Food Security" organised by the Federal Ministry of Agriculture recommended the establishment of a National Food Reserve Agency (NASFRA) to take over the implementation of the National Food Security Programme with a view to eliminating the current management bottlenecks. This is another major challenge ahead.

IRRADIATION IN GRAIN PRESERVATION

Generally, control procedures available for use in the preservation of grain are numerous and diverse both in their basic principles and in their levels of sophistication. This is due to the artificiality of the post-harvest system and the storage facilities which permits adjustment of many environmental factors (Haines, C.P, 1982). Haines (1982) listed the following among others as potential methods under investigation for management of pests (insects) in grain preservation:

(i) refined physical control procedures;
(ii) Govel insecticides based on pathogens or juvenile hormone analogue;
(iii) new chemical insecticides;
(iv) behaviour modifiers i.e.pheromones and repellents;
(v) sterile-male release

(vi) irradiation;
(vii) chemosterilants and
(viii) modification of traditional methods.

Mcfarlane, J.A. (1988) reiterated that various forms of electromagnetic energy are technically available for utilisation in the disinfestation of foodstuffs, inclusive of stored products. These are the application of radio-frequency heating, infrared, ultraviolet and ionizing radiation.

It has been observed that gamma radiation produced by radio-active materials such as cobalt 60 is effective against a wide range of insect pests. Mites are more resistant and may require dosages higher than the 0.5KGy that would achieve satisfactory control of most storage insects. Furthermore, it is noted that at a practical dosage levels mortality is not instantaneous, although sterility may be immediate. In addition, the time interval between treatment and death could be up to 40 weeks or longer. This depend on the dose applied and the species of insect. This according to Watters (1972) is an apparent disadvantage of this method of disinfestation when compared with fumigation treatments. Furthermore, Watters (1972) noted that in comparison with fumigation, it confers no protection against reinfestation. He suggested that based on this reason, insect resistant packaging would be a logical adjunct. However, in countries where the socio-economic circumstances favour the use of irradiation techniques, its inclusion in Integrated Pest Management System (IPM) will depend upon their relative cost efficiency as with the use of other techniques. Mcfarlane, J.A. (1988) noted that the use of irradiation techniques for stored products pest control is limited by the basic problems of capital and running costs.

CONCLUSION

The main principle of National Food Security is to provide adequate foodstuff for all at affordable cost at all times for a healthy and active life. The major thrust of the Food Security initiative of Nigeria is to store substantial quantities of grains, especially maize, for reserve purposes. This however does not take cognisance of the varied components of the Nigerian diet which includes yam, plantain, cow peas, millet, sorghum, fish, and cassava.

Unlike grains, however, most of these other foodstuffs are not readily amenable to prolonged storage. Yam, for example, sprouts in storage, thereby depleting the food content within the tuber. It is highly desirable to be able to incorporate yam into our storage programme.

National Root Crop Research Institute (NSPRI), University of Ibadan, Umudike, etc had carried out trials to explore the possibility of inhibiting sprouting in yam stored in barns. Available literature confirms that this preservation method does hold a promise. Furthermore a preliminary cost analysis has further reinforced the practicability of this method over the much more expensive refrigeration technique which already enjoys wide application for fish and meat storage. The true challenge ahead of us is that a kilogramme of meat costs 5-10 times more than 1 kilogram of yam tuber, hence a suitable preservation method over extended periods for yam storage must be far inexpensive to be cost effective.

The question then is - Is irradiation the answer? Does irradiation hold the key to the successful extension of the scope of our Reserve Programme to include all the other essential staples? Thank you very much.

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RADIATION DECONTAMINATION OF FOODS AND SPICES

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Abstract

Microbial contamination of agricultural proauce whether wet or dry and its persistence, jeopardizes subsequent use of these materials. Foods of animal origin particularly poultry and pork are known to be contaminated by pathogens such as Salmonella, Campylobacter, Toxoplasma, and Trichinella. In the past few years, there have been significant increases in diseases from other organisms, e. g. Listeria, E.coli, Vibrio, etc in food especially those of animal origin. Dry plant materials often harbour a variety of micro-organisms as a consequence of growing and harvesting conditions and post harvest handling. Common micro-organisms present in dried foods and food materials include Salmonella, Clostridria, Staphylococci, Aspergillus spp, Baccillus spp etc. Drying kills many bacteria, but not all microorganisms are destroyed and the population of the survivors can be rather stable in dried products. Most food borne diseases are associated with the germination and growth of these dormant pathogens present in dry foods. Applicable decontamination methods are therefore of considerable concern from economic, public health and environmental point of view. Chemical decontamination is presently a subject of international debate resulting to the banning or restriction of the use of some of them for health reasons. Two current decontamination methods are heat and irradiation. The sensitivity of some of the components of these foods and spices makes the use of heat difficult. The practice of radiation decontamination is well developed. This paper reviews the application of radiation in decontamination of foods and spices.

Introduction

Contamination of foods (especially those of animal origin) by microorganisms, particularly pathogenic non-sporing bacteria and infection of foods by parasitic helminths and protozoa are among the most important public health problems and a major cause of human suffering throughout the world. Also, many dry ingredients such as spices, herbs which are important sources of foreign exchange earnings for some developing countries like Nigeria, may be contaminated by spoilage organisms and to a certain degree pathogens. This causes difficulties during further processing into composite food products and create potential health hazards. Quite often foods produced in accordance with good manufacturing practices may still harbour low levels of disease-causing microorganisms. Such microorganisms may lead to outbreaks of food-borne diseases especially among groups such as the very young, elderly, and those with compromised immune systems. Hence it has been stated that illness due to contaminated food is perhaps the most wide spread health problem in the contemporary world and an important cause of reduced economic productivity (JECFS, 1984).

Thermal pasteurization is a well established and satisfactory means of terminal decontamination of liquid foods, however, it cannot be used for solid foods and dry ingredients. Alternatively, the use of chemical sanitizing techniques have regulatory limitations and/or pose public health problems, toxic residues and environmental pollution. For now, and in the foreseeable future, no known technique can guarantee the production of raw foods of animal origin, especially poultry and pork, without the presence of certain pathogenic microorganisms and parasites like Salmonella, Campylobacter Toxoplasma and Trichinella or sterile spices and herbs without tremendous reduction in their aromatic flavour characteristics. Therefore where such foods are important in the epidemiology of food-borne diseases irradiation decontamination/disinfection must be seriously considered.

The use of ionising radiation for the preservation of food was first suggested in 1916 and was the subject of patents in USA in 1921 and in France in 1930. Since 1950s it has been the subject of scientific, political and public interest and has been applied to a wide range of foods including fish, shellfish, poultry and red meat, grains, fruits and vegetables, nuts and spices. The technology has a number of attractions for food producers, traders and consumers, increased food safety are achieved by reduction/elimination of spoilage and pathogenic microorganisms, parasites and insect infection.

Contamination of Foods and Spices

For the purpose of radiation decontamination, foods and spices could be broadly classified into fresh/wet and dried foods. Fresh/wet foods are mainly foods of animal origin - pork, poultry, red meat, fish, shellfish, crabs, etc and their products. Whereas dried foods include spices and herbs, dried eggs, grains and animal feeds.

Contamination of fresh/wet food

Meat and meat products are foods specially asked for by consumers for their nutritive qualities and organoleptic properties. Modern production facilities for animals - cattle, swine, poultry and fishery tend to be large and specialized. Very large number of birds or animals are reared or maintained in each production unit. Under these conditions disease prevention and control is a critical concern and most producers start with disease-free stock and isolate their production units as completely as is practicable. At the present time the feed route represents a major remaining avenue through which disease organism can be introduced into the facility (Mossel, 1977; Ito et al 1981). The potential for dissemination of disease via the feed is compounded by the structure of the feed industry where large central feed mills supply feed or ingredients to many individual producers and where inedible parts of birds or animals are rendered and recycled as high protein feed supplement. Addition of antibiotics to the feed to control feed-borne disease is helpful but is not always effective and in addition has raised a variety of public-health concerns (Levy, 1987; Linton, 1985).

Contamination of meat could also stem from external sources like soil, human hands and slaughter houses. Indiscriminate pollution of streams, rivers and oceans with crabs, oysters, shrimps and fishes and so on to acquire large numbers of microorganisms. These aquatic animals also serve as intermediate host of many parasites of man like Clonorchis sinensis - the causative agent of liver fluke infection. (Williams, 1984). Some of the common pathogenic agents (viruses, bacteria, and parasites) found in foods of animal origin are shown in Table 1.

Salmonella is at present the most important causal agent of food-borne disease in many countries. Poultry and red meats had been identified to play major roles in Salmonellosis. Whereas Vibrio parahaemolyticus and V. cholerae are associated with marine products (ICGFI, 1987). Although Salmonella had been recognized as an important causal agent of food borne disease, it is not the most dangerous. Rather a bacterium, Listeria monocytogenes which grows well under low temperature and resists heat, salt, nitrite and acidity better than many microorganisms (Skinner, 1988).

Contamination of Dry Foods and Spices

Dry plant materials often harbour a variety of microorganisms as a consequence of growing and harvesting conditions and post harvest handling as well as the selective actions characteristic of given substrate (Katusin-Razem et al, 1988). The survival and multiplication of bacteria and fungi in dry materials was said to be limited but Goepfart et al (1972) have reported that contaminated spices are vehicles of spoilage and food poisoning. Hence, Konuma et al (1988) opined that the main source of B cereus contamination in meat products was contaminated meat product additives.

Although organisms of public health significance such as Salmonella and Clostridia are infrequently encountered in spices (Wilson and Andrews, 1976; Baxter and Holzapfel, 1982) populations of bacteria ranging from 10^2 to 10^8 colony forming units (CFU) per gram had often been reported (DeBoer et al 1985; Antai 1988; Popovic 1988). Popovic (1988) screened for bacteria in 80 natural spices and detected sulphide - reducing Clostridia in samples of ground paprika, pepper and sweet red paprika. Onyenekwe and Ogbadu (1993, 1995) and Onyenekwe et al, (1996) had also reported the presence of sulphide-reducing Clostridia and Staphylococcus in most common Nigerian spices like ginger, Capsicum and Ashanti pepper. Members of Bacillaceae have been observed to predominate usually as spores (Antai, 1988; Naito and Sakai, 1988). Other organisms isolated from dried foods and spices includes Micrococci, Diplococci, Salmonella, E. Coli (Table 2). Since spores are particularly resistant to heat, they are of great concern in processed foods.

Fungi microflora like bacteria are known to infest foodstuffs. Kurata and Hitkolo (1985) examined a total of nearly 6,500 samples of 26 categories of food from normal marketing channels and observed that spices and herbs ranked either in the middle or towards the higher risk end of the list evaluated as potential hazards to health. Their assessment was based upon the fungal flora including species of Aspergillus, Penicillium and Fusarium. Similar observations have been made by Garrido et al (1988) and Martinez et al (1988). In these two studies the genera of Aspergillus and Penicillium were dominant. Among the Aspergillus species A. flavus, A. niger and A. glaucis were more frequently identified. Earlier, Dandavate and Shindle (1986) screened Chili pepper. Peppers collected from 8 markets in India and ascertained that the spice was infested by Aspergillus, Fusarium and Macrophomina. They noted that 7 out of 19 cultures of A. flavus showed mycotoxin producing potentials.

In Nigeria, the story is not different from those reported elsewhere. Uzuegbu and Emifoniye in 1984 carried out a survey of important genera of fungi causing post harvest spoilage of fruits and vegetables in Ondo state. The products studied included red pepper, onions and melon among others. Out of the 15 products studies, 13 spoilage fungi species were identified. Aspergillus and Fusarium were the major and most abundant species in the samples. Other fungi species isolated were Penicillium and Geotrichium. Onyenekwe and Ogbadu (1993, 1995) and Onyenekwe et al (1996) also identified these fungi in chili pepper, ginger and Ashanti pepper. Fungal contamination of spices and foodstuffs have been demonstrated to show no definite correlation with the environment possibly because most fungal contamination occurred before the spice or food stuff reach the retail shop with the fungal spores, remaining dormant unless conditions are favourable for germination and growth (Llewellyn et al, 1988).

Health Implication of Contamination

Bacteria produce different toxins responsible for a variety of human diseases. When these diseases are contacted through food ingestion, they are usually referred to as food poisoning. Bacterial food poisoning has been differentiated between diseases transmitted by food and food poisoning. In the former, the food is contaminated with pathogens which when ingested develop in the host and cause disease (Mumuni, 1984). These pathogens grow in their host feeding on nutrients like carbohydrates and proteins producing acids with or without gases and other toxins, hence this type of disease is called food borne infection. In the case of food poisoning, it denotes a food borne illness caused by microorganisms which produce toxins and release them into food prior to ingestion. Some examples of organisms that cause food poisoning, the toxins produced and symptoms of disease are shown in Table 3.

In recent times, world attention has been attracted to listeriosis, a disease caused by Listeria monocytogenes. According to an informal working group of WHO Listeria monocytogenes should be considered as environmental contaminant, whose primary means of transmission to humans is through contamination of foodstuffs at any point in the food chain. Two reasons underline concerns about food-borne Listeria. First, Listeria, according to Skinner (1988) is a "tough bug" - a "macho microbe" within its microscopic world. It resists heat, salt, nitrite and acidity much better than many microorganisms. But perhaps more alarming, it survives and even grows at low temperatures - below 4^{O} C. This means listeria thrives on cold surfaces and takes over where other bacteria have a hard time surviving, it also means Listeria has penetrated a traditional line of food safety defense: refrigeration. Second, the disease caused by Listeria - listeriosis - can be very serious or even fatal for certain high-risk groups such as unborn babies, new borns and those with impaired immune systems. Generally, Listeria infections may lead to bacterremia, an infection of the blood stream; meningitis, an inflammation of the membranes covering the brain and spinal cord, and encephalitis, an inflammation of the brain itself.

Socio-economic Implications

The socio-economic consequence of food-borne disease is wide spread in both developing and developed countries and a significant cause of morbidity. Medical case and hospitalization may be required for those who are ill. Temporary disability, because of infection, can result in the inability to work or take care of a family. In the initial and recovery stage of illness, activities will be limited and work output restricted, especially if abdominal pain is experienced. Asymptomatic carriers of infectious organisms may unwittingly contaminate foods or infect other persons. Permanent disabilities or deaths are not uncommon. Gut damage can result in malabsorption which may lead to inadequate nutrient intake and the subsequent weakness may allow other infections microorganisms to cause further debilitating diseases. Although little information is available, on the social consequences of illness in developing countries like Nigeria, it is reasonable to assume that the situation is far worse than in developed countries. Repeated episodes of food-borne diseases may initiate and/or intensify malnutrition by adversely affecting the body's ability to digest, absorb and utilize the already inadequate diet and by inducing metabolic alterations, nutrition wastage and growth stunting (WHO, 1984). The experience of Nigeria in 1995 and early this year due to CSM and choleral out-breaks cannot easily be forgotten.

The economic impact of food-borne disease in Nigeria in particular and the developing countries in general is not clearly established because of several militating factors. However estimates for some developed countries like North America and Europe could be used to illustrate the danger of unchecked food-borne disease on a national economy. One estimate of the occurrence of diarrhoeal food-borne disease in the USA is as high as 24-81 million cases each year (Archer & Kvenburg 1985). In the then Federal Republic of Germany, Salmonellosis costs were estimated to be DM240 million, of which 55% represented losses to the cattle and poultry industries and the reminder to human infections (WHO 1984). Costs of medical treatment and lost productivity alone for trichinosis, toxoplasmosis, salmonellosis, campylobacteriosis and beef taeniasis total over US$1 billion in the United States annually (Morrison and Roberts, 1985). In Canada 763,000 cases of Salmonella infections were estimated to occur annually (about 1 in 30 persons) at a cost of Can $954 million including the cost of 763 deaths. Human illness and deaths due to E. coli, Staphylococus aureus and Listeria monocytogenes also cost over Can $100 million each. The overall cost of food-borne disease in Canada was Can $2.88 billion.

Apart from deaths, the main components of these costs are losses to the producer or retailer (server), followed by loss of productivity by ill persons. These costs apply to developed countries. Losses in developing countries had not been estimated but the overall impact could be much greater.

Food is one of the most important commodities in international trade. Many countries, in particular developing countries, export part of their food produce to obtain foreign exchange. Others depend to a large extent on imported food to guarantee the nutrition of their people. Commodities such as sea-food and foods vegetable origin are repeatedly found to be contaminated with pathogenic microorganisms and face rejection in international trade.

Methods of Decontamination

Chemical method

Although spices have antimicrobial properties their action is selective and hence do not provide enough protection against contamination therefore applicable decontamination methods are of considerable concern from economic, public health and environmental aspects. Different chemicals have been used at one time or the other to decontaminate both foods and spices.

Naito and Sakai (1988) used ozone in preservation of cereals, grains, peas and spices. They exposed these agricultural products to air containing 0.5 to 50ppm of ozone at 10% and a flow rate of 100L/min for an hour and then stored in polythene pouches at 10^{0} and 30^{0} C for 30 days. The decrease in microbial counts (Bacillus and Micrococcus) were predominant and at the order 10 to 10^{3}. Further decrease in count was observed during storage due to residual effect of ozone. The effect of ozone has been attributed to formation of peroxides and other oxide radicals and reduction in pH (Ben Ghedaha, et al, 1980).

The reduction in pH of ozone treated cotton straw from 6.11 to 2.25 was suggested to have stemmed from organic acids derived from oxidation of lignin by ozone. Although they reported increased in vitro organic matter digestibility of ozone treatment, the increased phenolic compounds raised more doubts than joy.

Another method of fumigation is the use of ethylene oxide, ethylene bromide or propylene oxide (Frohnsdorff, 1981; Farkas and Andrassy, 1988). This method of decontamination had been shown to be a time consuming batch procedure and it appears to be beset with problems of uniformity of decontamination and requires a complex process monitoring (Frohnsdorff, 1981). However, when properly carried out it was effective but not without affecting the sensory and/or other quality, characteristic of the treated product. A comparison of the antimicrobial efficacy of ethylene oxide and gamma irradiation at 4 or 8KGy shows that 4KGy was sufficient to achieve a reduction of the viable cell count equivalent to the effect of ethylene treatment (800g T gas per m^3 at 20% for 6 hrs), but without affecting their sensory quality or other quality characteristics. Despite the antimicrobial efficacy of fumigation, the process is not devoid of danger of chemical residues which represent a significant occupational health hazard for the handlers in the treatment plants hence its ban by many countries. Another defect of fumigation has been shown to be reduction in protein solubility, volatile oil content and aroma intensity.

Heat/Steam

Heat sterilization is the most regular method of decontamination. Usually the sample being decontaminated is heated to about 115 ^{o}C for about 55 minutes. The method is effective at low temperature and shorter time. Hayashi et al (1991) observed that the total plate count after holding a dehydrated plasma of initial microbial load of 2.2×10^4/g for 20 minutes at 100 ^{o}C was 1.1×10^3/g with severe deterioration of quality

Radiation Decontamination

Due to the observed effects and the resultant health consequences of other methods of food decontamination, there has been a call for a more viable non-residual process and irradiation has proved very effective. Food irradiation involves exposing foods to ionizing radiation, either to gamma rays emanating from a radioactive source such as Cobalt-60 or high energy electrons from an electron beam machine. In radiation processing of food, only gamma rays from cobalt-60 or caesium-137, x-rays generated by a machine at a maximum energy of five megavolts (5 MeV) or electrons from an accelerator at a maximum energy of 10 megavolts (10 MeV) can be used. Energies from these radiation sources have been shown to be too low to induce radioactivity in any material including food exposed to them.

The efficacy of gamma irradiation for decontamination had been examined and found effective. Moulds are moderately sensitive to irradiation. In grains and pulses, which are liable to support toxigenic moulds if mishandled, all moulds are greatly reduced in number by irradiation. For an example, A flavus strains are destroyed with a dose of 3.5KGy in corn samples containing 12.5-23% moisture, studies on flour, white bread and raisin bread showed that an irradiation dose of 0.5KGy reduced the total viable moulds by approximately half (Harting, et al, 1973). Sterilization doses for spoilage moulds of cereals grains and spices had been found to be between 5 and 6KGy and a dose of 3-4KGy significantly delay fungi growth and toxin production.

Unlike fungi microflora, bacteria are less radiosensitive, isolates of Clostridium spp had been reported to be isolated from freshly 10KGy irradiated spices and herbs. However, the isolates are known to die off upon storage of the irradiated food.

Packaging of poultry after slaughter and subsequent irradiation with doses of 2 - 7KGy has been shown to be effective in eliminating pathogens especially Salmonella and Campylobacter spp and could be applied now on a relatively wide scale. Most data applying to poultry irradiation are also valid for red meat. Irradiation in the dose range 2-7KGy will reduce the level of contamination considerably Table 4 shows a number of countries which have approved radiation decontaminated food.

Irradiation of parasitic protozoa and helminths causes loss of infectivity, loss of pathogenicity, interruption or prevention of completion of the life cycle, and/or death of the parasite. Doses in the order of 4-6KGy are required to kill food borne parasites outright (ICGF1, 1987). However, much lower doses are adequate to prevent reproduction and maturation, resulting in loss of infectivity. Hence, there is a concensus that doses below 1KGy are sufficient to prevent infections from food-borne parasites.

Gamma irradiation of pork infected with Trichinella spiralis at a dose of 0.15 - 0.30 KGy makes the parasite sexually sterile and blocks the maturation of ingested larvae in the host gut. Similarly, a dose of 0.3 - 0.5 KGy kills Toxoplasma gondii and 0.4KGy irradiation of beef infected with Taenia saginata cysticercus would prevent development of the parasite in the human host. Irradiation of fresh water fish with 0.5KGy can prevent infectivity of Opisthorchis viverrini metacercariae.

Advantages and Limitations of Radiation Decontamination

Advantages

1) Negligible rise in temperature of the irradiated product at the required absorbed dose, also the physical characteristic of the irradiated foods are not altered, hence their fresh, frozen or dried character is not compromised.
2) Its application reduces the need for the use of some chemicals, particularly fumigants which may leave residues of toxicological significance.
3) Irradiation with gamma rays, involves relatively little energy consumption and is an environmentally clean process.
4) It can be applied to (hermetically) packaged products which are protected against recontamination and to some packaging materials which will not withstand heat decontamination.

Limitations

1) High capital cost of irradiation facilities.
2) There is a threshold dose above which organoleptic change occur, however the threshold dose is higher when frozen and this should be considered in implementing the process.
3) All microorganisms or their toxins will not necessarily be eliminated. Bacterial spores are not destroyed by low radiation doses hence poultry, meat or fish products need to be stored in appropriate temperature control to prevent the germination of the surviving spores of Clostridium botulium or C. perfringens. Although moulds and Staphylococcus aureus are radiosensitive, their toxins (mycotoxins and staphylococcal enterotoxins) are not. Therefore foods subject to contamination by these microorganisms should be treated before these toxins are produced.

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Table 1:	Some Pathogenic Agents Isolated from Meat Products and Chicken and Officially Reported in Latin America		
FOOD	VIRUS	BACTERIA	PARASITE
Chicken (including turkey and wild duck)		*Campylobacter* *Salmonellae* *Cl. perfringens* *S. aureus* *E. coli* *B. cereus* *Yersinia*	*T. gondii*
Meat	F. aftosa	*Salmonellae* *Cl. perfringens* *S. aureus* *Campylobacter* *E. coli* *Tuberculosis* *Streptococci* *B. cereus*	*Cysticercus bovis* *T. gondii* *Hidatidosis*
Horse		*Salmonellae* *E. coli*	*Hidatidosis*
Sheep	F. aftosa	*Salmonellae*	*Hidatidosis* *T. gondii*
Pork	F. aftosa P. porcina clasica	*Salmonellae* *S. aureus* *C. perfringens* *Campylobacter* *E. coli* *Yersinia enterocolitica* *Tuberculosis*	*T. spiralis* *Cysticercus celluloseae* *T. gondii*
Salamines		*Salmonellae* *S. aureus*	*T. spiralis*
Sausages		*Salmonellae*	*T. spiralis*
Ham		*S. aureus* *Salmonellae*	*T. spiralis*
Pork sausages		*Cl. botulinum* *Streptococci* *Campylobacter*	
Mortadella		*Salmonellae*	
Liver		*B. cereus*	

Fish and Shellfish (esp. from warm waters)		*Vibrio para-haemolyticus* *V. vulnificus* *V. cholerae*	
Shellfish		*Salmonellae* *Shigella*	*Clonorchis Sinensis* *Opisthorchis Viverrini*
Meat		*Listeria*	*O. felineus* *Anisakis simplex* *Angiostrongylus Cantonensis* *A. costaricensis*
Chicken		*Salmonellae typhimurium enteritidus*	
Snails			*Achatina fulica* *A. Pilc*
Crabs			*Paragonimus Westermani* *P. heterotremus*

Table 2:	Some Pathogenic Agents Isolated from dried spices and condiments	
FOOD	**FUNGI**	**BACTERIA**
Spices	*Aspergillus flavus* *A. niger* *A. parasiticus* *Fusarium spp* *Penicilium spp.*	*Bacillus cereus* *B. subtilis* *B. coagulans* *B. polymyxa* *Staphylococcus aureus* *E. coli* *Diplococcus spp.*
Wheatmeal	*Aspergillus flavus* *A. niger* *Fusarium*	*Bacillus* *Serratia* *Enterococcus* *Clostridium*
Cornmeal	*Aspergillus flavus* *A. niger* *A. parasiticus*	*E. coli* *Bacillus* *Serratia* *Enterococcus* *Clostridium*
Oat	*Aspergillus flavus* *A. niger* *Fusarium*	*E. coli* *Bacillus* *Serratia* *Clostridium* *Pseudomonas*
Dried egg powder		*Salmonella lille* *S. enteritidis* *S. typhimurium*
Tea Herbs	*Aspergillus flavus* *A. niger* *A. parasiticus* *Fusarium spp* *Penicilium spp.*	*Clostridium* *Staphylococcus* *E. coli* *Salmonella* *Proteus spp.*

Table 3: Pathogenesis of food poisoning due to microorganisms			
Organism	**Incubation Period**	**Pathogenesis**	**Common Syndrome**
Clostridium perfringens	8 - 16	Enterotoxin resulting in hypersecretion of cyclase in the gut	Abrupt onset of profuse diarrhea.
Clostridium botulinum	24 - 96	Production of toxin which blocks acetyl choline formation functions	Dry mouth, respiratory embarrassment, infrequent vomiting cranial nerve paralysis, muscle
Escherichia coli	24 - 72	Toxin production leading to hypersecretion in small intestine	Generally abrupt onset of diarrhea, self limited in adults but serious in
Salmonella spp.	8 - 48	NoToxin production Little invasion, superficial infection.	Gradual onset of diarrhea. Low grade fever.
Shigella spp.	24 - 72	Production of toxin causes hypersecretion in small intestine, shedding of epithelium with pus.	Onset is abrupt with cramps, pus, blood and mucus in faeces. Lethargy cramps, fever malaise, clouded judgment.
Staphylococcus	1 - 18	Produces enterotoxin acts on medualllary centre.	Abrupt onset with intense vomiting lasting up to 24 hours.
Vibrio cholerae	24 - 72	Production of toxin causing hypersecretion in small intestine.	Abrupt onset of liquid diarrhea, severity varies. Liquid stool in grey, rapid dehydration, acidosis etc.
Vibrio haemolyticus	6 - 96	Production of toxin resulting in hypersecretion in small intestine.	Abrupt onset of diarrhea Blood and mucus in stool.
Listeria monocytogenes	168 - 720	No toxin produced. Infect the blood stream, meningitis and encephalitis.	Fever, headache, nausea and vomiting. Cirrhosis and ulcerative colitis.
Bacillus cereus		Intoxicication, production of penicillinase, phospholipase C and hemolytic enzyme.	Similar to those of C. botulinum.
Campylobacter jejuni		No toxin production.	Abrupt onset of diarrhea.

Table 4: List of Clearance		
Country	**Product**	**Dose Permitted (KGy Max)**
Argentina	Spices	30
Bangladesh	Chicken	7
	Fish	2.2
	Froglegs	7
	Shrimps	5
	Spices	10
Belgium	Shrimps	5
	Spices (80 different types)	10
	Herbal teas	10
	Arabic Gum	10
Brazil	Spices (13 different products)	
	Fish and fish products	2.2
	(salted, smoked, dried dehydrated, fillets)	
	Poultry	7
Canada	Spices and dried vegetables	10
	Onion powder	10
Chile	Chicken	7
	Teleost fish and fish products	2.2
	Spices and condiments	10
China	Sausage	8
Denmark	Spices and herbs	15
Finland	Dry and dehydrated spices and herbs	10
	all foods for patients requiring sterile diet.	no limit
France	Spices and aromatic substances	11
	Gum arabic	9
	Cereal flakes and germs for milk products	10
	Dehydrated vegetables	10
	Mechanically deboned poultry meat	5
	Frozen frog legs	8
	Frozen or refrigerated peeled deheaded	5
	Shrimps	10
	Animal blood	5
	Rice flour	10
	Aromatic herbs (frozen)	5
	Poultry	6
	Raisins, dried dates and dry apricots	4
Hungary	Frozen chicken	6
	Spices	10
Indonesia	Dried spices	10

Israel	Spices (61 different products)	7
	Animal feed	7
	Poultry and poultry sections	10
	Dry and dried vegetables	15
	Poultry feed	10
Rep. of Korea	Dried spices	10
Mexico	Spices	10
	Egg powder	7
	Cocoa powder	7
	Cereal products	7
	Prepared soup	7
	Milk powder	
Netherlands	Dried vegetables	10
	Frozen shrimps	7
	Fresh shrimps	1
	Spices and herbs	10
	Poultry	3
	Fish fillets	1
Norway	Spices (dried)	10
Pakistan	Spices	10
Poland	Spices and herbs	10
South Africa	Chicken	7
Syrian	Chicken	7
	Cocoa beans	5
	Spices and condiments	10
	(dried onion and onion powder)	
Thailand	Nham	4
	Moo yor	5
	Sausage	5
	Frozen shrimps	5
	Cocoa beans	5
	Chicken	7
	Spices and condiments	10
Russia	Poultry, eviscerated	6
	(in plastic bags)	
	any food for consumption by patients who require a sterile diet as essential factor of their treatment.	
USA	Spices and dried vegetable seasonings	30
	Dry or dehydrated enzyme preparations	10
	Pork carcasses or fresh, non-heat	1
	Processed nuts of pork carcasses	
	Poultry	3
Former	Egg powder	10
Yugoslavia	Herbal Teas, Tea Extracts	10
	Fresh Meat and Poultry	10
	Spices	10
Taiwan	Spices	30
	***Adopted from IAEA, 1991.**	

TECHNICAL SESSION II
Discussion: Questions, Answers and Comments

<u>Questions on the 1st Paper</u>

Question 1 - Dr. P. C. Onyenekwe, I.A.R/A.B.U. Zaria.

Have you considered the effect of radiation treatments on the chemicals used in combination with irradiation, especially if the chemical was applied first?

Comment:

Keeping yam up to 6 weeks before treatment may lead to use of higher doses because by then, DNAs necessary in sprouting may have been activated and since proteins are rarely affected hence the higher doses.

Answer

The observation was right and infact it will be better to do the irradiation before sprouting which could occur during the 8th week, and therefore the dosage can be reduced. But any wounds should be allowed to heal. One can either use radiation as a technique or as a pesticide. The best is probably the combination of heat treatment and radiation.

Question 2 - Prof. Phillip F. Olurinola, ABU, Zaria.

The success of yam preservation at laboratory level. How feasible is this for rural yam farmers? Are mobile irradiators possible? Will it be cost effective to move the yams from all over the country to SHESTCO Plant for irradiation?

Answer

It is expensive to install an irradiation plant. It also requires careful considerations about its location. Location is best where it is possible to use it for a wide variety of foods harvested at different times in the year. Raw material supply is paramount to irradiation plant.

Comments:

(i) - Mr. J. O. Opadokun

I recommend that irradiation equipment should be restricted to areas where abundant supply of raw materials can be realized.

(ii) - Prof. E. U. Emovon

Centralisation of irradiation has several benefits and would involve the farmers coming together or as a co-operative society type of marketing. It also promotes co-operation among farmers.

(iii) - Dr. A. J. Coker

We need to plan ahead and take into consideration the consequences of centralization e.g. hazards, safety, etc and that we need to get our priorities right.

Question 3 - Mr. G. A. Solabi, Nestle Foods Nig. Plc.

Dr. Adesuyi and Mr. Talabi need to explain the contradiction in their presentations on the issue of radiation using Co-60 for mites. Dr. Adesuyi says that the technique can sterilize and kill while Mr. Talabi says the technique is not very effective in eliminating mites.

Answer

In Mr. Talabi's paper (read by Mr. I. B. Allen), it was claimed that mites are resistant to irradiation, but he (Dr. Adesuyi) did not experience such. The insect may not die immediately but they cannot eat or do much damage when they move around.

Question 4 **Dr. G. A. Solabi, Nestle Foods (Nig.) Plc, Lagos.**

What about the use of irradiation on packages like tin plates and tetrapacks? Has irradiation been applied successfully?

Answer

From the literature, one could use all forms of packaging materials and still irradiate, unlike the use of chemicals where one would have to unpack the products. When irradiation is to be used, just package and then irradiate.

Comment:

(i) - **Dr. C. A. Adesanmi, SHESTCO, Abuja.**

In response to Mr. Solabi on packages, I have this to say. Irradiation technology allows the use of packages ranging from low density thin polyethene to high density steel boxes because of the high penetrating ability of the gamma radiation. What is required is to determine a suitable package for the product, then the irradiation conditions necessary, to ensure that the required dose is delivered to the product, can be worked out.

(ii) - **Engr. Dr. S. O. Awonorin, Fed. Univ. of Agric, Makurdi.**

There is the need to test the traditional packaging materials on irradiation systems for possible side effects and residues.

<u>Questions on the 3rd Paper</u>

Question 1 - **Dr. A. J. Coker, SHESTCO, Abuja.**

Work on cassava indicates that high yielding mutants are characterised by high cyanide (HCN) contents while low yielding mutants have low HCN contents. Is the HCN in the high yielding mutants lethal to consumers? What is being done to generate high yielding mutants with low HCN content?

Answer

The varieties of cassava developed at Umudike are bitter varieties, with high HCN content, and mutation induction is very effective.

Question 2 - **Dr. D. A. Pelemo, C.E.R.D, OAU, Ile-Ife.**

You have used gamma irradiation in roots and tubers to produce mutagens. Your results did not indicate the threshold level of irradiation. What is the threshold value to produce mutagens of your desired characteristics (e.g high yielding and ability for inter-cropping)? If you apply more than the threshold value what result would you expect?

Answer

The radiosensitivity dose is that which gives the mutation required, above that range would give some changes in the physiology and genetic damage and death.

Questions on the 4th Paper

Question 1 - Dr. A. J. Coker

At what stage from the pod to export of the cocoa beans should gamma irradiation technology be applied for maximum effect?

Answer

Since the bulk of cocoa beans to be exported go through Lagos, the irradiation process should be done in Lagos. Irradiation should be done after drying, when the moisture content of the beans is about 7% or less.

Questions on the 6th Paper

Question 1 - Dr. S. A. Shaibu, FRCN, Abuja.

Federal Ministry of Agriculture can be seen to be the greatest beneficiary of irradiation technology. We are talking of silos grain reserves. The silos approach, I am sorry to say is a pedestrian approach in our scientific era. What is the Federal Ministry of Agriculture's input to the development of irradiation plant in SHEDA?

Answer- Prof. S. B. Elegba

First, the installation of Co-60 will be a useful equipment for all the agricultural sectors with emphasis on some shelf-life extension, some to improve the genetic quality and some to prevent pest damage.

Comment:

(i) - Mr. G. A. Solabi, Nestle Foods (Nig.) Plc, Lagos.

When a new technology, such as irradiation applications, is being introduced we should also consider the logistics. When researchers, government functionaries and industrialists meet, we should discuss the technicalities of transferring the experimental results to the industry for practical use. For example, how do we get onions to the industry within the first 2 to 3 weeks of harvest?

(ii) - Dr. B. O. Ajagbonna

There is the need to get the necessary infrastructure in place. The use of jute bags to transport onions has been demonstrated to be successful. We can discuss more about other effective methods of transporting onions after the technical session.

(iii) - Prof. E. U. Emovon, Coordinator, SHESTCO Abuja.

I am happy that Dr. Solabi raised the points and the researchers were able to give some solutions to the problems of transporting onions. On whether we need to have enough raw materials for the irradiation plant, the industrialists would always source for their raw materials and they should attend this type of conferences in order to share ideas and discuss their problems with the researchers and government officials.

(iv) - Dr. R. K. Omotayo, NAFDAC, Lagos.

Exploiting the meetings of the sectoral groups of Manufacturers' Association of Nigeria (MAN) to provide information on the advantages of irradiation is important. This should sensitize the industries on the advantages of this new technology.

(v) **Dr. G. Hubner, Gamma Service, Germany.**

Scientific work on irradiation technology has been done in many countries. I believe, it is necessary to combine scientific work with technological studies on the whole process to get information on the handling, irradiating techniques, transportation and storage of bigger quantities of products, to get information on logistics.

TECHNICAL SESSION 3

IRRADIATION TECHNOLOGY FOR NATIONAL DEVELOPMENT

i. Sourcing for Raw Materials and Storage for the Food Industries
   a. G. A. Solabi - Nestle Foods Nig. Plc Lagos.

ii. Irradiation Technics in Science and Industry
   Dr. G. Hubner - Gamma Service Produktbestrahnlung Germany.

iii. Irradiation Cross Linking of Polymers and Rubber
   a. Prof. Kolawole E. G. - Textile Sc. & Tech. Dept, ABU Zaria.
   b. Prof. S. C. O. Ugbolue - Fed. University of Technology, Owerri.

iv. Applications of Gamma Irradiation in the Wood & Timber Industry.
   by Dr. Isaac Ero - Forestry Research Institute of Nigeria, Ibadan.

v. Applications of Gamma Radiation in the Wood & Timber Industry.
   by Dr. S. P. A. Okoro - Dept. of Forestry & Wildlife University of Benin, Benin.

vi. Irradiation Treatment as a Phytosanitary Measure
   by M. A. Ayodele & G. O. Adejare - Nig. Plant Quarantine Service, Ibadan.

SOURCING AND STORAGE OF RAW MATERIALS FOR THE FOOD INDUSTRY

G. A. Solabi
Nestle Foods Nigeria Plc
Lagos.

Abstract

The role of the food industry in the society which include transformation of perishable agricultural raw materials into high quality products at the lowest possible cost to ensure general acceptability and affordability are discussed. The availability of the major raw materials for the food processing industry in Nigeria was examined and the ease of obtaining and keeping such materials to ensure uninterrupted and optimum productivity level was reviewed. The available storage facilities and methodologies with their constraints were also considered.

Introduction

The food industry and agriculture are closely linked. Indeed, without the agricultural produce, there could be no food industry.

Hence food production is generally regarded as embracing activities that commence from "Farm" and end at the "Table".

However, for a better appreciation of the role of the food industry in the Supply Chain, it is often necessary to make some distinctions between agricultural food production and the food manufacturing operations. Many of the agricultural produce are not only perishable within a short time, they are also not consumable in the form they are harvested.

The primary objective of the food processing industry is the transformation of perishable agricultural raw materials into finished products of longer shelf life which serve the needs of the consumers.

And because the food needs of the consumers vary widely with the culture, the socio-economic and even the educational status of the society, the food industry, world-wide strives to produce variety of high quality products at the lowest possible cost to ensure general acceptability and affordability.

The raw materials needs of the food industry therefore vary equally widely as the food and food products being produced.

This paper attempts to examine the availability of the major raw materials for the food processing industry in Nigeria. The ease of obtaining and keeping such materials to ensure uninterrupted and optimum productivity level is reviewed. The available storage facilities or methodologies with their constraints are also considered.

Major Raw Materials for Food Industry

The food industry has been classified into about seventeen subsectors in accordance with the products being manufactured. The products are many and so are the required raw materials.

For the purposes of this presentation, some key Raw Materials requirements by many of the sub-sectors are presented in Table 1.

It can be seen that the use of some raw materials cut across the sub-sectors. However, the following raw materials deserve special mention in view of their numerous uses, viz Sorghum, Maize, Sugar, Vegetable Fats and Oil, Flavouring and Additives, Cassava and Soyabeans.

Quantifying the requirements of the industry for raw materials is a rather difficult assignment because of the dearth of information. Generally responses to survey questionnaires are poor (usually below 50% feedbacks and data provided are not always a reflection of the true situation on ground).

However, based on the Raw Materials Research and Development Council's, (RMRDC) survey report of the multi-disciplinary Task Force on Food, Beverages and Tobacco Sector of 1989, Table II reflects the demand and supply situation for the major raw materials in the food industry.

Today the situation has not changed significantly.

Local Sourcing

Apart from the Additives, some of which may be produced through chemical synthesis and few raw materials like Salt, Enzymes, Mineral Salts and Vitamins, virtually all the other raw materials are produced locally once or twice in the year. The availability is seasonal and climatically dependent. The quantities of the locally produced agricultural raw materials vary from season to season. The off season production is very minimal. The use of irrigation system to procure some of the raw materials during the dry season is at its infancy and is presently being practised in the Northern Zone of the country.

Many of the food processing industries are not located close to the sources of raw materials. For example, the commercial production of Sorghum and Maize is northern based. Yet, most sub-sectors of the food industry utilising the raw materials are southern based Breweries, Flour Mills, Cereal and Malt Extract products processors.

Except as in Soyabean which is currently being produced in commercial quantity in the Middle Belt Region/Central Zone of the country. Apart from Taraku Oil Mills sited close to the source of Soyabean production, other major users of the raw material are located far away in the South West and in Lagos Area

Also here is the great problem of shortage of intermediate raw materials processors for the food industry. Cassava and corn starch are primary raw materials for many food industries in the country. According to Falusi (1996) and Central Bank of Nigeria (CBN) Statistical Bulletin (1994), Maize and Cassava production have shown significant increase in the last four years.

Indeed, Maize has become the second most important staple crop in terms of production. Nevertheless, the food industry is constantly in shortage of Cassava or Corn Starch supply as input for secondary food processing.

Consequences

Sourcing of raw materials for the food industry locally has a lot of consequences.

(i) Unstable prices of raw materials, making annual cost of production difficult and unpredictable.
(ii) Stock piling of raw materials during harvesting period resulting in storage problem.
(iii) Capital is tied down unnecessarily.
(iv) Cost of storage and treatment for keeping quality increases the cost of production.
(v) Long distances transportation cost also increases the cost of production.

Sourcing through importation

From Table II and the available data on demand and supply of raw materials for the food industry, many of the desired raw materials still have to be imported from the developed countries.

In the last ten years, however, the food industry has made a lot of efforts at development of substitutes or alternatives for imported raw materials.

Table III shows the reflection of the joint efforts of the various Researchers/Scientists/Technologists and the food producers.

The national expectation in this direction is yet to be fully met. Most of the raw materials often claimed to be "locally available" are still imported.

It is however pertinent to state that the food industry has performed fairly well in the efforts to source raw materials locally in the last one decade.

The use of sorghum in place of malted barley for the production of beer, beverages, non-alcoholic drinks, the production of malt extract/syrup from local grains as well as the use of soyabeans and locust beans in the production of Hydrolysed Vegetable proteins for the food seasoning are some of the significant steps taken by the food industry towards reducing its dependency on imported inputs.

Even, fresh milk production, which our general climatic conditions do not favour, has substantially been sourced locally through the collaborative research work between the relevant food manufacturers/users and the foreign/local scientists and technologists.

The shortfalls in all these desired inputs for food manufacture have to be sourced through importation.

There are some food ingredients, like enzymes, vitamins, flavouring concentrates, essential oils and minerals or mineral salts that have no relative economic advantages producing then locally for our current level of industrial activities. They remain basically dependent on foreign sourcing.

Consequences of sourcing through importation

Like, local sourcing of raw materials, procurement through importation has its own characteristic features.

(i) Long delay between the demand (ordering) and supply.

(ii) Special packaging and shipment/transportation to protect quality, thereby increasing cost.

(iii) Unstable Governmental policies affecting tariffs and port clearance-resulting in possible storage of the raw materials in unfavourable conditions.

(iv) Deliberate importation of huge quantity of raw materials to prevent frequent production stoppages resulting from non-arrival of orders. Capital is equally tied down.

(v) Provision of adequate storage facilities and frequent good house keeping and environmental sanitation to prevent rodents, insects and physical damages of the raw materials.

(vi) Risk of low quality inputs, arising from shelf life of the raw materials and in some cases loss of inputs due to expiry date.

It is clear from both local sourcing and importation of raw materials that adequate storage is essential for the survival of the food industry in Nigeria.

What storage facilities are available and at what cost? What is the level of safety guaranteed by the mode of storage(s)?

How readily available and what level of losses expected?

These are some of the questions to be answered when considering raw materials sourcing and storage for the food industry.

Available Storage Facilities

There are many storage structures available for storing raw materials for the food industry. The type to be used depends on many factors.

(i) The nature of raw materials - perishable or non-perishable, semi-processed or raw.

(ii) The stage of storage in the supply chain:
On - Farm or Off- Farm, with the merchants/suppliers or with the processors.

(iii) The quantity(ies) of raw materials:
for small, medium or large scale processors.

(iv) The duration of storage:
short, medium or long period of time

(v) The cost of the structure in terms of capital outlay and running/operational cost etc.

Generally, three types of storage structures are well established in the country for grains in particular.

(i) Cribs for on-farm small storage of 10 - 50 tonnes.

(ii) Warehouses - for merchants/suppliers and processors for medium to large scale storage: 50 - 2,000 tonnes for a period of one to two years.

(iii) Silos - for big merchants/suppliers, Governmental Strategic Grains Reserve System (SGR) and large scale commercial processors for 500 - 2,000 tonnes.

The cost of establishing these types of storage facilities as at 1989 is shown in Table IV (Talabi, 1995).

It can be seen from the Table that Capital Costs is generally higher than operating costs for most of the facilities; except in the very large capacity Warehouses. Also the total project costs increases with the capacity of the storage structure.

In practice, in the country today, the use of Warehouses for storage of all kind of raw materials for the food industry is very common virtually at all levels of Supply Chain. Why?

It is readily available. It is adaptable to other forms of raw materials preservation and storage systems. Its environment could be better controlled and thus ensure high level of raw materials quality and safety.

Commercial Storage

For this presentation, consideration would be given to some aspects of Commercial Storage Operations that are applicable to the food industry in general.

(i) <u>Bagging and Fumigation</u>

Under commercial storage, grains handled by medium to large-scale merchants or suppliers, governmental agencies and food processors are normally shelled and stored in bags.

For this type of storage, losses are minimised through in-bag fumigation with fumigants (Phosphine), sealed up inside envelopes at the rate of 3 - 6 tablets per tonne.

In order to prevent re-infestation, safe storage pesticides such as Damtin, Actellic etc. at about 10μg/kg (PPM) is applied to the surface of the bags either before or after fumigation. Actellic dust could be mixed with the grains. This method has proved extremely effective.

State or Federal Government Agencies storing grains, retain them for much longer periods. In this class of Supply Chain are the Strategic Grains Reserves (SGRs) against natural disasters or for price stabilisation.

Storage in this case, is also in bags or in bulk. Wooden pallets are placed on the floor before bagged produce are arranged on them. Bags are stacked way from walls, leaving enough space to the roof for easy fumigation operations. Fumigation with Phostoxin is done under tarpaulins.

The main problem in this operation, apart from increasing cost of fumigants, is the toxic nature of the Phosphine. The Warehouse has to be shut and locked for about three or four days to allow the gas to percolate or penetrate through each bag of the produce. Workers are not allowed into the Warehouse during the fumigation to prevent intoxication by the gas. Residual ashes are usually safely disposed off.

(ii) Silo Storage

Bulk storage is normally done in Silos fabricated of metal, aluminium or concrete and installed on reinforced concrete platforms.

Problems experienced with this type of storage included:

(a) Leakage of gas (Inert gas, Nitrogen)

(b) Non-penetration to the bottom of the Silos of fumigant introduced at the top.

(c) Moisture migration and condensation.

(d) Cracking and caking of the raw materials due to the expansion and contraction of the Silos.

However, with well constructed Silos, using Nitrogen gas and with constant internal temperature control, grains stored in Silos are known to have kept pure with normal quality retained for more than two years. (Abiodun, 1983, Agboola, 1985).

Use of Silos is common with the Flour Millers and the Breweries.

(iii) Chemical usage for stored produce

Chemical pesticides which may be insecticides, fungicides, rodenticides are used to reduce the menace of a wide range of pests which infect stored produce at different stages of Supply Chain.

Several formulations of pesticides are available in the market as liquids, (Nuvan, Nuvanol), dusts (Actellic) and fumigants (Phostoxin, Methyl Bromide {now banned}) to deal with pests under various circumstances.

Fumigant like Phostoxin is preferred because no residue is left on the stored produce.

Others, in the organophosphates, pyrethroids and carbamates are not without some problems:

(a) Pesticide resistance

(b) Pesticide residues on stored produce.

The problems associated with pesticide usage have led to the various attention that have recently been directed towards alternative control and preservative techniques.

Among these new approaches to storage and preservation of agricultural produce, perishable and non-perishable, are biological control techniques and irradiation technology. But like the problems associated with the use of chemicals, the issue of preservation by ionising radiation and biological control techniques have become subject of national and international discussion.

No doubt, the symposium on Irradiation Technology for National Development would go along way towards the improvement of storage of raw materials for food industry.

CONCLUSION

It is difficult to provide adequate estimate for the total raw materials need of the food industry. The usage of some raw materials cuts across many sub-sectors. Utilization of some raw materials is concentrated in the hands of many cottage food industries who do not keep production data. No organised commodity marketing system. There is little or no systematic market information on agricultural commodities. Seasonal variation affects availability, quality and prices annually.

Limited knowledge of proper handling of agricultural produce during and after post harvest activities enhance deterioration even in storage.

It is in this context that any efforts at increasing agricultural production must be matched with equal and perhaps greater efforts at providing adequate and efficient storage and preservation methodologies in order to minimise the overall food losses and ensure availability of raw materials at relatively stable prices throughout the year for the food industry.

It is equally important to state that the provision of adequate and efficient storage facilities as well as safe preservation techniques would be beneficial in many ways.

Availability of raw materials at the right time, in the right quality and quantity would not guarantee greater capacity utilisation in the food industry.

Most importantly, the overall national objective of ensuring adequate food security for the populace within the next decade could be achieved.

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TABLE 1: KEY RAW MATERIALS UTILIZED BY MANY SUBSECTORS OF THE FOOD INDUSTRY

	RAW MATERIALS	SUB-SECTORS UTILIZING RAW MATERIALS
1	SORGHUM MAIZE WHEAT	Beer; Flour Millers; Cereal and Barley Products; Cocoa and Chocolate; Animal Feeds, Malt Extract Products
2	SUGAR	Beer; Soft Drinks, Cereal & Barley Products, Cocoa & Chocolate; Sugar & Sugar Confectionery; Fruit & Vegetable Products.
3	SOYA BEANS	Cereal & Barley Products; Dairy Products (Analogs); Animal Feeds; Spices & Flavouring; Margarines; Edible Oils & Industrial Fats; Fruits & Vegetable.
4	VEGETABLE OILS	Cereal & Barley Products; Dairy Products; Margarines; Edible Oils & Industrial Fats Products.
5	CASSAVA	Cereal & Barley Products; Animal Feeds; Sugar & Sugar Confectionery; Roots & Tuber Products.
6	ADDITIVES -Chemicals - Flavourings - Colourings	These are utilized in almost all subsectors.

SOURCE: RMRDC, Multi-disciplinary Task Force Report (1989).

TABLE 2: MAJOR RAW MATERIALS REQUIREMENTS FOR FOOD INDUSTRY AND ESTIMATED NATIONAL NATIONAL PRODUCTION (METRIC TONNES)

RAW MATERIALS		ASSOCIATED FOOD INDUSTRIES	SECTORAL DEMAND	NATIONAL PRODUCTION	% LOCAL SOURCING	COMMENTS/REMARKS
1	SORGHUM	Brewing Malt Extract (Confectionery & Beverages) Flour Milling Animal Feed	720,000	2,636,000	>100	Availability mainly from the northern part + seasonal Transportation & storage problem - insects infestation
2	MAIZE	Flour Milling Cereal Products Animal Feed	2.5M	1.4M	56	Competition between Food Industry, Human House & Animal F Importation not allowed High variation incost of sourcing Storage problem from season to season
3	WHEAT	Flour Milling Bakery + Cereal Products	4.5M	42000	<1	Local Production grossly inadequate Importation mainly Storage problem - mouldy + insects infestation Used mostly after semi-processing (flour)
4	SALT	Baking Confectionery Culinary Products	66,000	N/A	N/A	Mostly imported - Local industries merely purify and package Storage problem - caking or uptake of water
5	SUGAR	Soft Drinks Bakery & Confectionery Biscuit Beverages & Cereal Products	1M	50,000	5	Local Production grossly inadequate Importation mainly Storage problem - uptake of water wetting
6	VEGETABLE FATS & OILS	Bakery & Confectionery Biscuit Cereal Products Beverages Dairy, Snacks	80,000	610,000	>100	Quality keeping problem in storage Competititon between food industry & human domestic consum Not enough for refinery and use in food production Mostly consumed in crude form
7	MILK POWDER	Dairy Beverages Cereal - Baby Foods	60,000	N/A	N/A	Local Production grossly inadequate Importation mainly Storage problem
8	COCOA POWDER	Beverages	20,000	6,000	30	Less than 50% of cocoa beans produced could be processed High level of cocoa beans exportation Storage problem
9	TOMATOES	Seasonings	25,000	32,500	>100	Post-Harvest Storage problem High Level (30%) losses at farm gate Industries compete with human domestic consumption
10	CHILLI PEPPER	Seasonings	500	25,000	>100	High level post harvest losses (20%) Storage problem

Data Adapted from Report of Multi-disciplinary Task Force on Food, Beverages & Tobacco Sector (RMRDC), Lagos, 1989.
Comments are those of the Presenter of this Paper.
M - Million
N/A - Not Available

TABLE III IMPORT RAW MATERIALS' SUBSTITUTES		
	IMPORTED RAW MATERIALS	**LOCAL SUBSTITUTE/ALTERNATIVES**
1	Malted Barley	Sorghum, Sorghum Malt, Maize & Rice Grits
2	Hops	None yet Local R & D still in progress
3	Enzymes	None yet
4	Additives	None yet
5	Sugar	Local production grossly inadequate R & D on locally produced non-nutritive sweetener in progress.
6	Wheat	Local wheat production grossly inadequate, other cereal flours are being produced.
7	Fresh Milk, Milk Powder	Local production inadequate. R & D activities yielding positive results. Soymilk as alternative.
8	Milk Fat	Vegetable Fat
9	Flavouring Concentrates for Spirits and Soft	R & D on local flavours and bitters are in progress.
	Drinks	R & D on local new formulations in progress.
10	Dextrose & Glucose	Local R & D in progress to produce from cassava through acid of enzymes hydrolysis.
11	Cereal Starch	Modified Cassava starch.
12	Fish Meal	Poultry offal as alternative. Local production
13	Salt	No substitute envisaged. Local supply negligible relative to demand.
14	Hydrolysed Vegetable Proteins	Soyabean, locust beans, groundnuts, melon seed and cotton seed as sources for local production.
15	Essential Oils	R & D all activities at local industrial research centres are yielding encouraging results.
16	Chicory, Curry & Tumeric	Yere" and other local sources under investigation.
17	Butter Oil	Local refined and deodorized palm oil
18	Tea Leaves	Highland and Lemon Grass Tea

Source: Adapted/updated from RMRDC Survey, 1989.

TABLE IV: COST OF ESTABLISHING CRIBS, WAREHOUSES & SILOS OF VARIOUS CAPACITIES

	STORAGE CAPACITY (TON	TOTAL PROJECT COST (#)	CAPITAL COST (%)	OPERATION COST (%)
1	Cribs			
	10	23,535	64.7	35.3
	50	88,185	52.1	47.9
2	Warehouse			
	50	186,710	59.5	40.
	100	317,240	54.6	45.4
	500	970,676	30.6	69.4
	2,000	3,543,827	31	69
3	Silos			
	500	22,086,680	65.9	34.1
	2,000	7,619,290	65.1	34.9

SOURCE: TALABI, (1995) - NIFST 19TH ANNUAL CONFERENCE, KADUNA.

IRRADIATION TECHNIQUES IN SCIENCE AND INDUSTRY

by

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Abstract

Radiation interaction processes brought about in a material are caused by deposition of energy. Detailed accounts of the mechanisms by which ionizing radiations change molecular structures, induce mutations or inactivate microorganisms will be discussed.

These effects are used in research and many applied scientific fields like mutation research, breeding of new plant varieties, controlling of harmful insects and microorganisms, food irradiation and cancer therapy. Crosslinking of polymers, polymerisation and curing of adhesives and films, copolymerisation and grafting, flue gas cleaning just as solid and liquid waste treatment are fields of intensive research.

Main industrial application is realized in sterilisation of medical products by gamma facilities or electron accelerators, crosslinking of polymers in wire, cable and tubings, and food irradiation. An overview on the international development of irradiation technology will be given.

Introduction

The very short wavelength electromagnetic radiations, x- and gamma-rays, and the corpuscular radiations electrons (β-rays), helium nuclei (alpha-rays), protons, neutrons and accelerated heavy ions. (Fig. 2) are all ionising radiation.

X- and gamma-rays are radiations of the same character as ultra-violet or visible light, but they are of shorter wavelength and the energy of their quanta are of the order of 10^4 higher than the energy of the quanta of light.

Interaction of radiation and matter

Not all types of radiation are suitable for radiation techniques. Alpha particles, for instance, penetrate not deep enough into the irradiated material. Other radiations, like electrons and x-rays of very high energy (>10MeV) induce radioactivity within the irradiated material. When high-energy electrons are absorbed by matter they lose their kinetic energy. Interaction with orbital electrons of the atoms causes ionizations and excitations. Ionization means that orbital electrons are ejected from atoms of the medium. At excitation orbital electrons move to an orbit of higher energy.

When gamma- or X-ray photons interact with the absorbing matter, three types of interaction can occur, the photoelectric effect, the Compton effect, and pair production (Fig 3). Photoelectric absorption occurs largely with photons of energies below 0.1 MeV and pair production primarily with photons of energies above 10 MeV. Low and high energy ranges are not used in radiation techniques because of missing efficiency at low energies and the induction of radioactivity at higher energy levels, e.g. 5 MeV of photons or 10 MeV of electrons.

Thus, Compton effect is the main process of interaction of photons with matter. In this process an incident photon interacts with the electron shell of an absorber atom and ejects an orbital electron. The incident photon continues after the collision with less energy in a changed direction. The ejected compton electron has enough kinetic energy to cause excitations and ionizations in the absorber atoms.

Thus, it interacts with the matter in the same way as ejected secondary electrons produced by an electron accelerator beam. The induced chemical changes in the irradiated medium are largely the same, regardless of the type of radiation used. Ionized and electronically excited atoms and molecules as a result of the interaction between radiation and matter, cause the chemical and biological effects of radiation. Although all ionizing radiation interacts with matter in a similar way, different types of radiation differ in their efficiency in damaging a biological system. The distribution of ionizations and excitations in the tracks of a radiation through matter determines its biological effectiveness. In order to accommodate both the excitation and ionization events, the term linear energy transfer (LET) has been coined. LET is the mean energy released in keV per micrometer of the matter traversed. Alpha-particles, neutrons and protons are high LET radiations, X- and gamma-rays and fast electrons are low LET radiations.

Effects of ionizing radiation on water

When water is irradiated, the main primary reactions are ionization, forming the water cation radical H_2O^+, and excitation forming excited water molecules H_2O^*. Deprotonation, proton transfer, combination and recombination reactions occur with solvated proton H_3O^+, hydroxyl radical OH, solvated electron e^-_{aq}, hydrogen atom H, and water molecules (Fig 4). While OH, e^-_{aq}, and H are very reactive transient species, hydrogen H_2 and hydrogen peroxide H_2O_2 are the only stable end products of water radiolysis.

Oxygen effect

In the presence of oxygen hydrogen atoms reduce oxygen to the hydroperoxyl radical $H + O_2 \text{----}> HO_2$, which is in equilibrium with the superoxide anion radical O^-_2. Solvated electrons also form superoxide radicals with oxygen. Both the hydroperoxyl radical and this superoxide radical can react to hydrogen peroxide (Fig. 5). Thus, oxygen is quickly consumed when water or water containing products are irradiated.

Because diffusion of oxygen from the atmosphere is rather low, irradiation at higher dose rates creates anoxic (anaerobic) conditions in the irradiated medium. Thus, oxygen effect is higher under low dose rate conditions, the so called dose rate effect is actually an oxygen effect.

pH-effect

The pH of aqueous systems can also influence the result of radiation treatment because an acid medium favors disappearance of e^-_{aq}, while an alkaline medium favors the formation of e^-_{aq} (Fig 6).

Direct and indirect radiation effects

In radiation chemistry we distinguish between direct effects, when the molecules of the substrate are directly affected by the incident electrons or Compton electrons, and indirect effects of irradiation, where the substrate molecules are affected by reactions with reactive intermediary species, e.g. water radiolysis. The high reactivity of the intermediary radical species of water, especially in the presence of oxygen, is responsible for the fact that a given radiation dose has higher effects in wet than in dry products.

Radiation chemistry of macromolecules

From an analytical point of view reactions involving macromolecules can be detected at low dose levels because of the changes produced in physico-chemical properties. For example, the viscosity of a long chain polymer will be changed if one chemical bond in the main chain is broken. Main chain scission leads to a reduction in molecular weight. Direct or indirect radiation effects can form reactive groups on side chains of macromolecules. Such reactive groups can make two different macromolecules join together. This is called intermolecular crosslinking. As this process proceeds, a network is formed of molecules, which are no longer soluble. If a certain number of crosslinks is formed a gel can be detected (Fig 7). The dose at which the first gel appears is called the "gel point". On average there will be one crosslink for every molecule. During irradiation of macromolecules, both processes degradation and crosslinking occur. The number of broken bonds depends on the irradiation conditions, e.g. presence of oxygen, and of the chemical structure of the macromolecule. Examples of the behaviour of solid polymers under radiation are given in Table 1.

General goal of the irradiation is to improve the mechanical properties of plastics and their temperature dependence. The most important features of a cross-linked plastic, the strain and degree of reset should be constant even at extended mechanical and/or thermal load. In several cases it is recommended to add cross-linkage accelerating additives to minimize the doses for economical reasons. Finished products as well as starting materials can be irradiated. Certain materials show already significant effects when only a low percentage of irradiated (pre-crosslinked) material was added to the mixture (Fig 8). Increased tensile and breaking strength, increased hardness, better resistance to chemicals, reduced cold flow and decreased strain at failure and break are some changed mechanical properties. Better thermal features as improved form stability at higher temperature, reduced melting index, and decreased shrinkage are also results of radiation induced crosslinking. Better electric features as increased bulk resistance, better electric breakdown and minimized electric loss factor also result from irradiation of polymers.

Specific properties can be selectively improved by modified irradiation conditions, e.g. dose, temperature, or used gas phase.

Effects of ionizing radiation on food components

Food components are of biological origin. Thus, investigations on effects of ionizing radiation on food components are just as important for radiobiology as for food irradiation. Reactions with small molecules are unlikely to be of biological importance, because only a minute fraction of the total number present can be effected.

Carbohydrates

In irradiated aqueous solutions carbohydrates are mainly attacked by OH radicals. The OH radicals abstract predominantly the hydrogen of C-bonds, forming water (Fig 9). The resulting radicals react by disproportionation, dimerization or dehydration to an acid, a ketone, or an aldehyde. Table 2 demonstrates the main radiolytic products of maize starch after 10 kGy gamma-irradiation.

Proteins

Radiation effects on proteins base on an understanding of the radiation chemistry of amino acids. Hydroxyl radical, atomic hydrogen and hydrated electron cause abstraction of hydrogen or reductive deamination (Fig 10). The produced radicals react further yielding mainly ammonia and pyruvic acid. This indicates that deamination plays a greater role than decarboxylation.

With some 20 amino acids as constituents of the proteins, very complex interactions with the three reactive species of water radiolysis are possible. Besides scissions of C-N bonds in the backbone of the polypeptide chain, other reactions, such as the splitting of disulfide bridges, can cause degradation of fibrous proteins. Globular proteins irradiated in dilute solutions undergo aggregation reactions, resulting in increased viscosity.

Lipids

In contrast to the radiation chemistry of proteins and carbohydrates, where indirect radiation effects mediated through reactive species of water radiolysis play a major role, in radiation chemistry of fats the primary effect of incident electrons or Compton electrons leads to cation radicals and excited molecules (Fig. 11). Deprotonation of cation radicals followed by dimerization or disproportionation, or electron attachment followed by dissociation and decarbonylation or dimerization result in many different radiolytic products. In presence of oxygen, peroxide radicals initiate autoxidation of irradiated fats. Peroxide values can reach high levels during storage in the presence of air. Some oxidized compounds not present or present in lower concentration immediately after irradiation will be present in higher concentrations after days or weeks. Such post-processing effects are important for food irradiation.

Irradiated lipid-containing foodstuffs may change their taste after a storage period of days or weeks by such autoxidation chain reactions.

Deoxyribonucleic acids (DNA)

DNA carries the genetic information in a double helix molecule of the molecular weight of about $M = 10^9$. The function as the carrier of genetic information depends on the intactness of this large molecule, from which is only one copy present in a cell. The probability X that a molecule with the molecular weight M will change upon irradiation is given by

$$X = 10^{-7}\ G\,M\,D \qquad \text{(Fig. 12).}$$

where G, M and D are .... respectively.

The high probability of molecular changes of the large DNA molecule explains the lethal effect of radiation on cells and organisms. DNA size, arrangement in the cell, association with peptides, proteins or lipids,. repair processes and other factors can influence the radiation sensitivity of a cell. Bacteria are less radiation-sensitive than insects, and those less sensitive than mammalian organisms, containing DNA molecules which must provide much more genetic information. Changes in the structure of the DNA can cause cell death or mutations, which may be used in experiments for plant improvement.

Inactivation dose

When a population of microorganisms is irradiated, dependent on the dose part of the cells will be damaged or killed. With increasing radiation dose the number of surviving cells decreases exponentially (Fig. 13). A measure of radiation sensitivity is the D_{10}value (or D_{10} dose), which is the dose required to kill 90% of a given population. Different species and different strains of the same species require different doses to reach the same degree of inactivation, they differ in their D_{10} values. Typical D_{10} doses of bacteria are 300 to 600 Gy for Salmonellae, 200-400 Gy for Listeriae, and 80-120 Gy for Pseudomonae. Spore- forming bacteriae like Clostridium botulinum need higher doses for inactivation. Their D_{10} values are in the order of 1.5 to 3.0 kGy.

Radiation Techniques in applied sciences

Plant improvement

Irradiation of plant seeds, cuttings or tissues induce mutations resulting from changes in the molecular structure of the DNA. A lot of work has been done on use of radiation as a mutation inducing agent in plant breeding. There is no directed mutational effect. Thus, it is necessary to irradiate a big number of seeds and to select the mutants after cultivation. An optimum dose has to be chosen for such experiments, since doses which induce high mutation rates also cause high mortality. An essential step in all breeding of plants is the process of selection of novel, potentially useful, phenotypes from among the large populations of unwanted individuals. It is, of course, possible to effect selection at the level of the whole plant. In such cases, the techniques of selection used in conventional plant breeding may be applied. For many plant characters, however, a far more efficient procedure would be to screen for novel variants in vitro before the regeneration of plants. In vitro culture of plant cell protoplasts allows a scale of selection that would be difficult to achieve in other ways, resulting in a very significant saving of space and time. Whereas a plant breeder, working with seedling plants, may screen about 100,000 individuals in a year for resistance to disease, 20 million protoplasts obtained from only 1g of leaf tissue could be screened in vitro in a single operation. This is particularly important where resources available for plant breeding are limited and for crops with long breeding cycles. The major target characters of agronomic importance for modification and in vitro selection are:

- efficiency of uptake and utilization of nutrients

- efficiency of carbon fixation
  nutritional quality of the crop
- resistance to stress induced by
  - low or high temperatures
  - water deficit
- resistance to herbicides
- resistance to pathogens and pests.

Culture conditions and selection strategies have been developed to select mutants and to regenerate intact plants with the properties requested.

Sterile Male Techniques

Pest control programmes have been developed by a method of releasing gamma irradiation sterilized males of insects. Codling moth, Cydia pomonella L., and corn borer, Ostrinia nubilalis Hb. are examples of insects, which populations can be controlled and reduced by releasing gamma irradiation sterilized males. The method uses males, which are irradiated as pupae or adult insects with doses not reducing their locomotory and sexual activity but inhibits a successful fertilization or development of the F1-generation. Such a dose is about 100 or 150 Gy. Successful use of the sterile male technique requires a restricted area, and a thorough and adequate knowledge of the life history, biology and ecology of the pest species. A surplus of sterilized males should be released at the right moment of the development of a population. Methods for breeding insects, sterilizing, dividing males and females, and releasing sterile insects must be evolved and tested. The method is species specific and directed toward a particular pest species.

Radiation technique in industry

For product irradiation in an industrial scale two types of irradiators are used, gamma sources and machine sources. In gamma irradiators mainly the isotope cobalt-60 with a half-life of 5.27 years and with emission of gamma radiation energy of 1.17 and 1.33 MeV and beta-radiation of 0.31 MeV is used.

^{60}Co disintegrates to stable ^{60}Ni. An annual repleshment of 12.4% is needed if a cobalt-60 source is to be kept at its original strength. The cobalt is present in a metallic, low water soluble form. Some gamma-irradiator work with the radionuclide Cs-137, which has a half-life of 30 years and emits gamma radiation energy of 0.66 MeV and beta-radiation energy of 0.51 and 1.18 MeV. ^{137}Cs decays to stable ^{137}Ba.

In commercial gamma irradiators the sources are stored in a water pool when they are not in the irradiation position. Because Cs-137 is as CsCl in a water soluble form in the sources, cobalt-60 has become the choice for gamma irradiators. Worldwide about 200 gamma irradiators with about 25-30 million Curie cobalt-60 are in operation.

An alternative to gamma irradiation facilities are electron accelerators. Such machines became available in the 1950's and have been much improved since then. The energies of the electron beams depend on their purpose. Low energy accelerators with energy levels up to 300 keV are used for surface modification. Medium energy electron beam accelerators (300 keV-1 MeV) also can only be used for treating thin-layer materials because these electrons penetrate a thickness of not more than a few millimeters. High-energy electron accelerators produce electrons with energies above 1 MeV. The upper energy limit for product irradiation is 10 MeV, because at higher energies activation of the irradiated product may occur. To prevent product activation there is a limit of 10 MeV for accelerated electrons and of 5 MeV for gamma and X-rays in food irradiation.

Gamma irradiation facilities

In a commercial cobalt-60 irradiation facility the material to be irradiated is placed in carriers which move around the source rack, so that their contents are irradiated equally from two sides. The irradiation field should be homogeneous to guarantee a low overdose ratio, that means a low difference between maximum and minimum dose in the product. To calculate how much product can be irradiated in such a facility, the energy emitted by the sources and the energy absorbed by the product should be calculated.

Each radioactive decay of a cobalt-60 atom produces one gamma photon of 1.17 MeV and another one of 1.33 MeV, together 2.5 MeV. A radiation source of 1 MCi (37 PBq) produces 2.5 x 37 x 10^{15} MeV/sec or 9.25 x 10^{16} MeV/sec (Fig 14). The energy dose absorbed by the irradiated product is measured in Gy. 1Gy corresponds to 6.242 x 10^{12} MeV/kg. Depending on their construction gamma irradiation facilities have efficiencies of 12% to 25%. At an efficiency of 20% an energy of 1.85 x 10^{16} MeV/sec or 6.66 x 10^{19} MeV/h would be absorbed by the product. This corresponds at a dose of 25 kGy to an amount of 426 kg product per hour.

Sterilization of medical products

Most commercial irradiators are used for sterilization of medical products. The purpose of a sterilization procedure is to inactivate all microorganisms on or in the material exposed to the procedure. The term microorganisms includes bacteria, fungi, other single-cell organisms and viruses.

International standards specify requirements for validation, process control and routine monitoring in the radiation sterilization of health care products. The term "validation" means: Establishing documented evidence which provides a high degree of assurance that a specific process will consistently produce a product meeting its predetermined specifications and quality attributes. Material evaluation, equipment documentation, product dose mapping, and sterilization dose auditing to maintain the validation are main elements of such a programme. Process control includes control and monitoring of process equipment, handling of product prior to, during and after irradiation, routine and preventive maintenance, production dose monitoring, process continuity and documentation. Dosimeters shall be used to monitor routinely the irradiation process. Dosimetry monitoring locations at the product to be irradiated shall be determined from current dose mapping data for the product. Descriptions of these locations shall become part of the current processing specifications to help ensure proper placement of dosimeters.

The international standard ISO-11137 "Sterilization of health care products - Requirements for validation and routine control - Radiation sterilization" describes the requirements for ensuring that the activities associated with the process of radiation sterilization are performed properly (Fig 15).

Health care products to be irradiated are surgical sutures, plastic and rubber instruments and apparatus (dialyzer, gloves), equipment for preservation of blood and blood transfusion, needles, tubes, non-biological materials for implantation and for use in contact with circulating blood, and medicines and pharmaceutical base materials.

Food irradiation

Practical uses of food irradiation are grouped into low-, medium-, and high-dose applications. High-dose applications are of limited significance. The Joint FAO/IAEA/WHO Expert Committee on the Wholesomeness of Irradiated Food (JECFI) concluded by 1980 from a wealth of experimental data, provided by research work of many countries over a period of more than 20 years, that the irradiation of any food commodity up to an overall average dose of 10 kGy presents no toxicological hazard and introduces no special nutritional or microbiological problems.

With a dose of 10 kGy all aims of food irradiation can be reached. Thus, worldwide interest in evaluating the health safety of foods irradiated with doses above 10 kGy is quite limited. High dose applications are used for some foods, such as meat, poultry, and certain seafood items. These foods tolerate doses in the range of 25-45 kGy if certain precautions are taken. Practically complete sterility can be achieved. However, autolytic enzymes present in all raw foods are resistant to these radiation doses and must be inactivated by a mild heat treatment at about 70°C. Astronaut meals have been prepared in this way and were consumed on the Apollo 17 flight to the moon 1972. An important purpose of radiation sterilized foods is feeding of hospitalized patients whose immune system is suppressed. The irradiated items are not offered instead of heat-sterilized items but in addition to them. The intention is to provide the patients with a more balanced, more varied choice of foods.

Low dose irradiation

Low dose treatments are used to inhibit sprouting of potatoes, yams, onions, garlic, and shallots (Fig 16). Radiation doses of 40 to 150 Gy inhibit cell division in all tissues of tubers, bulbs, and root crops. Normally, during long-term storage these products lose quality by sprouting and big losses are caused by rotting. Losses of product or of quality may be reduced by refrigeration, which is costly, particularly in subtropical and tropical regions, or by chemical sprout inhibitors. Such sprout inhibitors as maleic hydrazide, propham (isopropyl carbamate, IPC) or chlorpropham (isopropyl chlorocarbamate, CIPC) are almost effective and relatively cheap, but they leave residues in the produce, and for health reasons the use of such sprout inhibitors has been banned in many countries. Radiation induced sprouting inhibition allows to store onions, garlic, or potatoes without refrigeration, and keeps quality over a long storage period. Inhibition of sprouting of onions can be achieved with a dose of 30-40 Gy, when the irradiation is applied immediately after harvest. Irradiation also inhibits sprouting of potatoes most effectively when applied soon after harvest when the tubers are dormant. Higher doses are needed after the dormant period. The required radiation dose of 40-150 Gy to prevent sprouting, however, also reduces the ability of the tubers to heal cuts and bruises received during harvest and transport. Rot-causing organisms can enter through these cuts and cause spoilage. Unless the tubers have been handled carefully, irradiation at this dose level may cause increased losses. To prevent this is to allow a curing time of about 2 weeks between harvest and irradiation in order to let heal any damage. Adesuyi and Mackenzie from Nigeria reported (1973) on sprouting inhibition of yams, the tubers of Dioscorea rotunda. Doses of 75 - 125 Gy applied before the tubers began to sprout, prevented sprouting and reduced rotting and weight loss during a period of 5 month.

Delay of maturation and senescence

Delay of ripening or keeping quality for a longer period by irradiation is discussed for fruits and vegetables like bananas, mangoes, avocados, and mushrooms. The extension of marketable shelf-life of such fruits is mostly in the range of few days. Thus, time and cost of transport and irradiation make it questionable that this method will be applied on a large scale. Only with fresh mushrooms was successful commercial irradiation carried out. A dose of about 1 kGy applied soon after picking at the closed button stage inhibits opening of the cap, elongation of the stem, and darkening of the gills for some days.

Insect disinfestation

Insect control in stored dry foodstuffs is usually achieved by fumigation. The use of some fumigants has been banned or severely restricted in most countries. As an alternative method of insect disinfestation treatment with ionizing radiation has received much attention.

In order to secure lethality of insects within 24 hours, absorbed doses of 3 to 5 kGy are needed. However, it has been accepted, that such a short-time effect is not a necessary requirement. In the case of radiation disinfestation of cereal grains and other dry products, an absorbed dose of 0.5 kGy produces sterility and death of beetles, moths, and mites within a few weeks, and eggs and larvae present before irradiation do not develop into normal adults. Irradiation has potential as an effective quarantine treatment for a variety of fruits and vegetables against a number of fruit flies and other arthropod pests. The need to implement the use of irradiation as a broad spectrum quarantine treatment is even more important because methyl bromide, which is widely used for this purpose, is being phased out for environmental reasons. For international acceptance in using irradiation as a quarantine treatment it is proposed to develop a quality assurance programme which should include growing, harvesting, packing, handling, transport, treatment and storage of produce required for international trade.

Destruction of parasites in meat

A number of parasitic protozoa and helminths occurring in meat, fish, or on the surface of contaminated vegetable foods have been studied with regard to their radiation sensitivity. It appears that all could be inactivated by radiation without affecting the sensory quality of the treated food. Toxoplasma gondii, Trichinella spiralis, Taenia solium, and Anisakis simplex are some of the food-borne parasites. Infections caused by consumption of undercooked beef containing cysts of the beef tapeworm are very common in some parts of the world. A dose of 400 Gy renders the cysts incapable of development in humans. The absorbed dose which renders Trichinella spiralis non-infectious in fresh, non frozen pork is 0.3 kGy. This does not require the parasite to be killed by the irradiation.

Medium-dose irradiation

Shelf-life extension

Populations of bacteria, molds, and yeasts on fresh fruits and vegetables can be eliminated or reduced by irradiation with doses in the range of 1-3 kGy, to retard spoilage caused by these organisms. However, most fruits show radiation-induced damage at this dose-level, such as softening of texture, altered flavor, or darkening. Strawberries seem to be the only fruits with a remote potential for commercial irradiation because they tolerate the radiation dose needed for the control of micro-organisms.

Successful extension of refrigerated shelf-life of meat and poultry has been achieved, but there is no interest in applying irradiation for this purpose where refrigerated distribution chains exist and where deep freezing is available for extended storage. This is also valid for fresh ocean fish. In case of fat containing foodstuffs, the above mentioned radiation-induced autoxidation chain reactions may result in loss of sensory quality. Irradiation of frozen and/or vacuum-packaged products give better results.

Inactivation of pathogenic bacteria

Frozen frog legs, fish, shrimps, and other seafood may be contaminated with pathogenic bacteria such as Salmonella, Shigella, Vibrio, Listeria and Yersinia. The irradiation of these foods is for the purpose of inactivating such pathogenic vegetative bacteria and not for the purpose of their preservation, which is achieved through freezing. The use of irradiation to control pathogenic bacteria which can grow at refrigeration temperature (e.g. Listeria, Vibrio) is highly significant. In frozen shrimp reduction of pathogens by a factor of 10^{-4} requires a dose of 3 kGy for Vibrio spp. and of 3.5 kGy for Listeria monocytogenes. Eggs and egg products are often contaminated with salmonella. Frozen egg and dried egg can be irradiated without quality loss only in the close range up to 2 kGy. A given population of salmonella in egg powder, irradiated or not, decreases during storage. In a sublethally irradiated product the rate of decrease is faster. Thus, it is suggested to irradiate egg powder at 1kGy followed by 3 weeks storage. This procedure keeps quality and is approximately equivalent to the immediate bactericidal effect of 3 kGy. In many countries up to 100% of poultry may be contaminated with pathogens such as Salmonella or Campylobacter. Poultry has therefore received particular attention in proposals to apply ionizing radiation for hygienization, even in such countries like Germany which ban food irradiation. After previous clearance by the Food and Drug Administration (FDA) of the United States, the irradiation of poultry to reduce the potential for foodborne illness is permitted. Small quantities of irradiated poultry have been sold. However, the U.S. poultry industry has not introduced this technology on a major scale. The only industrial activity up to now whereby irradiation of poultry is routinely practised takes place in France, where an electron accelerator is installed for the irradiation of frozen deboned chicken meat. The facility is processing 7000 t of chicken meat per year at a dose of 3 kGy.

Reduction of microbial load

The main application of food irradiation is to reduce the contamination of spices, dehydrated vegetables, herbs, and other dry ingredients. Irradiation of spices is a reality in more than 20 countries.

The fresh plants from which these dry products are prepared contain microorganisms from the soil, from windblown dust, from bird droppings, and from other sources of contamination. During the drying process these organisms can multiply and the end product often contains more than 10^6 viable microorganisms per gram.

When such products like black pepper or paprika which may have 10^8counts/g are used as ingredients in the manufacture of processed foods, and the manufacturing process does not include a sterilizing step, foods or meals prepared with such ingredients can spoil quickly. The spices may also contain pathogens, as could be demonstrated for white and black pepper after epidemics of Salmonella infection in Canada and Norway.

Detection methods of irradiated foods

Although the wholesomeness of irradiated foods is no longer a question, the attitude of consumer organizations in some countries is not in favour of the process. One problem is that the process of food irradiation produces practically no change in appearance, shape or temperature of products. Consequently, it is difficult to determine whether a food has been irradiated or not. For acceptance it is important the process will have to be controlled by administrative means. A system of control through documentation and labelling should apply to national and international trade. The administrative control could be supplemented by methods, which are able to detect the radiation treatment in the food itself. Three main reasons for the development of detection methods for irradiated foods are specified in the IAEA-TECDOC-587:

- to strengthen national regulations on irradiation of specific foods
- to enforce the labelling of irradiated food stuffs
- to enhance consumer confidence in the regulation.

The damage of nucleic acids has been studied extensively in radiation biology. The big molecules are easily damaged. Sensitive techniques such as gel electrophoresis may detect fragments of the DNA molecules as a result of strand breaks caused by irradiation.

Changes in physical properties

The viscosity of homogenates and suspensions of biological materials in solvents like water differs between irradiated and unirradiated samples. Viscosity changes in suspensions of spices, herbs, dry vegetables, and in shrimp homogenates. However, there are also a big biological variability and an influence of sample preparation. Thus, the method should be rigorously standardized.

By interaction of radiation and matter free radicals are produced. In dry foodstuffs these free radicals persist for longer periods than in wet material, and could be considered for possible identification purposes. Spices, herbs, dehydrated vegetables, cereals, bones in meat and fish, shell of molluscs or crustucea, stones and seeds in fruits and similar natural products can be used for detection of free radicals. Free radicals can be detected using luminescence techniques such as chemiluminescence and thermoluminescence. For direct detection of free radicals, electron spin resonance will be the method of choice.

Changes in biological characteristics

Failure of root formation of irradiated onions, chromosomal aberrations in root tip cells, and cytological abnormalities in the cells of primary root of germinating seeds after irradiation have been proposed as detection methods. However, these tests are not very specific and the effects may be a result of other influences.

Changes in microflora as a result of irradiation have been demonstrated as applicable for detection of irradiated meat, fish, or spices. A shift in the typical microbial population of a food as a result of irradiation may be an evidence for radiation treatment.

Regulations on food irradiation

In 1980, the Joint FAO/IAEA/WHO Expert Committee on the Wholesomeness of Irradiated Food (JECFI) concluded after studying the available evidence that the safety of foods irradiated up to a dose of 10 kGy had been established. JECFI, as a Committee of Experts, had no regulatory authority. The FAO/WHO Codex Alimentarius Commission, which was established to implement the Joint FAO/WHO Food Standards Programme, adopted in 1983 a Codex General Standard for Irradiated Foods and a Recommended International Code of Practice for the Operation of Radiation Facilities used for the Treatment of Foods. More than 120 countries are members of this Commission. The purpose of the Joint FAO/WHO Food Standards Programme is to protect the health of consumers and to ensure fair practices in the international food trade. An international group of experts designated by Governments to evaluate and advise on global activities of food irradiation is the so called ICGFI (International Consultative Group on Food Irradiation). This group is established under the aegis of FAO/IAEA/WHO. Experts of about 40 Countries discuss scientific and commercial results on food irradiation, prepare and publish codes of good irradiation practice, regulations for the control of food irradiation facilities, and an international inventory of authorized food irradiation facilities. The inventory provides a list of 29 authorized food irradiation plants in 19 countries. Most food irradiation plants are registered in South Africa with 6 and 4 in France. The International Atomic Energy Agency also publishes periodically the "Food Irradiation Newsletter" with information on all topics of food irradiation. Most countries have national regulations for production, importation, and sale of individual irradiated foods. The existence of such regulations permitting irradiation of certain foods in a country does not mean that the food industry in that country actually makes use of this exemption. Each country itself has to decide if food irradiation should be applied and what kind of foodstuffs should be irradiated.

TABLE 1: Behaviour of Solid Polymers under Radiation in the absence of Oxygen

Polymers which crosslink	Polymers which degrade
↑	↑
Polymethylene	Polyisobutylene
Polyethylene	Polytetrafluor ethylene (PTFE)
Polypropylene	Polyvinylidene chloride
Polystyrene	Polymethacryl amide
Polyvinyl acetate	Cellulose
Polyacrylamide	Cellulose derivatives

TABLE 2: Main Radiolytic Products of Maize Starch Containing 12-13% Water Gamma - Irradiated Without Exclusion of Oxygen

Radiolytic product	mg/kg per 10 kGy
Formic Acid	100
Acetaldehyde	40 (up to 8 kGy)
Maltose	20
Glycolaldehyde	9.8
Hydrogen peroxide	9
Glucose	6.6 (1 - 4 kGy)
Glyceraldehyde and/or dihydroxyacetone	5.8
Glyoxal	4.5
Methanol	3.5
Acetone	2.8
Malondialdehyde	2.1 (above 20 kGy)
Erythrose	2
Hydroxymethylfurfural	1.2
And others at still lower concentrations	1

Fig. 1

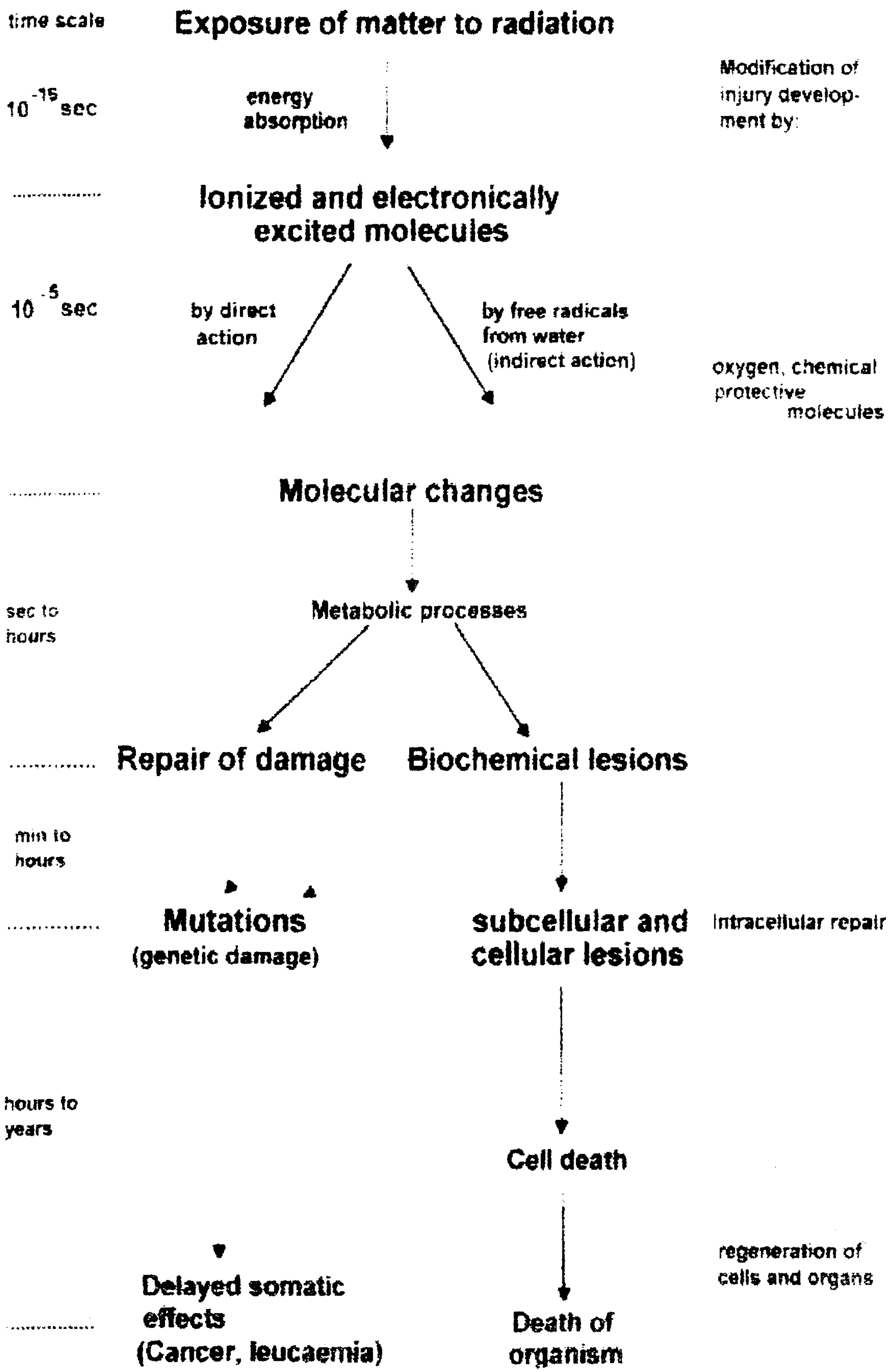

time scale
Exposure of matter to radiation
Modification of injury develop-ment by:
10^{-15} sec
energy absorption
....
Ionized and electronically excited molecules
10^{-5} sec
by direct action
by free radicals from water (indirect action)
oxygen, chemical protective molecules
....
Molecular changes
sec to hours
Metabolic processes
....
Repair of damage
Biochemical lesions
min to hours
....
Mutations (genetic damage)
subcellular and cellular lesions
Intracellular repair
hours to years
Cell death
regeneration of cells and organs
....
Delayed somatic effects (Cancer, leucaemia)
Death of organism

Figure 2: Types of ionizing radiations

Electromagnetic radiations

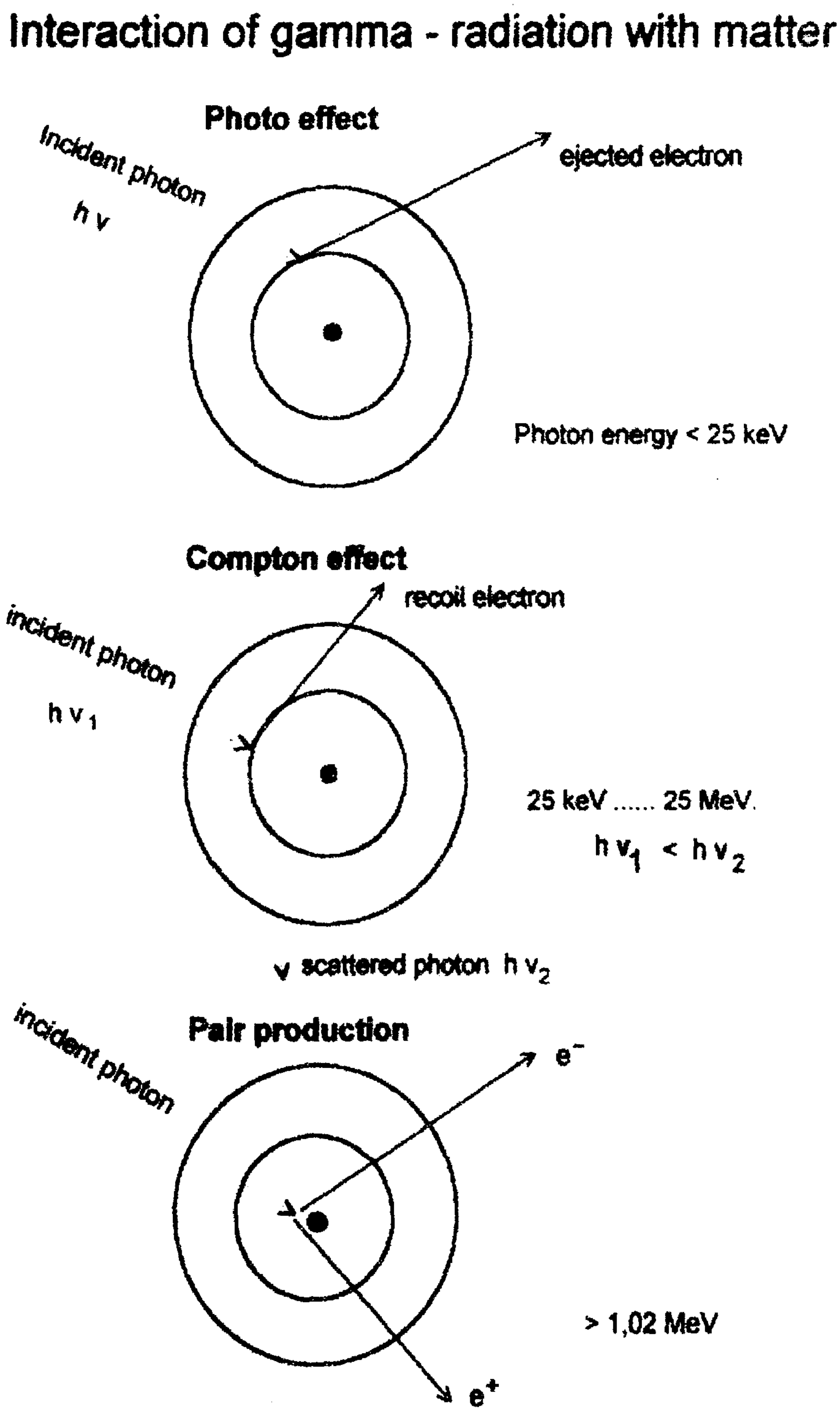
	Wavelength	photon energy
x - radiation	10^{-6} - 10^{-10} cm	10^{2} - 10^{6} eV (10^{9} eV)
γ - radiation	10^{-8} - 10^{-11} cm	10^{4} - 10^{7} eV

Corpuscular radiations

e^-	electrons	β (- rays)
$^{4}_{2}He$ - nuclei		α (- rays)
^{1}p		(proton) = $^{1}_{1}H$
$^{1}_{0}n$		(neutron)

accelerated heavy ions

Fig. 3



Interaction of gamma - radiation with matter
Photo effect
incident photon
h v
ejected electron
Photon energy < 25 keV
Compton effect
recoil electron
incident photon
h v 1
25 keV ...... 25 MeV.
h v1 < h v2
scattered photon h v2
Pair production
incident photon
e-
> 1,02 MeV
e+

Figure 4: Water radiolysis

$$H_2O \longrightarrow \cdot H_2O^+ + e^- \qquad \text{ionization}$$

$$H_2O \longrightarrow H_2O^* \qquad \text{excitation}$$

$$H_2O^* \longrightarrow \cdot H + \cdot OH \qquad \text{dissociation}$$

$$\cdot H_2O^+ + H_2O \longrightarrow H_3O^+ + \cdot OH$$

$$\cdot H + \cdot OH \longrightarrow H_2O$$

$$e^-_{aq} + \cdot OH \longrightarrow OH \cdot$$

$$e^-_{aq} + H_3O \longrightarrow H_2O + \cdot H$$

$$e^-_{aq} + e_{aq} + 2H_2O \longrightarrow H_2 + 2OH^-$$

$$H_3O^+ + OH \longrightarrow 2H_2O$$

$$\cdot OH + \cdot OH \longrightarrow H_2O_2$$

$$\cdot H + \cdot H \longrightarrow H_2$$

$$H_2O_2 + e^-_{aq} \longrightarrow \cdot OH + OH$$

$$H_2 + \cdot OH \longrightarrow H_2O + \cdot H$$

Figure 5: Oxygen Effect in Water Radiolysis

$$\cdot H + O_2 \longrightarrow \cdot HO_2$$

$$\cdot HO_2 \rightleftharpoons \cdot H^+ + \cdot O_2^-$$

$$e^-_{aq} + O_2 \longrightarrow \cdot O_2^-$$

$$2\ \cdot HO_2 \longrightarrow H_2O_2 + O_2$$

$$\cdot O_2^- + \cdot HO_2 + H^+ \longrightarrow H_2O_2 + O_2$$

Figure 6: pH - effect

$$e^-_{aq} + {}^+H \rightleftharpoons {}^\cdot H$$

$$^\cdot H + OH^- \rightleftharpoons e^-_{aq}$$

Figure 7: Crosslinking

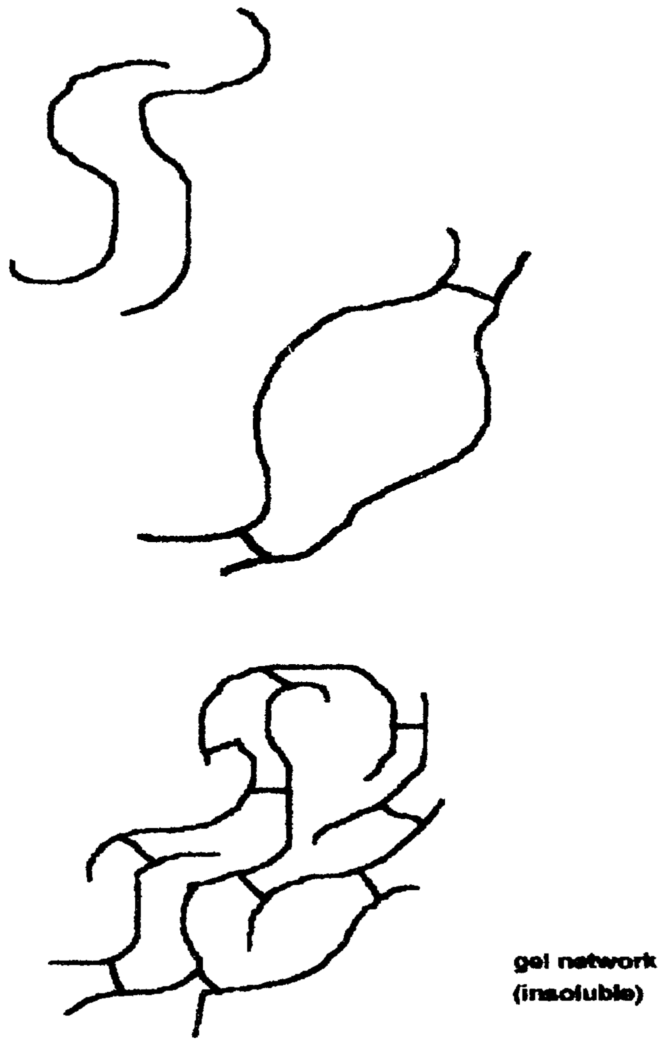


Figure 8: Reduction of cooling time of polypropylene at injection moulding

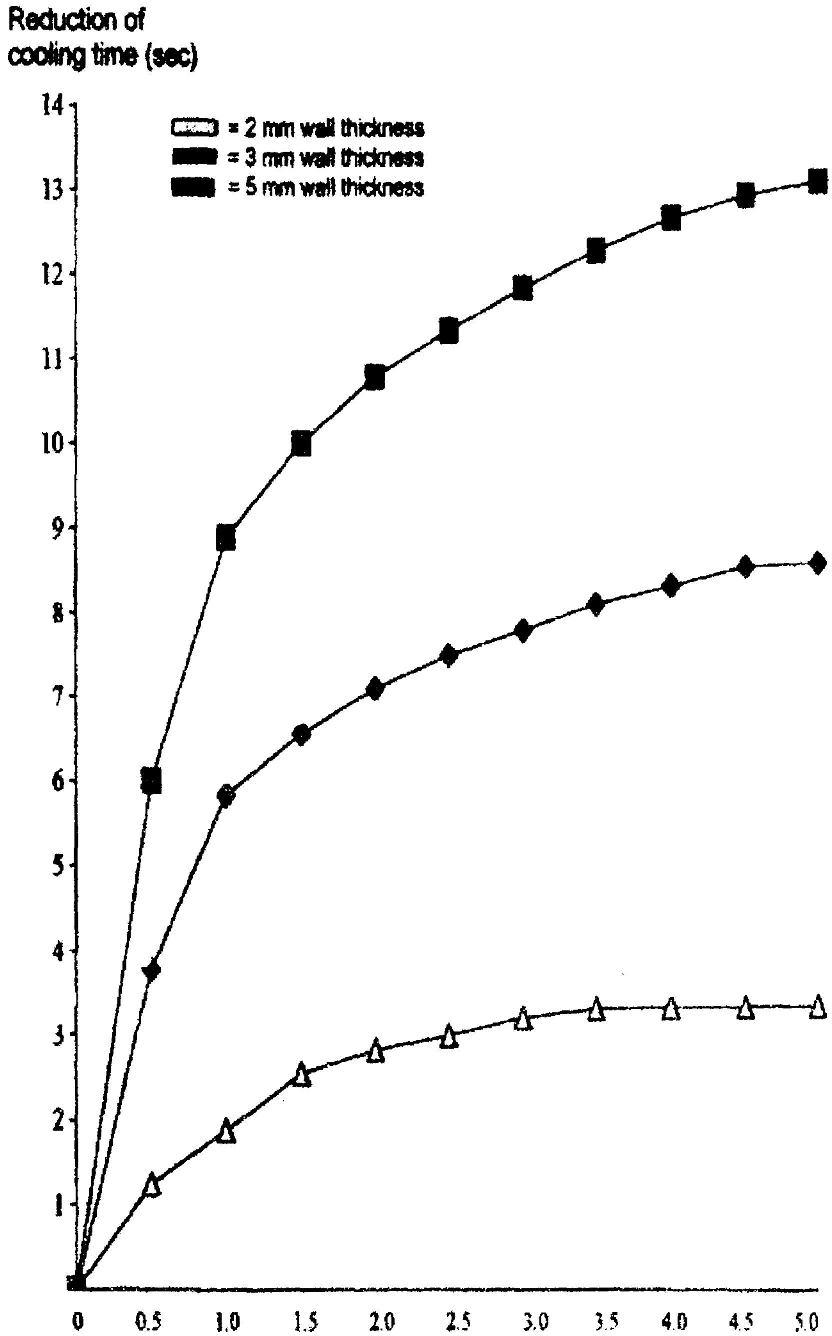


Fig. 9

Indirect radiation effect on carbohydrates

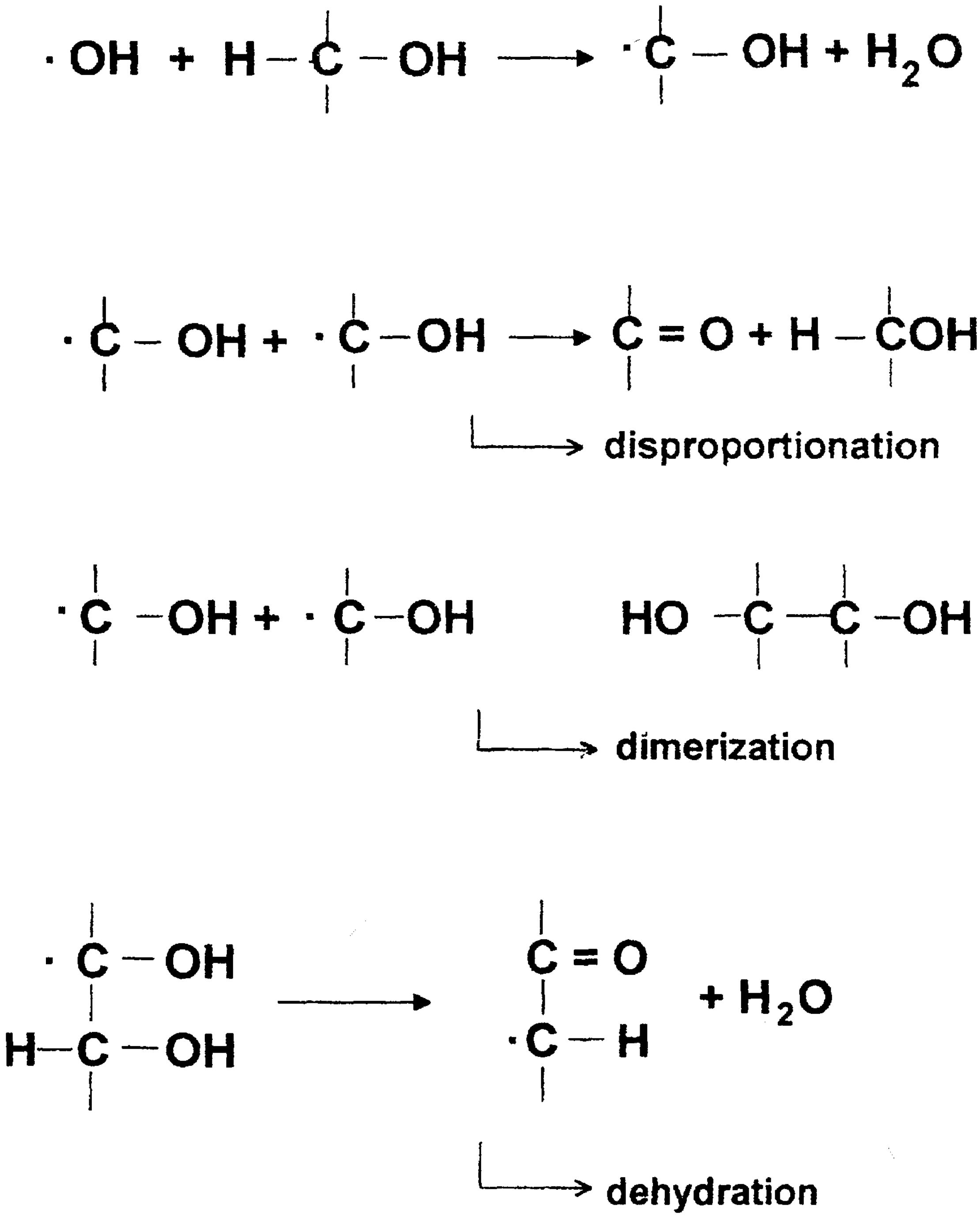


Fig. 10

Indirect radiation effects on amino acids

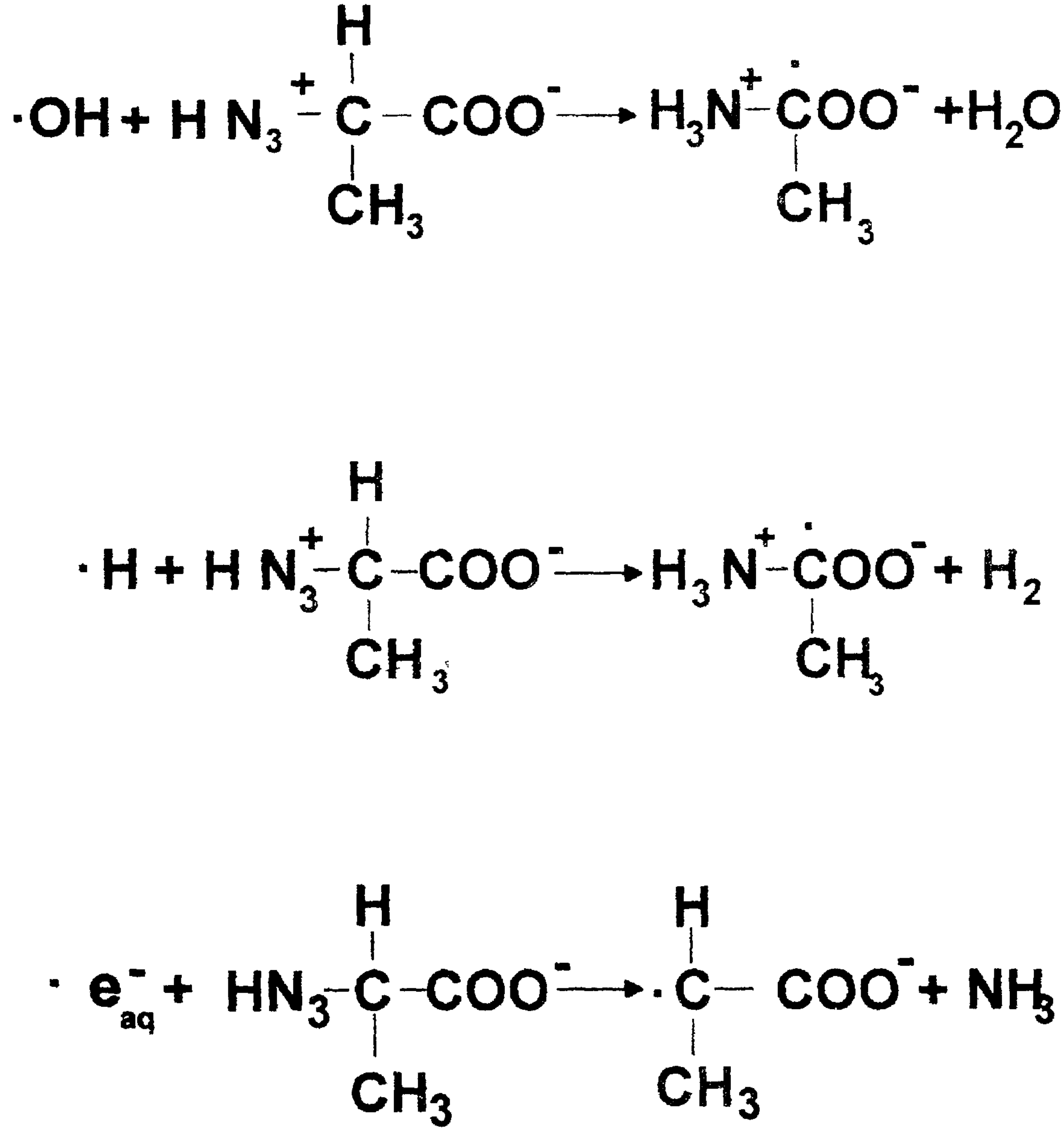


Fig. 11

Primary effect of radiation on lipids

$$(RCH_2-O-CO-(CH_2)-CH_3)^{+\cdot}_{n} + e^-$$

ionization

$$RCH_2-O-CO-(CH_2)_nCH_3$$

excitation

$$(RCH_2-O-CO-(CH_2)_nCH_3)^*$$

Fig. 12

$$X = 10^{-7} * G * M * D$$

G : number of changes per 100 eV of absorbed energy

D : Dose in kGy

In aqueous systems : $G = 4$

$M = 18$

$D = 1$ kGy

$$X = 10^{-7} * 4 * 18 * 1.0 = 7.2 * 10^{-6}$$

DNA : $G = 0.07$ (double strand breaks)

$M = 10^{9}$

$D = 1$ kGy

$$X = 10^{-7} * 0.07 * 10^{8} * 1.0 = 7$$

Fig. 13

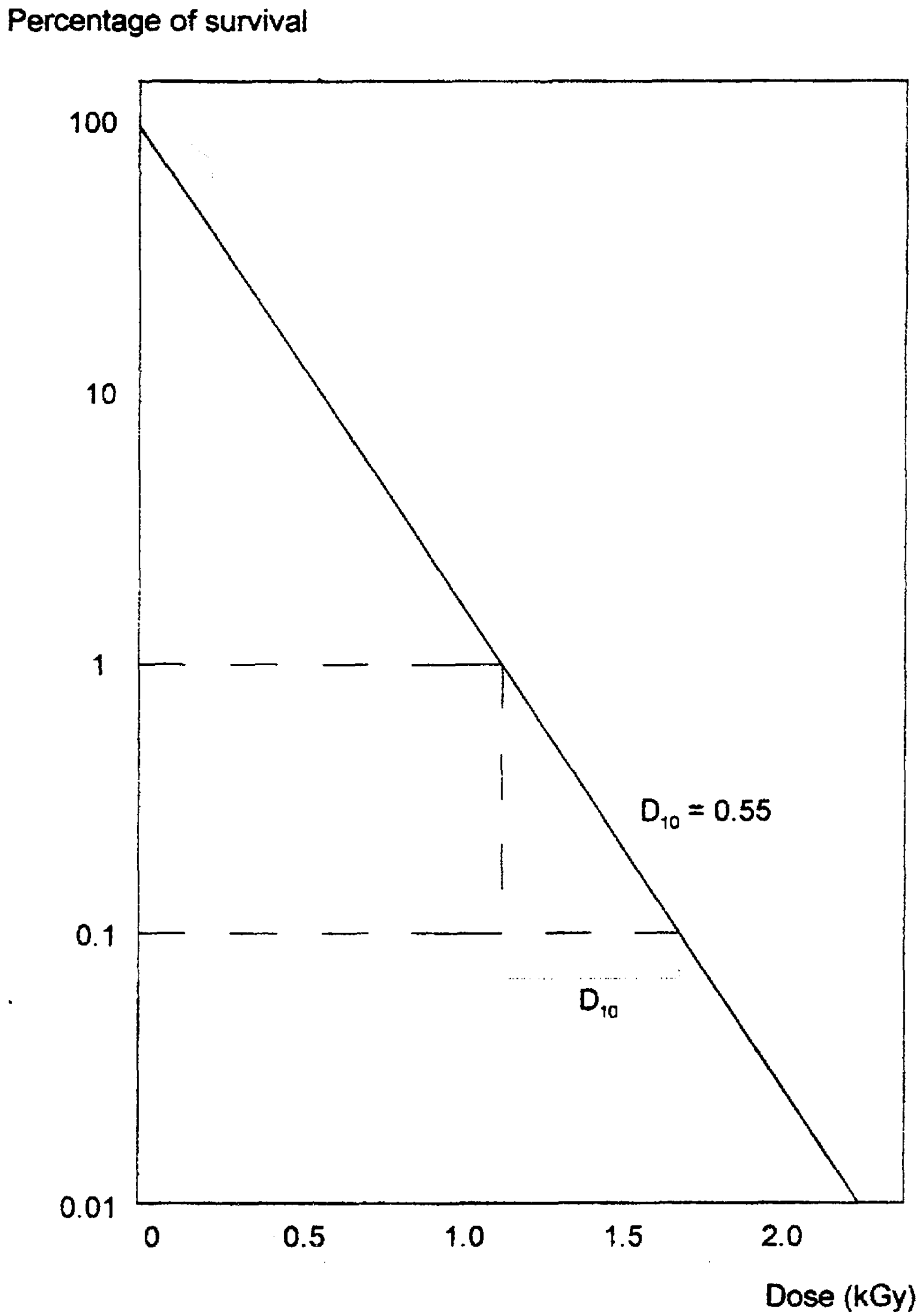

Percentage of survival
100
10
1
0.1
0.01
D10 = 0.55
D10
0
0.5
1.0
1.5
2.0
Dose (kGy)

Fig. 14

Efficiency of gamma irradiatiors

Energy of cobalt-60 gamma radiation

1.14 MeV
<u>1.33 MeV</u>
2.5 MeV per decay

$37 * 10^{15}$ Bq = 1 MCi source :

$$2.5 * 37 * 10^{15} \text{ MeV / sec}$$

$$= 9.25 * 10^{16} \text{ MeV / sec}$$

20 % efficiency: $1.85 * 10^{16} * 3600 = 6.66 * 10^{19}$ MeV/h

dose: 1 Gy $\hat{=}$ $6.242 * 10^{12}$ MeV / kg
25 kGy = $15.605 * 10^{16}$ MeV / kg

irradiated product P per hour: 6660 : 15,605 = <u>426.79 kg</u>

$$P = \frac{3600\ W * \eta}{D}$$

P = product per hour
W = emitted energy in kW
(Co-60: 67480 Ci = 1 kW)
(Cs-137: 312000 = 1 kW)
η = efficiency
D = dose in kGy

W = 1000000 : 67480 = <u>14.8</u>
η = 0,2
D = 25

$$P = \frac{3600 * 14.8 * 0.2}{25} = 426.79 \text{ kg}$$

Fig. 15

Food irradiation

Low - dose irradiation		dose (kGy)
Sprout inhibition	Extension of storage life	
potatoes, yams onions, shallots garlic		0. 04 - 0.15
Delay in maturation und senescence	keeping quality	
fruits vegetables		0. 25 - 1.00
Killing or sexual sterilization of insects		
cereal grain, flour dried fruits nuts, pulses	prevention of losses caused by insects	0, 2 - 0, 7
Fresh fruits	Quarantine treatment (prevention of spreading pests)	0.15 - 0. 7
Destruction of parasites (Trichinella, Taenia)		
Meat	Prevention of food transmitted parasitic diseases	0. 3 - 0. 5

Fig. 16

Food irradiation

Medium dose irradiation		dose (kGy)
Reduction of population of microorganisms		
fruits and vegetables	Shelf-life extension	1 - 3
meat, poultry, fish	Improved refrigerated storage	1 - 5
Destruction of pathogenic microorganisms		
meat, poultry, eggs, egg powder, frog legs, frozen seafood	Prevention of food poisoning	3 - 8
Reduction of population of microorganisms		
spices, dried vegetables	Prevention of food contamination	3 - 10

IRRADIATION IN CROSS LINKING OF POLYMERS AND RUBBER

by

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Abstract

Ionizing radiations cause crosslinking in many synthetic and natural polymers. Beneficial changes due to curing are thus attainable without the addition of chemical reactants. The development of nuclear reactors during and after world war II was the great stimulus needed for concerted exploration of the effects of massive ionizing radiation doses upon plastics and rubbers. Mixed nuclear radiation effects in natural rubber and polyisobutylene have been studied. Physical changes in a large number of polymers subjected to reactor radiations have been studied, with general recognition that the changes could be attributed to predominant crosslinking or to predominant scission in a given polymer. Major strides forward were made in extensive studies of crosslinking by nuclear reactor and cobalt - 60 irradiation and by 800KVP (Kilovolts peak) electron beam irradiation.

RADIATION TYPES AND SOURCES

Polymer crosslinking may be induced by non-particulate radiations (UV, x=rays, gamma rays), or particulate radiations (alpha particles, beta particles, high-energy electrons, protons, deuterons, neutrons, etc). One finds that mixed nuclear reactor radiations (principally gamma rays and neutrons), spent nuclear fuel element radiations (gamma rays), cobalt - 60 gamma rays, and machine generated high energy electrons account for nearly all the studies of polymer crosslinking by radiation. The choice of a radiation source depends principally upon availability, comparative case of handling and shielding, radiation penetration depth required, and desired dose rate. Machine accelerated high-energy electrons have been found most useful for crosslinking thin samples (e.g. 5mm thickness) of polymer at high dose rate. The ability to focus the radiation, to turn it on and off at will and to shield operating personnel with reasonable simplicity are advantageous to the machine-generated high-energy electron beams. Large-dimensions polymer specimens require the penetrating power of 'hard' (high-energy) x-rays or gamma rays. Because of the lower dose rate attainable in such gamma-ray facilities, large residence times are required, a handicap that is partially offset by large useable volume in the radiation field. Also, materials can be irradiated in walled vessels or complex apparatus since the penetrating gamma rays can reach them through considerable large (wide) thickness. (Gamma rays can penetrate up to 0.1 5m of steel).

The range of radiation energies most commonly used in crosslinking polymers has been 0.25 to 5 Mev. In this energy range, the interactions of non-particulate and particulate radiations with polymers produce essentially the same after effect.

Precise dosimetry for polymers undergoing crosslinking by radiation is difficult. Colorimetric measurement or calibrated chemical or ionization chamber measurements may be used. A consistent dose unit the "rad", defined as the dose corresponding to 100ergs of radiant energy absorbed per gram of the particular material being irradiated. This is equivalent to 6.25 x 10^{13} ev/g or 2.39 x 10^{-6} cal/g (or Gray (Gy), 1Gy = 100 rad). Since the absorption capabilities of materials differ, some investigators now use water as a standard and report dosages in terms of the unit rad (H_2O).

MECHANISM OF THE REACTIVE SPECIES THAT CAUSES CROSS- LINKING IN POLYMERS BY IONIZING RADIATION

Three types of reactive species are formed under irradiation and may become trapped in polymers: ionic species, radicals and peroxides.

The basic mechanisms of radiation-initiated transformations in polymers are not yet completely understood. Most reactions are commonly interpreted on the basis of free radical processes.

PRIMARY EVENTS

The primary interaction of radiation with matter leads to the formation of positive ions and excited molecules. Thus, in a medium constituted of molecules of a substance AB, the primary radiation - chemical event can be written:

$$AB \longrightarrow AB^{+} + e \qquad \text{------------------------------ (1)}$$

$$AB \longrightarrow AB^{*} \qquad \text{------------------------------ (2)}$$

The electrons ejected in processes (1) usually carry enough kinetic energy to enable them to ionize and excite many more molecules, AB. Ultimately, the electrons having lost most of their energy become "thermalized" and mav then either attach to a neutral molecule:

$$AB + e \longrightarrow AB^{-} (\text{or } A + B^{-}) \qquad \text{------------------------------ (3)}$$

or else recombine with a positive ion:

$$AB^{+} + e \longrightarrow AB^{**} \qquad \text{------------------------------ (4)}$$

The excited molecules formed in reactions (2) and (4) may dissociate to form radicals:

$$AB^{*} \longrightarrow A^{\cdot} + B^{\cdot} \qquad \text{------------------------------ (5)}$$

It follows that irradiating any substance (including a polymer) will lead to the formation of ions and free radicals and these are responsible for most of the observed chemical changes. If the irradiated substance is a solid, these reactive intermediates often remained trapped for a considerable time after irradiation and cause further chemical transformation, the so-called "after effects".

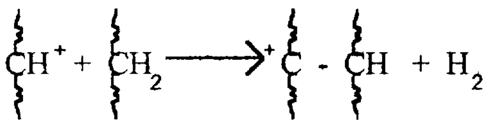
Oxygen plays a major role in radiation - induced processes. It is either present during irradiation or admitted to the substance after irradiation then another type of reactive species may arise - a peroxide. Peroxides are usually fairly stable at moderate temperatures and accumulate in the system to a certain extent. They are easily decomposed at elevated temperatures, moreover they are selectively decomposed on further irradiation.

IONIC SPECIES

Little information is available on the role played by ions in the ultimate transformation occurring in irradiated polymers, although this matter has given rise to numerous speculations. Most ionic reaction mechanisms which have been suggested are based on extrapolating from the known behaviour of ionic fragments in the mass spectrometer. Thus, a condensation process similar to the one observed with methane in the mass spectrometer.

$$CH_3^{+} + CH_4 \longrightarrow C_2H_5^{+} + H_2 \qquad \text{-------------- (6)}$$

has been suggested for the crosslinking of polyethene



------------------- (7)

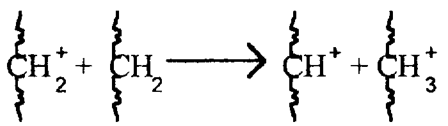
Alternatively, the well known proton transfer process:

$$CH^{+} + CH_{2} \longrightarrow CH_{5}^{+} + CH^{\bullet}_{3}$$

-------------- (8)

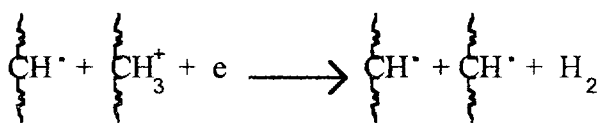
could also account for the crosslinking of polyethene via the following sequence of reactions.

PROTON TRANSFER



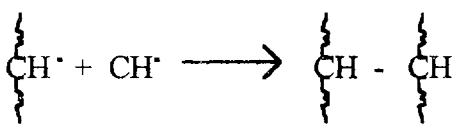
-------------------- (9)

NEUTRALIZATION



-------------------- (10)

This would lead to the formation of two polymeric radicals in close vicinity, and these would almost certainly recombine to form a crosslink:



------------------- (11)

The weak point of a theory based on such mechanism is the fact that reactions (6) and (8) are known to occur only in the gas phase at the low pressure existing in the mass spectrometer, and no direct evidence is available to show that such processes occur in a condensed state and could involve polymer molecules.

However, ionic species are undoubtly present in irradiated polymers and persist for a considerable time after irradiation. This is demonstrated by the radiation induced conductivity observed in most plastic insulators and by the slow decay of this conductivity, which may still be noticeable several months after irradiation. Detailed studies of this effect, coupled with an investigation of the chemical transformations occurring in irradiated polymers will be discussed later.

FREE RADICALS

Free radicals are produced in the radiolysis of all organic molecules, and in the case of solids they remain trapped in the substance after irradiation. Electron Spin Resonance (ESR) has been widely used to detect and study radicals in irradiated polymers. Usually, in a polymer subjected to ionizing radiation, in vacuo, free radicals accumulate until a limiting concentration is reached beyond which the number of radicals remains independent of dose.

The combination of two radicals to form a crosslink raises a number of problems, some of which have not yet been satisfactorily solved. If the radicals are produced in pairs such as by reactions (9) and

(10) or by a "hot" hydrogen atom mechanism (2) they would combine almost instantaneously at ordinary temperatures and these radicals could hardly be responsible for long-lasting ESR Signals. On the other hand, radicals distributed at random in a solid polymer are stable and can meet only if they migrate over long distances in the solid. Physical migration e.g. by molecular diffusion seems unlikely in view of the low diffusion rates of macromolecules in a polymeric medium. Therefore, several chemical processes leading to effective migration of radical sites have been suggested. The simplest 'chemical' migration via hydrogen atom transfer (reaction 12) is a slow process at room temperature since this reaction requires an activation energy of 10kcal per mole for aliphatic hydrocarbons.

$$\overset{A}{\sim}CH^{+} + \overset{B}{\sim}CH_2 \longrightarrow \overset{A}{\sim}CH_2 + \overset{B}{\sim}CH^{*} \qquad \text{------------------ (12)}$$

It has been established that hydrogen (deuterium) molecules exchange with irradiated polyethene, and the following reactions have been suggested.

$$\sim CH^{\bullet} + D_2 \longrightarrow \sim CHD + D^{\bullet} \qquad \text{------------------ (13)}$$

$$D^{\bullet} + \sim CH_2 \longrightarrow \sim CH + DH \qquad \text{---------------------- (14)}$$

It was further found that the trapped radicals in polyethene decayed more rapidly in a hydrogen atmosphere. The migration of the free valencies was therefore explained on the basis of a process similar to reaction (13) and (14), assuming an exchange reaction involving the hydrogen which results from the radiolysis of the polymer. However, reaction (13) is endothermic and therefore unlikely to occur at room temperature.

Thus, it appears that several processes which may play a major role in radiation-induced crosslinking, such as migration of free valencies and hydrogen exchange cannot be accounted for by simple free radical reactions. An alternative explanation could be found in a chemical process involving the long-lasting ionic species which are present in irradiated polymers and which could simultaneously lead to hydrogen exchange and free radical migration. However, any specific reaction which one could imagine for a process of this type would be highly speculative in character at the present time.

PEROXIDES

If a polymer is irradiated in the presence of oxygen, the free radicals produced are rapidly converted into peroxidic radicals:

$$R^{\bullet} + O_2 \longrightarrow RO_2 \qquad \text{------------------ (15)}$$

These may remain trapped for some time in the system and are easily detected by their ESR signals. Their ultimate fate depends to some extent on the nature of the irradiated substance and also on several physical parameters of the experiments, such as temperature, dose rate, and total dose. The two main reactions involving peroxidic radicals are:

Hydrogen Atom Abstraction

$$R^{\cdot}O_2 + R^1H \longrightarrow RO_2H + R^{\cdot} \qquad \text{------------------- (16)}$$

Which may lead to a chain peroxidation process, since R^1 will be rapidly converted into R^1O_2 by reaction (15).

Recombination

$$RO_2^{\cdot} + RO_2^{\cdot} \longrightarrow ROOR + O_2 \qquad \text{------------------- (17)}$$

These two reactions compete. Reaction (16) requires a significant activation energy and will therefore be favored at elevated temperatures and in polymers containing liable hydrogens. It will also occur at low doses when the concentration of RO_2 is too small to make mutual combination likely. This reaction is actually responsible for the well known autoxidation process, which can be initiated in certain polymers by fairly low doses of radiation.

Conversely, reaction (17) will take place chiefly at low temperature and high doses and will primarily apply to linear, nonsubstituted polymers.

The two products formed in reactions (16) and (17) - i.e hydroperoxides and diperoxides, respectively - exhibit different properties, and this makes it possible to assign a reaction mechanism to a given peroxidation process if one can establish the nature of the resulting peroxide. Thus, hydroperoxides are usually less stable to heat than diperoxides.

CROSSLINKING OF SPECIFIC POLYMERS

Examination of radiation effects in specific polymers is a convenient method of understanding the nature of the crosslinking of polymers with radiation. The efficiency of polymer crosslinking is expressed by G_{Cl}, the number of crosslinking (consisting of two crosslinked polymer unit) formed per 100eV of radiant energy absorbed, or by Ec, the radiant energy (eV) absorbed per crosslinked polymer unit formed. Obviously, $G_{Cl} = 100/2E_c$. A measure of main-chain scission is $G_{scission}$ the number of breaks per 100eV of energy absorption, or E_d the energy (eV) absorbed per break. The relative scission-to-crosslinked unit ratio is $B/x \cong$
$^1/_2\ G\ scission/G_{cl} \cong E_c/E_d$, where α and β are the probabilities that one crosslinked unit or one scission, respectively, will be produced per chain unit of gram formula weight, 1, when one electron volt of energy is absorbed per gram, thus:

$\alpha R/2a$ = Moles of Crosslinks formed per gram of polymer
= $R/2NE_c$

where R is radiation dose (eV/g), a is the formula weight per chain unit, and N is Avogadro's number.

Similarly,

$\beta R/a$ = moles of scission formed per gram of polymer
= R/NE_d.

POLYETHENE

Ionizing radiation induced crosslinking, hydrogen evolution, formation of trans-vinylene unsaturation disappearance of Vinyl and Vinylidene (normally present in low concentration in L.P) and slight chain cleavage. A G_{cl} of about 3.0 and B/α of 0.15 at room temperature are noted. An approximate fivefold increase in crosslinking efficiency is found as temperature is increased so also is increase in efficiency as temperature is increased from -100° to +150°C. Since $G(H_2) \cong 3.1$ and

G(trans-CH = CH-) ≅ 1.3 are nearly constant over the range -196° to +100°C, the following simple relation does not hold well:

$$G(H_2) = G_{cl} + G(\text{trans-CH-CH-})$$

Changes induced in polyethene by irradiation are summarised below.

IRRADIATION INDUCED CHANGES IN POLYETHENE

	LOW DENSITY MATERIAL		HIGH DENSITY MATERIAL	
PROPERTY	NOT IRRADIATED	IRRADIATED	NOT IRRADIATED	IRRADIATED
Specific Gravity	0.91 - 0.93	0.91 - 0.93	0.94 - 0.96	0.94 - 0.96
Tensile Strength (Psl) at 77° F	1500 - 2000	1500 - 2000	2800 - 6400	2800 - 6400
230° F	0	0	500	1400
Elongation (%) at 77° F	200 - 550	200 - 550	25-500	25-500
230° F	0	1000	500	1500
Melting point° F	212 - 230	None	275 - 275	None
Transparency	Clear	Clear	Translucent	Clear
Stress Cracks	Yes	No	Yes	No

POLYPROPYLENE

Isotalic polypropylene at room temperature exhibits a considerably low G_{cl} (≅ 0.60) and a considerably higher β/α (≅ 0.8 - 10) than does polyethene. Early data indicated essentially no difference in the radiation responses of isotactic and atactic polypropylene, but subsequent data have created uncertainty in both the relative and absolute values of crosslinking and scission in these polymers[1]. An increase in crosslinking efficiency occurs upon post-irradiation annealing at 180°C.

POLYSTYRENE

Polystyrene is crosslinked inefficiently by radiation with $G_{cl} \cong 0.045$ and $\beta/\alpha \leq 0.2$. The presence of oxygen increases scission efficiently and can make β/α exceed 2, thus causing predominantly main-chain scission. The crosslink yield is even lower than one might expect by comparison with radiation-induced decompositions in alkylarene hydrocarbons of low molecular weight. Addition of hydrogen atoms to the phenyl rings in polystyrene with subsequent crosslink, or disproportionation[2], may explain the low crosslink yield and an apparently lesser number of hydrogen molecules than crosslinks produced. The major crosslinking radicals are still somewhat in doubt, however, and gamma-radiation crosslinking of ring-substituted polystyrene-suggests backbone crosslinking at the α - carbon position. The mechanical properties of PS are changed noticeably only at high radiation doses owing to the low cross link yield and to the glassy condition of this polymer.

POLY (VINYL CHLORIDE)

Irradiation induces crosslinking, scission, and dehydrochlorination of PVC. In the absence of air, crosslinking predominates over chain scissions and $G_{cl} \cong 2.15$. Plasticizing or raising the temperature, especially above the glass transition, increases the crosslink yield. There have been many studies of the dehydrochlorination reaction, the coloured polyene structures produced, and possible free-radical species participation in the dehydro- chlorination and crosslinking[3,4]. Allylic radicals of the form ~CH = CHCH CH(Cl)~ are the species in both radiations and thermal dehydrochlorinations. At low temperatures irradiated PVC is found to have both $\sim CH_2CHCH_2\sim$ and ~CHClCHCHCl~ radicals.

POLYESTERS

Aliphatic polyesters of structures (a) or (b) below, predominantly crosslink upon irradiation. The crosslink yield increases with increasing x and y. PET (c), having only two methylene groups and a phenylene ring, crosslink with low efficiency. Both radiation crosslinking and chain scission are low yield and nearly equal, and have led to some reports of predominant scission. Oxygen does not appear to affect main chain scission but hinders crosslinking. PET can sustain desirable physical properties over tens of megarads exposure, however, beyond 50 Mrad(0.5MGy) strength and elongation decrease and beyond 1MGy, most mechanical use features disappear.

$$-[O(CH_2)_xCO]-_n \qquad\qquad -[OC(CH_2)_xCOO(CH_2)_yO]-_n$$

(a) (b)

$$-[OCC_6H_4COOCH_2CH_2O]-_n$$

(c)

POLYAMIDE

Nylon-6 (d) and Nylon-6,6 (e) below are crosslinked by radiation. Analysis of gelation and NH_2 production data in Nylon-6 suggests $G_{cl} \cong 0.5$ and $\beta/\alpha = 0.6$. Nylon-6,6 appears to have about the same G_{cl} but higher β/α. Oxygen can change the response from predominant crosslinking to predominant scission. Mechanical evidence of crystallinity decreases, in reactor-irradiated Nylon-G, 10 has been reported. X-ray examination of irradiated nylon-6 and nylon-6, 6 failed to detect crystallinity decrease, but melting points were lowered. Rather sophisticated ESR investigations and other data have definitely established the free radicals:

$\sim CH_2CONHCHCH_2\sim$ as the principal radical formed in polyamide irradiations. Coupling of such free radicals seems the most probable mechanism for polyamide crosslinking.

$$-[OC(CH_2)_5NH]-_n \qquad\qquad -[OC(CH_2)_4CONH(CH_2)_6NH]-_n$$

(d) (e)

POLY BUTADIENE

A high efficiency, $G_{cl} \cong 3.8$, has been found for radiation crosslinking of polybutadienes. Some evidence were cited for short polymerization process in the crosslinking. 40-50% reduction of unsaturation in sodium polymerized 1,4- and 1,2 butadiene rubbers during gamma irradiation to only 4Mrad indicates intramolecular cyclization as well as crosslinking. Even more strikingly, a, 1,2-butadiene rubber produced by ziegler catalysis lost 80% of its unsaturation in less than 10 KGy exposure. Here, both cyclization and crosslinking may proceed by short polymerization involving pendant Vinyl groups.

NATURAL RUBBER

Natural rubber and other polyisoprenes are crosslinked by radiation with $G_{cl} \cong 1.1$ and $\beta/\alpha = 0.1$. The major physical properties changes caused by radiation curing having been well defined in early studies. See Figure 1.

The Effect of Crosslinks in Rubber

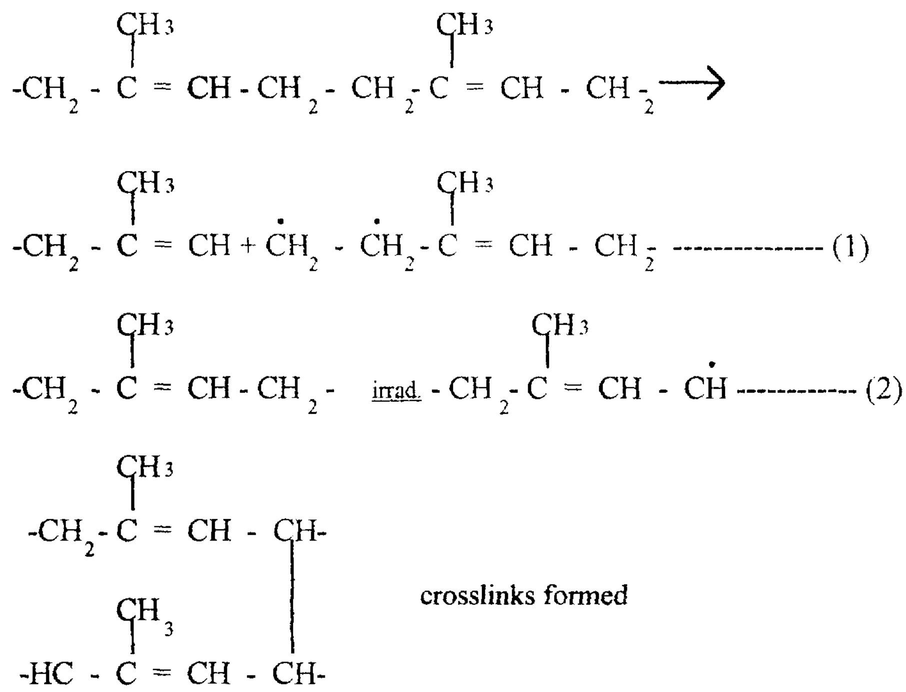
When rubber forms crosslinks 5-7 during irradiation (curing) they become insoluble. The static modulus increase with CLD to a greater extent than the dynamic modulus[8]. The dynamic modulus is a composite of viscous and elastic responses whereas the static modulus is a measure of the elastic component alone. Crosslinking thus causes a shift from viscous to plastic behaviour to elasticity.

Tear strength, fatigue life and toughness are related to energy at break. These properties increase with small amount of crosslinks but are reduced with increasing amount of crosslink formation. Hysteresis diminishes with increasing crosslink formation and is a measure of deformation energy that is not stored or born by the network chains, but instead is converted to heat. Properties related to energy at break increase with increases in the number of network chains and hysteresis; but hysteresis decreases as more network chains are developed. The energy - to - break related properties peak at some intermediate crosslink density.

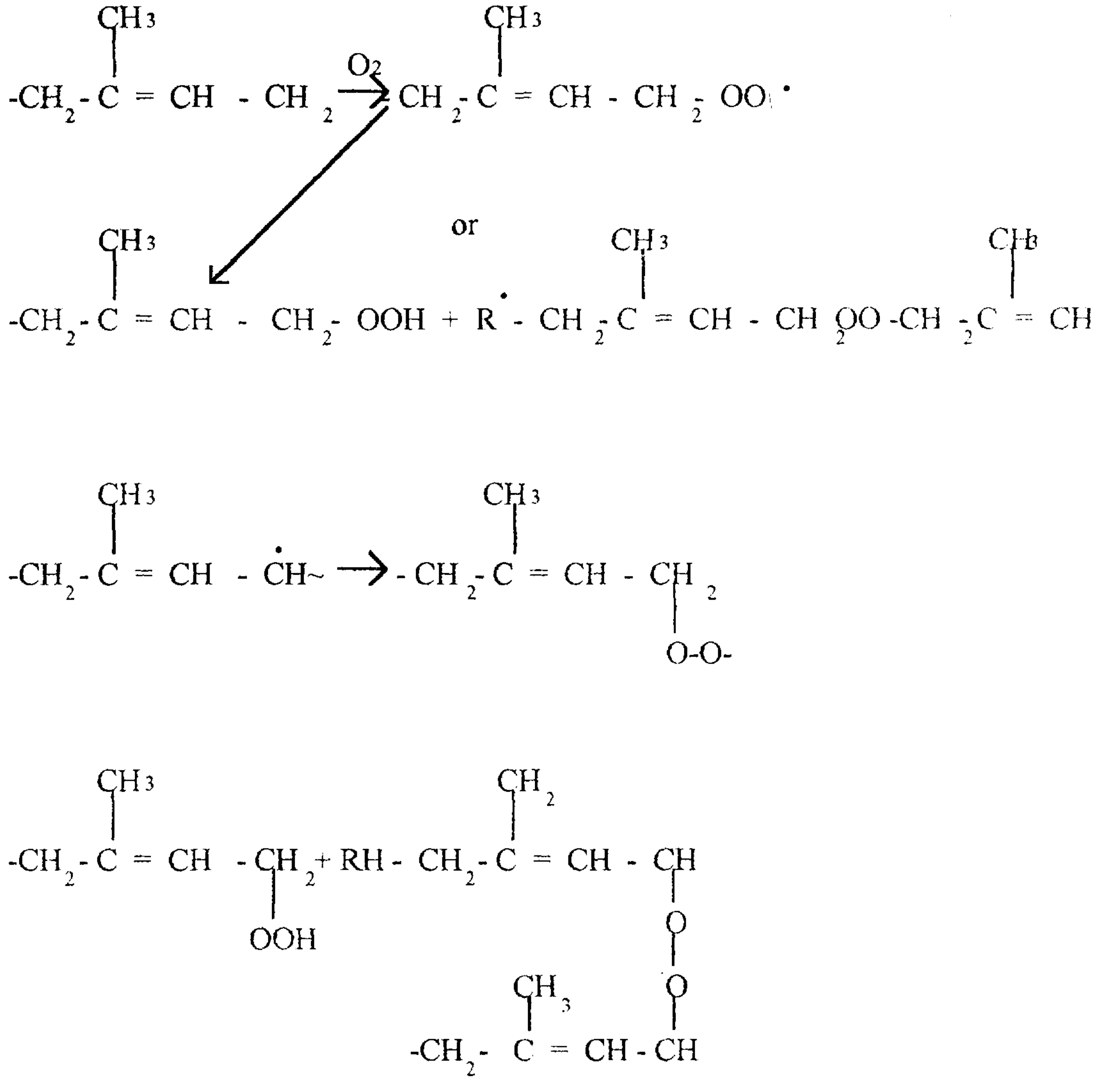
The properties in Figure 1 are not functions of crosslink density alone but are also affected by the type of crosslink, the nature of the polymer, type and amount of filler etc.

The mechanics of the changes observed above can be explained thus: Hydrogen, $G(H_2) = 0.64$, accounts for nearly all the gas evolved and amounts to only about one half of the crosslinks yield. Addition of the nascent hydrogen to double bonds and cyclyzation have been postulated modes for observed unsaturation decreases. Irreconcilable reports of large and slight reduction of unsaturation in rubber by irradiation are known. The crosslinks induced in natural rubber most likely results from coupling of allylic free radicals in the polymer chains. Very low apparent activation energies for crosslinking have been observed and temporary isolation of free radicals even at room temperature occurs as the network develops. Oxygen increases chain scission and decreases crosslinking during rubber irradiation. Some halogen - containing compounds increases crosslink yields whereas certain radical-topping additives depress crosslinking, and possibly oxidative scission, in rubber undergoing irradiation.

High energy irradiation is an important technique in effecting mechano-chemical modifications in rubber and polymeric materials. During high energy irradiation in vacuum, e.g. from a C_0 source, some main chain degradation of natural rubber and other polyisoprenes occur, according to the equation below:



However, much of the irradiation energy is also adsorbed by the removal of hydrogen atoms[1]. The irradiation of natural rubber in the presence of a vinyl monomer thus leads primarily to a synthesis of graft copolymers, but some block copolymer is certainly always present. Irradiation synthesis may be carried out in solution, either in contact with liquid monomer (with or without a crosslinks formed diluent) or in contact with monomer in the vapour phase; or in emulsion or suspension. The rubber may be preirradiated in the absence of air to produce free radicals for later monomer addition, but the life of these radicals is short due to mobility within the rubber matrix. Irradiation at very low temperatures makes it possible to use the trapped radicals technique for a variety of natural and synthetic rubbers. Plastics and polymers with a crystalline phase are more readily preirradiated to initiate later grafting or crosslinking by trapped radicals. Irradiation may also be carried out in air to introduce peroxide groupings.

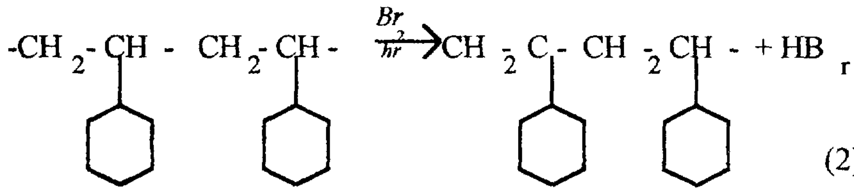


These groups can then be used to initiate grafting by any methods already discussed. Latex phase grafting is generally favoured for its simplicity; natural rubber grafts with methyl methacrylete styrene, acrylonitrile and vinyl chloride have been made in this way(2).

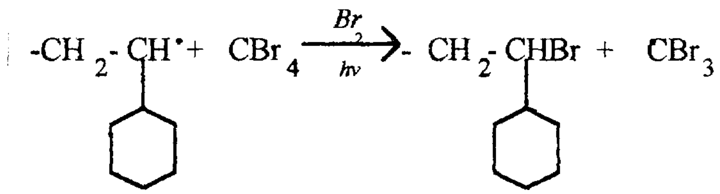
The irradiation of mixed latices for subsequent combination of the ruptured chains is another approach; it has been carried out with natural rubber and poly vinyl chloride latices to prepare graft (and block) copolymers in fairly high yields without the problem of monomer recovery. The same method has been used to graft polychloroprene onto synthetic polyisoprene dispersions and onto polybutadiene latices of various compositions.

Macromolecules containing photosensitive groups which absorb energy from ultraviolet frequencies often degrade by free radical processes. The degradative process as a rule is fairly low, but by the addition of photosentisizers such as Xanthone benyl, benzoin and 1-chloroanthraquinone, the rate can be speeded up to enable graft co-polymerisation to take place in the presence of methyl methacrylate or any other monomers. This can be done in the case of natural rubber in the latex phase with reasonably high yields of graft copolymer. Natural rubber-g-polystrene and poly (butadiene-g-stryrene) have both been prepared by UV irradiation of sensitized latex-monomer dispersions. A combination of photochemical synthesis and redox type initiation can also be carried out - process known as one-electron oxidation to relief grafting with minimal homopolymer formation.

High energy irradiation will be useful in synthesising flam retardants. Bromine atoms on the backbone of a polymer can be liberated readily by UV irradiation to give free radical sites for grafting/crosslinking reactions. The bromination can be photochemically induced, or a chain transfer agent such as carbon tetrabromide may be used in the polymerisation step to introduce the liable groups(4).

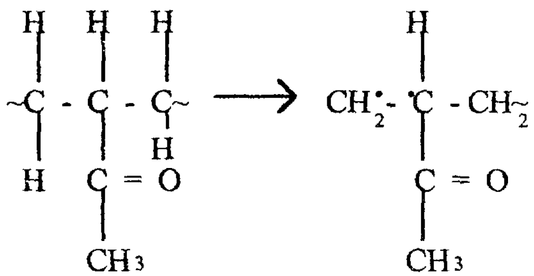


(2)



------- (3)

With the aid of suitable sensitizers, polymers such as brominated butyl rubber, valuable because of their flame retardancy, may act as backbone polymers for a variety of grafting reactions. An early synthesis of block copolymers was based upon the UV irradiation of poly (methyl vinyl ketone) in the presence of acrylonitrile. The initial degradative step is



The degradation reaction, supplemented by various subsequent oxidation steps, has found renewed interest in the form of the introduction of photodegradable plastics as part of the campaign to reduce plastic litter from throwing away packaging. Although, as yet there has been no demand for photodegradable rubber, the incorporation of a small percentage of vinyl ketone into a rubber copolymer or homopolymer would open the way to a useful synthesis of block copolymers.

INDUSTRIAL APPLICATION OF POLYMER IRRADIATION

When considering industrial use of polymer irradiation, the following four questions arise:

- What are the advantages of irradiation?
- Which properties can be improved?
- What kind of irradiation source is preferred?
- What does radiation cost?

ADVANTAGES OF IRRADIATION

The major advantages are:

(a) that the desired reactions can be carried out generally at lower temperatures than in operations employing chemical means,

(b) that monomers can be polymerized free of catalyst contaminations,

(c) that crosslinking and grafting can be performed in situ on fabricated articles and,

(d) that coatings can be applied in monomeric form, eliminating solvents.

WHICH PROPERTIES CAN BE IMPROVED?

Increasing heat resistance and strength, reducing stress cracking and lowering, permeability are a few of the advantages obtainable through gamma or electron irradiation. Surface improvements, such as weather resistance, hardening, dyeability, or destaticizing are obtainable through ultraviolet light treatment.

Impregnating wood with monomers, such as methyl methacylate, hydroxylethyl mesharrylate, or vinyl acetate and polymerizating it by irradiation results in increased hardness, higher strength, and better form stability. For instance, the hardness of pine can increase by 700% and oak made as hard as teak by irradiation. Considerate research is being devoted to the graft and homopolymerization of various monomers on sheet paper and on paper-making fibres. This enhances bulkiness, resilience, acid resistance, and tensile strength of paper - all properties in demand for applications such as grocery bags.

WHAT KIND OF IRRADIATION SOURCE IS PREFERRED?

Radioactive isotopes appear practical when considerable depth of treatment is required. For upgrading the physical properties of the polymer, an electron accelerator may be used. For surface treatment, an electron accelerator, X-ray machine or ultraviolet light can be employed depending on the depth of treatment desired.

Radioactive sources of commercial interest are γ - and β - ray emitters. The choice of sources has narrowed down to roughly three elements - cobalt - 60, strontium - 90, and cesium - 137 - as a result of their useful characteristics, reasonably long half-life, availability and cost.

RADIOACTIVE ISOTOPES

ELEMENTS

	COBALT	STRONTIUM	CESIUM
Atomic Weight	60	90	137
γ-rays, MeV	1.17,1.33		0.66
β-rays, MeV	0.306	0.61, 2.18	0.51 (95%),1.17(5%)
Mv/hr. output/curie at	14,400	-	3750
Curies in $^1/_8$ x $^1/_8$ source	5	-	1.45
Half life, years	5.27	28	33

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IRRADIATION CROSSLINKING OF POLYMERS & RUBBERS

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Abstract

An overview of the concept, principles, applications and import of irradiation technology in the study and development of industrial radiation - chemical processes for polymers and rubber has been presented. It is shown that the study of radiation-induced polymerization and of radiation effects in polymers has contributed to understanding of some of the elementary reactions of radiation chemistry.

Introduction

In solids, the interaction energy which is available for the ionization and excitation of molecules is deposited in a region whose dimensions depend on the type of radiation. Free radicals formed in irradiated solids by ionization or homolytic dissociation of molecules are relatively stable in the solid phase. In practical radiation chemistry the most frequent sources are gamma radiation sources (especially ^{60}Co), since gamma radiation is capable of penetrating even thick layers of materials such as polymeric, producing a homogeneous distribution of secondary ionization in large volumes. The total radiation energy absorbed per unit mass in matter is called the radiation dose (D) and the unit for the dose is the gray (Gy), 1 Gy = 1 Jkg^{-1} (formerly, the unit rad., 1 rad = 10^2 Gy, was used). The dose rate D is the mean dose increment dD in a time interval dt (Equation (1)).

$$\dot{D} = \frac{dD}{dt} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

The absorbed radiation dose can be measured by both physical and chemical methods. Radiation dose measurements are called dosimetry. For ^{60}Co emitted gamma rays have energies 1.17 and 1.33 MeV and half life of 5.3 years.

Covalent Cross-linking Theory

Based on the early work by Meunier and Guyot[1] in 1929 and the extended work by Cameron and Morton[2] in 1949, it was shown that a greater part of the crease recovery (ability of polymeric to recover from deformation) is due to the part of the precondensate which reacted bifunctionally with the cellulose to form a covalent link between them. It is also accepted that cross-linking imparts improved resilience by tying cellulose molecules together into a three dimensional network so that inter molecular creep is prevented and thereby enabling the fibre to, as it were, "remember" to return to its original configuration.

Physical Chemistry Associated with Crosslinking of Cellulose

The process of cross-linking is agreed to proceed in the following order:

(i) diffusion of the cross-linking molecules from solution phase to the cellulose/solution interphase;
(ii) absorption of the cross-linking molecules from the interface onto the cellulose surface;
(iii) diffusion/penetration of cross-linking molecules into the microstructure of cellulose;
(iv) reaction between cross-linking molecules and cellulose hydroxyls;
(v) partial degradation of cellulose; and
(vi) hydrolysis of some of the cross-links formed[3].

In the wake of cross-linking theory, it became evident that any compound with two or three functional groups that can react with cellulose is a potential crease - proofing agent. These led to the use of several types of compounds which can be represented by a general formula R - (x)n where R is a radical to which are attached two, three or more X-groups and X represents any of the functional groups such as ketones, acetals. ketene, urons, trazines, carbonyls and isocyanates etc.

Cross-linked Polymers

Cross-linked alkylene sulphide polymers for use in elastomers can be prepared using two principal routes both of which involve incorporation in the polymer chain of small amount of an alkyl halide monomer which can act as a chain branching site. One type of monomer is an unsaturated dihalide, such as 1,4 - dicholoro butene-2, the presence of which permits the elastomeric polymers to be vulcanised by methods applied to unsaturated polymers in general[4]. A much more widely used approach is to copolymerize small amounts of alkyl trihalides and tetrahalides.

Epoxy resins constitute a class of crosslinked polymers prepared by a two-step polymerization sequence in which the first step is based on step growth polymerization reaction of bifunctional alkylene epoxide with a bifunctional or polyfunctional nucleophile. A typical epoxide monomer is epichlorohydrin and a typical bifunctional nucleophilic monomeric 2,2-bis (4^{I}-hydroxyphenyl) propane (Bisphenol A). The polymers formed in the first stage polymerization reaction are of much too low a molecular weight to have acceptable and useful properties. These polymers are thus further reacted, or cured, to form high molecular weight macromolecules in a reaction which is the second stage crosslinking reaction.

Crosslinking reaction is also the most important type of reaction applied to the modification of the backbone of a polymer molecule. Crosslinking is used to achieve a number of special effects, including an increase in the softening point or a decrease in the solubility of linear polymers or a very rapid increase in the size of low molecular weight polymers and it is absolutely essential for the development of useful, reversible elastomeric properties in most rubbers. Of all application of crosslinking reactions, the most important is the crosslinking of natural or synthetic elastomers, which is generally termed vulcanization.

The word "vulcanization" was coined shortly after the discovery by Goodyear in 1839 of the valuable property improvements imparted to natural rubber by treatment with sulphur (4). Today, the term is applied to all types of controlled crosslinking reactions carried out on elastomers. The random crosslinks introduced into elastomers by vulcanization impart to these materials their characteristic ability to quickly and completely recover from large deformations imposed by the application of stress. Without crosslinking, these elastomers would undergo an irrecoverable deformation, or flow, under any appreciable stress.

Dissociation of Covalent Bonds by High Energy Radiation

Several types of high energy radiation such as α-particles (fast moving helium ions), β-rays (high-energy electrons), and τ and x-rays, have been used to initiate free radical chain reactions. Most often, the energy absorbed by the molecule is so excessive that an electron is not just excited into a higher energy state, but it is completely ejected from the molecule hence these types of high energy radiation are frequently referred to as ionizing radiation.

Ionizing radiation can also be used to initiate polymerization reactions of olefins which under certain conditions and with certain monomers, are best interpreted as being cationic in mechanism(5). Indeed, ionization radiation can produce active carbonium ions from hydrocarbons by a two-step process involving first ionization or electron expulsion (Eq.2)

$$C_nH_{2n+2} \longrightarrow [C_nH_{2n+2}{}^{\oplus}\cdot] + e \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

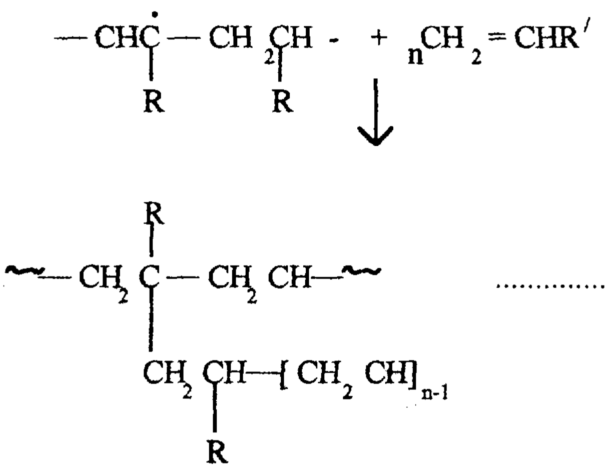
resulting from absorption of ionization radiation, followed by fragmentation of the ion-radical formed into a free radical and a carbonium ion. (Eq.3)

$$[C_nH_{2n+2}]^{\oplus\bullet} \longrightarrow [[C_mH_{2m+1}^{\oplus}] + [[C^{-}_{n-m}H_{2(n+m)+1}]^{\bullet} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

In the presence of olefin monomers, the carbonium ions generated can initiate a cationic polymerization reaction. Cationic polymerization reactions initiated by irradiation can be greatly facilitated by addition of solids capable of capturing and retaining the free electron generated in the ionization reaction (6,7,8).

Graft Polymer Formation

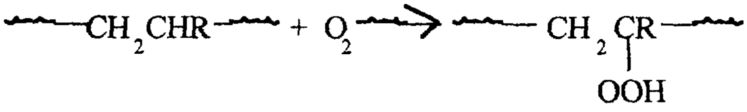
Free-radical-initiated graft-polymerization reactions in general are closely related to free-radical-induced vulcanization reactions in that active radical sites are created in either polymer backbones or pendant groups, usually as a result of a hydrogen abstraction reaction but, instead of permitting two such sites to combine to form a crosslink, the radical formation reaction is carried out in the presence of an olefin monomer and polymerization ensures. The polymerization reaction is initiated directly by the polymer chain radical, and the newly formed polymer is covalently bound, Equation 4, or grafted, onto the existing polymer molecule.



.... (4)

The effects of grafting and other modifications on cotton have been presented by Ugbolue (9). The structure of cotton grafted by radiation - induced polymerization with butyl methacrylate and acrylonitrile has been investigated by light and electron microscopy. The internal structure of the fibres was studied with the transmission electron microscope, and changes in fibre structure and damage caused by abrasion were evaluated with the scanning electron microscope. The results indicate that the grafting procedure changed the surface as well as the internal fibrillar character of the fibres; the extent of such changes increased with graft-polymer content(9). Ibeagi, Yabani and Ugbolue (10,11) have also presented data on various modified celluloses. Generally, grafting (10, 11) with vinyl monomers is shown to lower the dye affinity towards Chlorazol Sky Blue FF of standard and crosslinked celluloses. The physical properties of natural and modified cotton celluloses grafted with acrylate monomers have been studied(12). The results show that density, birefringence, and moisture regain are less than the corresponding properties of natural cotton.

One important method of graft co-polymers involves radioactive or photochemical activation of polymer molecules. Activation grafting is the term applied to the preparation of graft copolymers in which the reactive sites on the polymeric substrate are created by absorption of radiant energy. There are two general methods for preparing graft polymers by activation; these are mutual irradiation and pre-irradiation. In the mutual irradiation which is also referred to as direct method, the substrate polymer and the monomer to be grafted are combined before being irradiated, while in the latter the polymer is first irradiated then exposed to the monomer. A modification of the latter technique is to irradiate the polymer in the presence of oxygen to create stable peroxide groups (Eqn. 5), which are subsequently decomposed thermally in the presence of monomer to initiate grafting (Eqn. 6).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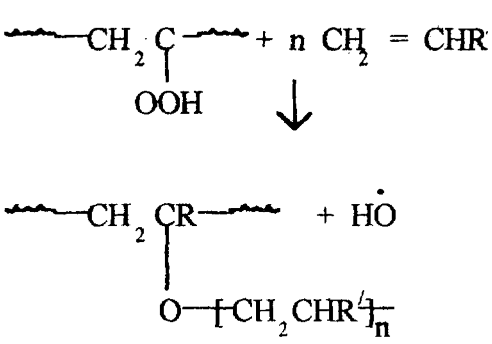
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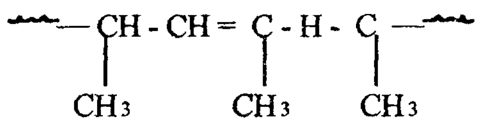
Structural Elucidation Via Free Radical Formation

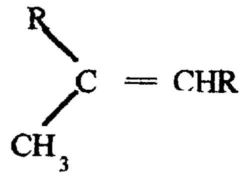
It is recognized that when polymers are irradiated, normally by gamma-radiation from ^{60}Co or by fast electrons from an electron accelerator tube, free radicals are produced and their identification can sometimes give vital information regarding structural features of the original polymer.

Slovakhotova et al [13] have applied infra red spectroscopy to a study of structural changes in polypropylene in vacuo with fast electrons from an electron accelerator tube (200kv accelerating field) and with gamma radiation from ^{60}Co. They found the infra red spectrum of irradiated polypropylene contains absorption bands in the1645cm^{-1} (6.08μ), (Figs 1&2) 890cm^{-1} (1.23μ) and 735cm^{-1} (13.60-13.51μ) regions. The first two bands correspond to RR'C=CH_2, vinylidene groups and the band in the 735-740cm^{-1} (13.60-13.51μ) region to propyl branches, R-CH_2 CH, CH_3. It must be noted that when polypropylene is degraded thermally these groups are formed by disproportion between free radicals formed by rupture of the polymer backbone.

In the spectrum of amorphous polypropylene irradiated with a dosage of 4000 Mrad (40 MGy) at 196°C and measured at -130°C, in addition to the band at 1645cm^{-1} (6.08μ), a weaker band appears, with a maximum near 1665cm^{-1} (6.00μ) possibly due to internal double bonds (Equation 7).


.... (7)

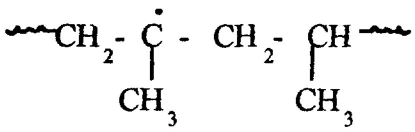
When the spectrum of this specimen is recorded after it is heated to +25°C this maximum disappears, leaving only a shoulder on the strong band at 1645cm^{-1} (6.08μ). Supplementary evidence of the formation of internal double bands in irradiated polypropylene is provided by the presence in the spectrum of bands in the 815 -855cm^{-1} (1 2.27 - 11.69μ) region. In this region lie bonds due to deformation vibration of CH at double bonds in (Equation 8)



.... (8)

groups, existing in various conformations([14]).

A study of the electron spin resonance, ESR spectra of irradiated polypropylene ([15]) has shown that the alkyl radicals formed during irradiation at -196°C (Equation 9).



.... (9)

undergo transition to alkyl radicals when the specimen is heated i.e on heating the radical centres migrate to internal double bonds with the formation of stable alkyl radicals. Irradiation at room temperature leads immediately to the formation of alkyl radicals.

Radiant Energy Degradation of Polymers

The subject of radiant energy degradation of polymers must be considered in order to appreciate fully the subject of this paper in so far as reaction mechanisms are concerned.
Two areas of focus are:

(1) degradation by ultraviolet light radiation termed photolysis and
(2) degradation by high energy radiation termed, radiolysis, involving x-rays, electron beams and gamma rays.

As far as degradation of polymers is concerned, both ultraviolet light and ionizing radiation are responsible for two general types of reaction: chain scission and crosslinking. The competition between these two reactions determines whether the net result of exposure of a polymer to radiation will be the formation of low molecular weight fragments of that polymer or the formation of insoluble, infusible network structure .

Chemical changes in irradiated substances occur as a rule after a dose of 0.1- 1MGy which causes in low molecular-weight substances changes in approximately 0.01-1% of the molecules. Substantially more pronounced are the changes in macromolecular substances where the same doses are sufficient even for multiple "hit" of the molecules whereby local ionization or excitation of the polymer chains occur ([16]). However, all polymers when subjected to very high doses of ionizing radiation will degrade.

The behaviour of olefin polymers on irradiation can thus be generalised by stating that those polymers with two substituents on every other carbon atom in the chain will tend to degrade while those with only one substituent are sufficiently stable to remain intact until crosslinking can occur.

Concluding Remarks

On irradiation of many polymers (polyethylene, polyvinyl chloride) double bonds are formed and in polymers with double bonds cis-trans isomerization occurs, especially at low doses. However, a typical phenomenon during the irradiation of all types of polymers is the formation of gaseous products, the composition of which will depend on the structure of the monomer unit (H_2, Co, Co_2, HCN, etc). Radiation induced chemical changes of polymers also cause changes of their mechanical and physical properties. This phenomenon of radiation modification of polymers has been exploited in packaging, products using polyethylene. In this case, a block of polyethylene is irradiated and a foil is cold drawn. The irradiated polyethylene becomes transparent and maintains its new dimensions. Thereafter, the goods are packed into the foil and heated above 100°C, and on heating, the foil shrinks back thereby providing a tight packing. Radiation destruction of cellulose on the other hand, followed by chemical treatment of the product, is a process that has yielded a material which has found a useful application as hemostatic agent (stopping large area capillary or bone bleeding) perfectly resorbable and acceptable by the organism ([16]). Unlike polyethylene and polystyrene, poly (methyl methacrylate) degrades on exposure to ionizing radiation and the decrease in molecular weight for this polymer is linear, increasing with radiation dose.

In concluding this paper, it must be emphasized that all staff involved in irradiation experiments must exercise maximum care and observe all safety regulations. Injury to living organism caused by ionizing radiation is associated with the damage of important biomacro molecules. However, biological effects of radiation depend very strongly not only on the radiation dose and dose rate, but also on the kind of radiation i.e on the value of linear energy transfer, LET.

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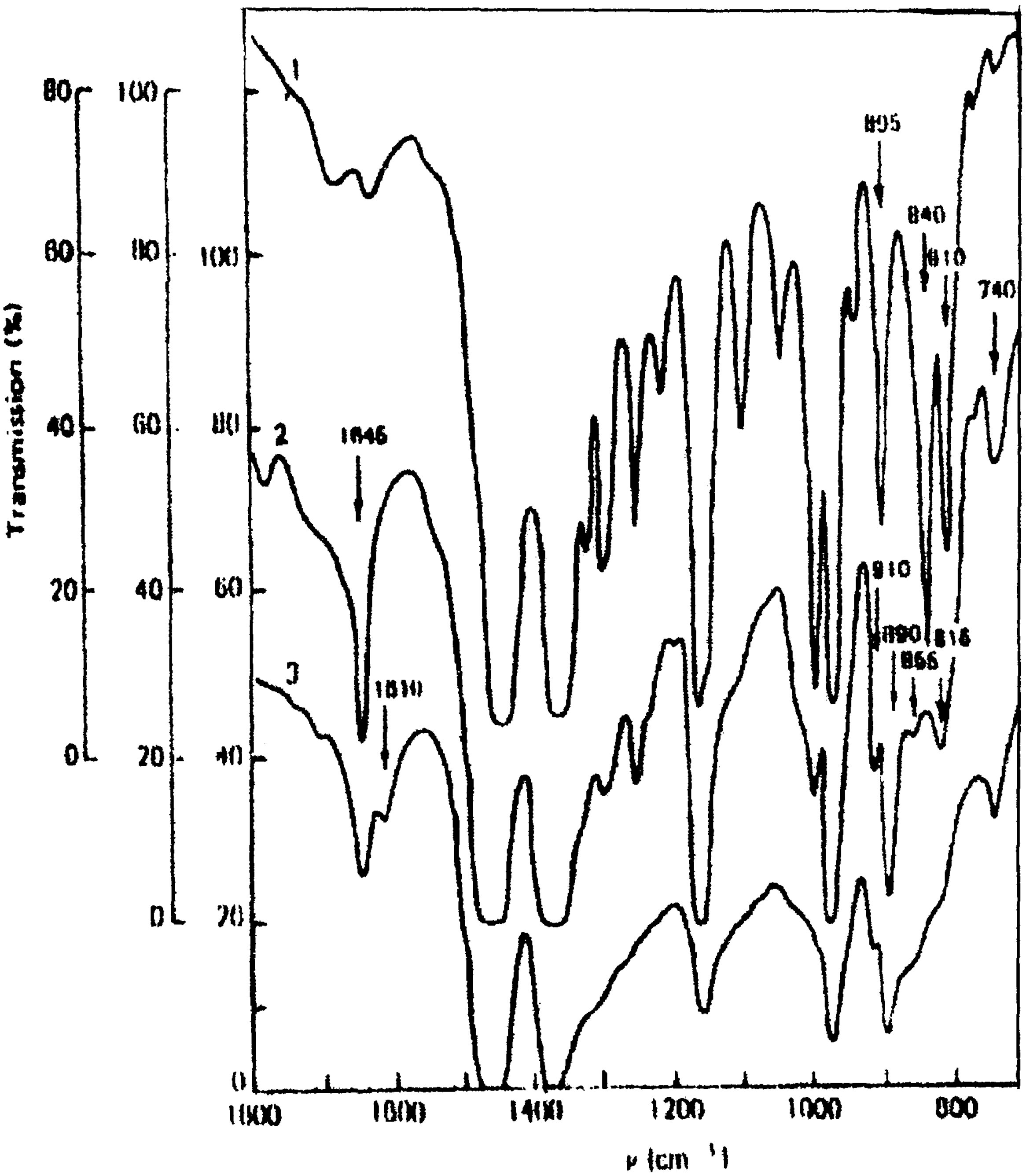

Figure 1: *Infrared spectra of isotactic polypropylene* (1) original (d - 200μ);
(2) irradiated by fast electrons at 25 C, dosage 5MGy (d - 300μ);
(3) dosage 4MGy (d - 200μ)

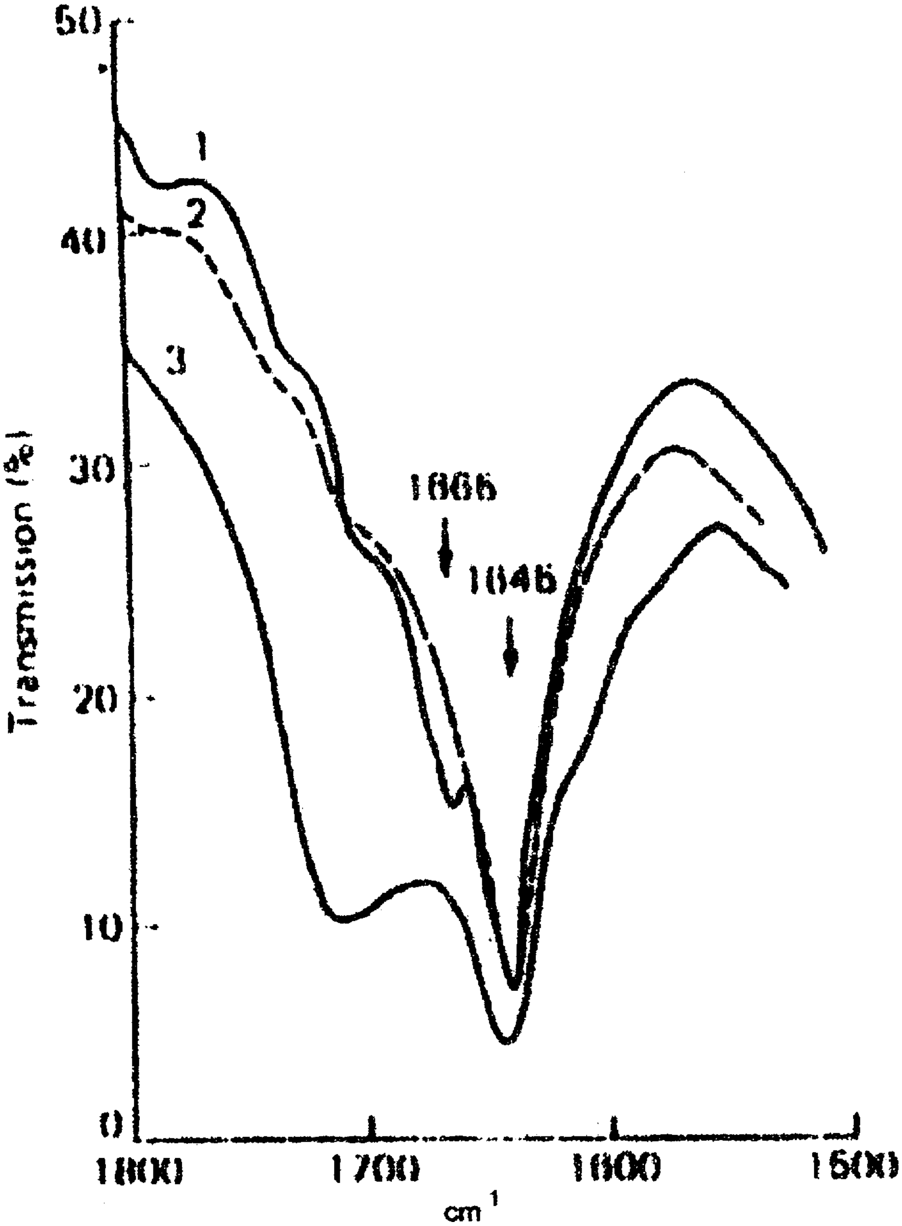

Figure 2: Infrared spectra of amorphous polypropylene (d - 300); irradiated by fast electrons with a dosage of 4MGy at -196 C (spectrum recorded at -130 C;
(2) the same specimen after heating (spectrum recorded at 25 C); (3)
(3) the same specimen 2 weeks after irradiation (spectrum recorded at 25 C). Ref. 13

APPLICATION OF GAMMA RADIATION IN WOOD AND TIMBER INDUSTRY

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Abstract

Use of isotopes and radiation techniques have attained prominence in agricultural measures aimed at increasing world food production. These include solid fertility, plant nutrition, animal production, crop management, insect pest control, food preservation and pesticide residue studies. These techniques are gradually being extended to wood production and industrial wood processing. The whole mechanism of timber production begins with its growth for which soil plays a major significant role. Site selection for plant growth is closely associated with soil density assessment relating to its looseness or compactness. The interaction of gamma radiation with soil has provided a useful method for measuring the total density of the soil. The radioactive isotopes most used in soil fertility and plant nutrition studies emit gamma and/or beta radiation. Radiation techniques like the neutron moisture meter and gamma density probes have been applied to develop improved water management practices in arid and semi-arid environments. Direct gamma ray densitometry has been adopted as a simple non-destructive technique to determine wood density, a property upon which most uses of wood depend. As lignocellulosic materials deteriorate rapidly on exposure to high doses of ionizing radiation, gamma radiation has therefore been used for study of lignin distribution in the wood cell wall. This is of paramount importance in pulp and paper science. Gamma radiation has been a useful measure for accurate determination of moisture content in construction timber. Moisture distribution in wood is crucial in timber seasoning and formulation of appropriate drying schedule . The destructive power of gamma rays which has been turned on food destroying insects and bacteria has a great potential in wood preservation practices. Irradiation can keep wood from deterioration which allows it to be stored without preservative application. Gamma ray attenuation is one of the simple wood quality evaluation techniques for some tropical hardwoods. Scanning and image techniques have been used to assess decay and wood quality in logs and standing timbers. A substantial amount of money is being saved in the wood and timber industries in the developed countries through the use of radio-isotopes. Sawmilling industry operations in Nigeria have changed significantly in recent years with respects to choice of raw materials and size dimensions of logs processed. The logs are relatively becoming smaller with consequent low recovery figures. In the past, rationalisation trends were more often related to choice of certain processing technology.

What is essential now is to increase yield from small size logs through use of existing equipment and technology as well as sensible application of electronics. Diameter sizes of logs can be measured with use of gamma rays. Although the logs are measured over bark, the data provided is diameter under bark. For optimum yield from logs, scanning systems which use infra red beams could be applied to measure logs for diameter sizes, length, taper and shape and scan them for grade and quality.

Introduction

The different types of radiation available for use of mankind are neutrons, protons, heavy charged particles, beta-rays, X-rays and gamma-rays. Among these however, gamma-rays have been reported to have the widest application (Narayanamurti et al. 1970) for the following reasons:

(i) Gamma-rays are easily produced and controlled.

(ii) Gamma-rays with low dose do not induce radio-activity in any substances.

(iii) Gamma-rays have high and uniform penetration.

(iv) Gamma-rays do not produce considerable changes in irradiated specimens .

Cobalt, with an atomic mass of 60 (Co^{60}), is one of the most commonly used source of gamma radiation because of its ability for high penetration and for the fact that it works practically without operational costs and additional investments for many years.

Use of isotopes and radiation techniques have attained prominence in agricultural measures aimed at increasing world food production. These include solid fertility, plant nutrition, animal production, crop management, insect pest control, food preservation. These techniques are gradually being extended to wood production and industrial wood-based product manufacturing. Forestry and its related wood-based industries are primary producers of wood and wood products such as roundwood, lumber, poles, wood-based panels and pulp/paper products which support the dwelling and other cultural uses of mankind. The whole mechanism of timber or wood production however begins with its growth for which soil plays a major significant role. Site selection for plant growth on the other hand is closely associated with soil density assessment relating to its looseness or compactness. The effect of radiation on soil and plant growth consequently therefore has a major impact in the wood and the timber industry. Furthermore, tree plantings for subsequent wood production generally start from the seed and follow-up tree improvement activities. In view of this therefore, the effect of radiation on seed and tree improvement similarly have a major impact on the wood and the timber industry.

Although the objective of this paper is to discuss the application of gamma radiation in the wood and timber industry, mention will however briefly be made on the effect or application of radiation on soil and plant growth as well as seed and tree improvement.

Isotopic Techniques and the Effects of Radiation on Soil Fertility and Plant Nutrition The radioactive isotopes most used in soil fertility and plant nutrition studies emit beta and/or gamma radiation. Beta radiation penetrates a few millimetre of water, soil or plant materials. Gamma radiation which are electromagnetic radiation at high energy end of the spectrum is similar to X-rays but of shorter wave lengths and higher penetrative power. Suitable isotopes either stable or radioactive exist for most elements of interest in soil fertility and plant nutrition.

The interaction of gamma radiation with soil provides a method for measuring the total density of soil. Gamma rays are absorbed in soil as a function of their energy, the atomic number of the constituent elements of the soil and the density of the soil.

There are large varieties of neutron and gamma radiation devices such as neutron moisture meter and gamma density probes which are designed to measure both soil water content and soil bulk density. These have been applied to improve water management practices in arid and semi-arid environments. These devices are based upon the principles of scattering and attenuation for both kinds of radiation sources and are adapted to take measurement at the soil surface and throughout soil profiles to any desirable depth. The basic mechanisms of photosynthesis and central metabolism could be best understood by the use of both stable and radioactive isotopes in experimental studies of plant physiology. Isotopes such as ^{3}H, ^{14}C, ^{32}P and ^{35}S are available as long lived low energy beta particles emitters.

Isotopic techniques have been used extensively to measure the amounts of exchangeable nutrients in soils, their rates of exchange and their mobility and availability to plants and to investigate mechanisms of nutrient uptake by plants.

The ^{14}C and ^{15}N isotopes are being used to study the fate of carbon and nitrogen from different trees and shrubs in alley cropping systems. The alley cropping has been credited with the ability of sustaining soil fertility and productivity.

The use of a ^{15}N dilution technique is potentially useful for measuring N_2 fixation. The amounts of nitrogen which enters the soils due to the process of symbiotic N_2 fixation can be determined by isotopic method. Isotope technique has been used to study nutrient uptake by plants when the nutrients are applied at different distances away from the base of the plants. Zaharah et. al. (1989) reported that mature oil palms were able to absorb ^{32}P applied to the soil as far as 36 metres away from the point of application, indicating that root exudates are active in absorbing nutrients.

Both stable and radioactive isotopes have been used to study microbiological and biochemical reactions in soil. The use of radioactive isotopes have enabled scientists to understand better many reactions involved in organic matter decomposition, pesticide degradation and biosynthesis of numerous microbial products important in humus formation.

The radioactive isotope of phosphorus: ^{32}P was used to study the utilization of phosphatic fertilizers by various crops (Dean et. al. 1948; Nelson et. al. 1948): The use of ^{32}P has dealt with vesicular abuscular mycorrhizae which infects plant roots. It has been known to be important in plant nutrition especially in soils with phosporus deficiency. In the work done by Hattingh et. al. (1973), the endomycorrhizal fungus enabled the plants to remove phosphorus uptake from a larger volume of soil under phosphorus deficiency conditions.

The Effects of Radiation on Seed and Tree Improvement

The use of radiation in tree improvement started about a century ago. In an earlier preliminary work, Lundstrom (1903) used X-ray analysis technique to determine the seed quality of pine cones. About two and half decades later, Yausa (1926) pointed out the advantages of the X-rays analysis method and advocated its application in the detection and identification of suspected insects in seeds of some plant species. Other researchers such as Shevchenko (1937) and Milner et al (1950; 1952) have similarly pointed out the importance of the X-ray analysis for seed quality determination.

Apart from seed quality assessment, X-ray analysis technique was further used to estimate the germinability of scots pine seeds applying barium chloride as contrast agent (Simak 1957); as well as spruce seeds (Kamra 1963a) and the possibility of estimation of mechanical damage done on Scots Pine seeds (Kamra 1963b).

At the Forestry Research Institute of Nigeria, Howland and Bowen (1977) used the X-ray analysis technique to determine the seed quality of Triplochiton Scleroxylon K. Schum (Obeche).

Today, the use of X-rays in seed technology and other aspects of tree improvement has been on the increase. Areas of use include the following:

1. Detection of Insect-Infestation in seed Grain
2. Detection of Empty and Filled Seeds
3. Determination of Polyembryony
4. Embryo and Endosperm development
5. Determination of germinability
6. Detection of weather damage on seeds
7. Determination of mechanical damage on seed
8. Stereoradiography and Microradiography
9. Seed Stratification.

Application of Gamma Radiation in the Timber Industry: Radiation & Wood Drying

Moisture distribution in wood is crucial in timber drying and the subsequent formulation of appropriate drying schedules for different wood species (Bramhall and Wellwood, 1976) .

Gamma radiation has been applied as a useful measure for accurate determination of moisture content in construction timbers. Kober and Mehlhorn (1991) reported on the radio-metric measurement of moisture content in construction timbers with high spatial resolution. In their report on the principles and description of the measuring apparatus, it was indicated that moisture content can be measured with high accuracy of greater than 1%.

In recent years, radiation techniques using gamma-rays produced from Cobalt-60-source in combination with High frequency, HF - heating, have served as heat treatment of wood-polymer combinations (Meyer 1965; Siau et. al. 1965; Kollmann et. al. 1975).

Radiation and Wood Quality:

Direct gamma ray densitometry has been adopted as a simple nondestructive technique to determine wood density. Wood density is an essential parameter upon which most uses of wood depend. Reporting on their study on some South African timber species, Malan and Marais (1991) indicated that gamma ray densitometry is a quick and reliable method of wood density determination which can easily be automated. Elias and his co-workers (1992) reported on the use of gamma ray attenuation as a simple wood quality evaluation technique. Working on some tropical hardwoods, these scientists indicated that there is a linear relationship between gamma-ray attenuation co-efficient and wood density. The method was suggested as a simple non-destructive evaluation technique. Scanning and image techniques have been used to assess decay and wood quality in logs and standing timbers. Diameter sizes of logs can be measured with use of gamma-rays instead of lasers. Moreso, as wood and bark have different levels of absorption. Although the logs are measured over bark, the data provided is diameter under bark (Segerdahl 1987). For optimum yield from logs, scanning systems are applied to measure logs for diameter sizes, length, taper and shape and scan them for grade and quality.

Radiation and Wood Preservation:

The destructive power of gamma-rays which was focused on food destroying effects and bacteria has a great potential in wood preservation practices. Biological deterioration of wood has remained a set back for optional utilization of available timber resources. Deterioration by fungi and insects can occur or originate from the standing tree and carried over to sawnwood and wood in service. Some of the deep seated decay situations and attack by beetles and insects are not readily detected visually. Consequently therefore, other methods of detection have to be employed in the elucidation of these types of wood deterioration. Gamma-rays can be useful in the detection and elimination of internal defects in timbers. In the chemical wood treatment processes, depth of wood preservative penetration into the wood and distribution of same within the wood tissues can be quantified and measured employing gamma rays measuring devices (Jing et. al. 1990).

There is the possibility that the destructive power of gamma-rays may enable wood to be stored without application of chemical preservative treatments .

Radiation and Wood-based panel production:

Siempelkamp, a world leader in planning, supplying and erecting of complete plants for the wood products industry (including engineering and production know-how) developed a density profilometer, a reliable system, which measures, evaluates and records the density profile of wood-based panel products-plywood, particleboard and fibreboard.

This is an important element in:

(i) Quality control

(ii) Product optimization

(iii) Product comparison

The surface density of a product is an indicator for abrasion resistance, bending strength and ıbility. The interior density influences the internal bond, screw-holding strength and other mechanical operties. The density profilometer makes use of focused beam of gamma rays which scans the ›od-based panel over its entire thickness cross-section with a pre-determined speed. The radıoactive urce issues only very low emissions and is shield in a case.

The values measured are tape recorded and displayed by a plotter in a graph. The equipment, hich provides quantitative measurements of the density profile for a variety of panel products provides ‚sy and quick operation (Anon 1988).

pplication of Gamma Rays in the Wood Industry:

The effects of gamma radiation on chemical changes within the wood (Seifer 1954; Weichert ›63); changes in strength properties (Siau and Meyer 1966; Aioki et. al 1977; Burmester 1966; and aidlaw et al. 1967); and on digestibility and decay susceptibility (Kenaga and Cowling 1959) are well ocumented.

As lignocellulosic materials deteriorate rapidly on exposure to high doses of ionizing radiation, amma-rays have been used to study the lignin content and distribution in cell walls (Hachihama and 'akamuku 1960; Lhoneux et. al. 1984). The results of their work bear much on choice of chemical ulping for wood raw materials and is therefore of paramount importance in the pulp and paper industry.

Industrially, gamma radiation has been used to process wood-plastic materials. Compared to the atalytic or heat hardening processes of producing these wood-based products, Narayamurti et al. (1970) eported that gamma-ray inducing technique using Cobalt-60-source has the following advantages:

(i) Induction of polymerization without catalysts and heat.

(ii) Quick completion of the hardening process with a suitable irradiation dose.

(iii) Controlled hardening processes.

(iv) Possibility of partial hardening if so desired.

(v) Formation ‹ ‑ three dimensional network of high density products instead of chain formation.

With the gamma-ray application technique, most properties of the wood-plastic products are improved. These are strength, dimensional stability and resistance against wood destroying fungi. The process is quite economical if low-cost polymers are used. The products are applicable in construction, furniture, special uses such as chopping boards, knife handles, knitting needles, ash trays, musical instruments and sporting goods. The products are also useful in photo engravings, chemicals and shuttle industries.

In their work on radiation processed wood-plastic materials, Narayanamurti et. al. (1970) listed the following advantages in use of gamma-rays:

1. The hardness of the material surpasses that of the natural wood very considerably.

2. Higher crushing strength and abrasion resistance than that of natural wood.

3 Greater dimensional stability due to slower absorption of moisture.

4. Improved shear and static bending strength.

5. Maintenance of natural wood grain and colour.

6. Relative ease of working, sawing, drilling and turning of the products.

Summary and Conclusion

The fields of application of gamma radiation in the wood and timber industry have been reviewed. A substantial amount of money is being saved in the developed countries through use of radio-isotopes. The sawmilling operation in Nigeria have changed significantly in recent years with respect to choice of raw materials and size dimensions of logs processed. The logs are becoming smaller with consequent low recovery figures. In the past, rationalisation trends were more often related to choice of processing technology. What is essential now is to increase yield from small size logs through use of existing equipment and technology.

Researchers are investigating the use of gamma-rays as an adapted technique to measure the quality of sawlogs. Branches of a tree absorb gamma rays more than the stem. By measuring the absorption, it should be possible to give a log an "acceptance number" thereby expressing its quality. So, batches of log supply to a wood industry can be sorted out into sawlogs and veneer logs with a view to increasing and improving lumber and veneer recovery respectively; while the low quality logs can pass into the particleboard and fibreboard industries.

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APPLICATIONS OF GAMMA RADIATION IN THE WOOD AND TIMBER INDUSTRIES

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Abstract

Man has a history with wood, man developmental history is so closely associated with wood that the higher the level of economic development the greater is man's dependence on wood. Man is able to use wood in the various forms through the products of the wood and timber industries. For developing economies, rich in forest resources such as Nigeria, the wood and timber industry is a potential foreign exchange saver or earner.

In this paper, the contributions of the wood and timber industries are discussed. The various components and products of wood and timber industry are highlighted. the applications of gamma radiation in these various industries are discussed. Also in this paper, its uses in quality control for failure detection; as a research tool for the effect of depolymerisation on wood strength properties; monitoring and measurements of moisture content/density of panel products are highlighted along with its use in radiation gauge which permits automation by ensuring uniform thickness in composition boards.

Introduction

Man has a history with wood. The development of man from the primitive state to the present day's highly advanced technology has been closely associated with dependence on wood. In the pre-historic era, wood was used for shelter, fuel, weapons and tools. As technology advanced, wood came into its own in boat making, vehicles and bridges and as fuel for smelting and metal works. As technology continued to advance, the more the diverse and sophisticated uses wood was put. Man's advancement is so intricately tied to wood, that it has been said and is a truism that, the higher the level of economic development, the greater is the dependence of man on wood, not only in many of its conventional forms, but also variety of less readily recognizable forms among which are films and other wood-pulp products. In fact, this our dependence on wood and its products is increasing because of the renewable resource nature of wood.

In every country worldwide where there is a significant forest resource, wood and timber industries have played and will continue to play a significant role in the socio-economic development of that country. These enterprises (large and small) produce wood products both for the domestic and export market thereby contributing to the economic base of these countries. The annual value of wood and timber forest products to the global economy is estimated to be more than two percent of the gross domestic product (GDP). Wood and timber industry in any nation provides a potential for foreign exchange earning or saving depending on whether the products of such industries are targeted at the domestic markets or the foreign markets. The extent of this earning or savings can be seen from the review of the global situation of the values of wood and wood products market for the developing economies in 1982. During this period, the developing economies exported wood and wood products valued at 100 million US dollars while they imported ten times this values of wood and wood products. The contribution of the component sectors of wood and timber industry in world product market are as follows: Industrial round wood which had the largest share of export amounted to 45% followed by wood leased panels - plywood and other composition boards with an export share of 35%. Sawn wood accounted for 17% while wood chips and paper and paper products had 7% and 3% respectively.

With regards to imports developing countries' share was substantial. Industrial roundwood and wood based panels amounted to 20% and 25% respectively while sawnwood amounted to 18% of the world wood and wood product import trade. Pulp, paper and paper products accounted for 31% of the world trade in this product which was 53 million US dollars as compared to an export value of 1100 million US dollars. From the foregoing illustration, the benefits that will accrue to the developing economies if reductions in their export of industrial roundwood can be achieved will be enormous.

Wood and timber industry provides direct and indirect employment in a variety of ways. This industry is also vital in stabilizing income throughout the year. The extraction, processing, production and trade in wood and timber products as well as the associated secondary industries are significant sources of income and employment for a sizable proportion of the population (20% to 30%) of these countries that live in the rural areas where alternatives are limited.

Demand of Wood and Timber in Nigeria

FORMECU, in a study of the demands by Nigerians for the products of wood and timber industry production between the period of 1990 and 2010, found for the population growth of from 88.5 million in 1990 to 144.48 million in the year 2010; the total wood consumption was estimated to rise from 77.6 million cubic meters in 1990 through 89.4 million cubic metres in the year 2000 to 94.4 million cubic metres in the year 2010. Fuelwood alone accounts for 95% of the total wood requirement for this period. Sawnwood and poles place second and third respectively in the total wood requirement by volume. The others are as in table 1. It is worth noting that these first four entries are wood products in demand at relatively unprocessed forms. These are wood consumed in solid wood forms. The other items such as particleboards, pulp, paper and paper products are reconstituted wood. These, though small in absolute quantitative volumes consumed, usually attract higher monetary values. The foregoing situation is indicative of the state of our technological development. In the technologically advanced countries, the pattern of consumption is usually the reverse which is, more wood is consumed in the reconstituted form than in the solid wood forms. This trend is brought out more clearly in table 1. The per capita consumption rate of wood and wood products of the unprocessed type, that is, the solidwood type is increasing at a decreasing rate, while the rate of consumption of the relatively processed wood and wood products is increasing. There is a shift from the consumption of wood with less technological input in their production to those wood products that require more technological input in their production. This is a clear indication of the advancement of the country technologically.

Classification of Wood and Timber Industries

The wood and timber industries are classified into primary and secondary industry groups. The secondary industry group is made up of such industries as furniture manufacture, joinery, prefabricated housing etc. The primary industry group is made up of sawmilling, veneer and plywood manufacture, particleboard manufacture and paperboard manufacture. This write up will be concerned with this latter group. The products from this primary wood and timber industries are delineated into solidwood products, where wood is in its solid natural state in the manufactured product. Examples are the products from the sawmill industry - lumber, splint manufacturing, veneer and plywood mills. The other category is the composition wood, which are products where the wood's natural state and properties have been altered. This category is represented by particleboard, paper and paperboards.

The product of the sawmill industry is lumber. Lumber is a piece of wood in a suitable form for construction, carpentry or joinery, reconversion or other manufacturing process. It is a product of the saw or planing mill, not further manufactured other than by sawing, re-sawing and passing through lengthwise a standard planing machine, crosscutting and working. The sawmilling industry is the most important of the wood and timber industries in Nigeria. It accounts for over 96% of the total log volume extracted from the Nigerian forests. There are over 1,000 of such mills in the country. They provide employment for over 20,000 workers, this is more than 80% of the total labour force in the wood processing industry. Most of the sawmills in Nigeria use the CD 4, 5 or 6 horizontal band headrigs. The operational efficiencies of these are variable and the average are of different degrees of efficiency, lumber recovery factor is calculated at 45%.

The veneer and plywood industry, in terms of log input, ranks a poor second to the sawmilling industry in Nigeria. It accounts for about 3% of the total log volume extracted from the Nigerian forests. It provides employment for less than 3,000 workers. Plywood is a glued wood panel made up of relatively thin plies or veneers. The grains of adjacent veneer layers are usually placed at 90° to one another. They are usually built up of odd number layers of plies. Veneers are tin slices of wood, usually of uniform thickness, produced by peeling, slicing or sawing. They are usually less than 0.5cm thick.

The composition board products are particleboards, blockboards, fibreboards, softboards, harboards and medium density fibreboards (MDE). In Nigeria, there are two functioning particleboard mills. These are integrated to the sawmill, plywood and veneer mills. They use the solid wood residues from these mills as their raw materials in addition to some plantation grown species such as Gmelina arborea. There are two paper mills in Nigeria, The Nigerian Paper Mill, Limited at Jebba and the Nigerian Newsprint Manufacturing Company, Oku-Iboku. A third mill is still under construction at Iwopin.

The products of the composition board industry is in a variety of forms. They range from particleboard through fibreboards to paper products. The standard product of the particleboard mill is the homogenous board, flat pressed, usually 18mm thick. The products may be finished with wood veneers or laminated with plastics. The raw material input are chips which are small fragments of wood, these could be the primary products or by-products from sawmills or plymills. All the fibreboard at present consumed in the country are imported. There is no fibreboard mill irrespective of the fact that particleboard and pulp production have the same raw material base. The problem is that the machinery is more complicated and the technology more sophisticated than the particleboard mill

Nuclear Radiation and its Applications

Nuclear radiation has had its applications in the wood and timber industries but this paper is concerned with the applications of gamma radiation in the timber and wood industry. Gamma radiation is an electro-magnetic radiation of the same character as an X-ray but they are different due to the fact that they have a much shorter wavelength. Radioactive elements give off gamma rays when they disintegrate to form new elements. It should be noted that not all rays are electromagnetic. Moisture content monitoring is very critical particularly in drying. Wood drying is an integral part of the sawmill set up. Before the development of the "beta gauge", the oven dry method was used to determine the moisture content of sample boards that were placed at strategic places in the drying pile. The oven dry method is destructive method but the beta gauge is a non destructive, quick and efficient method of moisture content and density determinations. It is as easy as pressing the "gun" to the surface of the wood and reading off the dial after calibration. This became possible as result of the development of the "beta gauge" for measuring the density or moisture content of wood and timber products. It is based on the principle that beta particles are fast electrons produced from the nuclei of certain isotopes during radioactive decay. When these are passed through matter, they are absorbed approximately as the exponential function of the material they are passed through. Thus, if a beta source is placed against the surface of wood or wood products with a detector of beta radiation placed on the opposite surface, the rate or number of beta particles per unit time that reaches the detector is essentially proportional to the product density for a given thickness. This also has its applications in the monitoring of the moisture content of wood veneers and wood chips used in particleboard manufacture and drying process.

The drying of veneers is critical in the manufacture of plywood because it has a major effect on the quality and performance of the resultant product. It affects adversely, the gluability and the dimensional stability, particularly the irreversible swell of the final product.

In the pulp and paper products manufacture, fine quality control is possible with radiation thickness gauges. This is possible because the count rate registered from a radiation source depends on the thickness of the sheet of material passing between the two. The signal from the counter can then be used to control automatically the pressure of the roller in order to maintain precisely the desired thickness of the product. This principle has its applications also in the manufacture of continuous ribbon of thin particleboard used for wall panels and furniture components. This has led to the development of the high speed single daylight highly precise presses. This also has found applications in the medium density fibreboard (MDF) manufacture. In this application, gamma radiation serves a dimensioning function. In the forming stage during the process of fibreboard manufacture using the dry method, the mass of fluffy fibres pose problems of handling, uniformity and evenness of spread on the platens to ensure uniform thickness and density. The application of the radiation thickness gauge has made automation of the process possible. The principle of this application form is not without its limitation, this is due to the high absorptivity of beta particles in solid material such as wood. This, in effect, restricts the upper range of thicknesses of veneers and other products for which this method can be applied.

The principle of radiation has made the in-process monitoring of moisture content possible in the wood and timber industry. This involves the use of two different kinds of radiation simultaneously. In this method, high energy neutrons generated from "fast" neutron generator, are directed into the material to be measured. Some of these fast neutrons lose much of their energy in the material and become slow or moderated neutrons as they are reflected back to a slow neutron detector. Hydrogen is an effective neutron moderator, and being present in wood as a constituent of the chemical make up of the wood as well as the water or moisture in wood, adjustments have to be made by calibrating the instrument for the moderating effects of the hydrogen that is part of the constituent of the wood.

Density measurements by the normal methods usually involves the measurement of its moisture content on a weight basis. This is due to the fact that the neutron radiation system of monitoring this variable only measures the amount of water per unit volume of material. This is normally done by means of a gamma radiation and detection system, in which a beam of gamma rays is directed at the material. The intensity of such radiation that is reflected or transmitted through the material to the gamma detector is inversely proportional to the density of the material. Thus, the combined output data from the two radiation systems can be used to give the moisture content on a weight basis. This system is readily adaptable for the measurements of such variables in granular materials used in a continuous manufacturing process such as wood chips. It will be recalled that wood chips is the raw material for the manufacture of particleboards and chipboards in the wood and timber industry.

As a research tool in the utilization of wood, gamma radiation has been used in the investigation of strength properties of the wood. In this application, the cellulose fraction of the wood is subjected to random depolymerization by exposure to varying doses of gamma irradiation This irradiation method aided in the study of cellulose chain length on the mechanical behaviour of wood loaded in tension parallel to the grain. The result of this study indicated that, the strength of wood with low degree of polymerization of cellulose is more sensitive to moisture changes than that of wood having cellulose of long chain structure. This, in practice, means that the agencies which depolymerize cellulose will not only weaken wood but will also make it more sensitive to variations in atmospheric humidity.

Gamma radiation is used in the investigation of effects due to a random defect distribution on the physical properties of panel products such as plywood and particleboards, during manufacture. Gamma radiation is also used to detect foreign bodies in the wood that would otherwise damage the machinery in the process of lumber manufacture.

CONCLUSION

Wood and timber industries convert forest resources into economic and social values. Gamma radiation's contribution to the attainment of these through its varied and important applications in the manufacturing process of wood and timber product, are in various forms. It contributes as a research tool in product development while it enhances automation by its use in radiation gauges for panel products. Its contribution in the economies of product manufacture is in the areas of moisture content and density measurements and monitoring. For product quality control, gamma radiation finds use as a tool in the detection of random fault distribution.

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Table 1: Population and Wood Class Consumption by Product Quantity

Population (x 1000)	1990 88.5	2000 113.482	2010 144.488
	Requirement (x1000)	Requirement (x1000)m^3	Requirement (x1000)
Fuelwood	7394m^3	8352m^3	8813m^3
Poles	1678m^3	2182m^3	2729m^3
Plywood	131m^3	217m^3	359m^3
Sawnwood	1996m^3	3289m^3	3289m^3
Particleboard	41m^3	86m^3	182m^3
Newsprint	39 tonnes	71 tonnes	131 tonnes
Printing & Writing Paper	4m^3	8m^3	16m^3
Paperboard	21m^3	38m^3	69m^3

Source: Update of Supply and Demand Data FORMECU, 1994.

IRRADIATION AS A QUARANTINE TREATMENT

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Abstract

Irradiation is a treatment which is well established as a very efficient and convenient industrial process for achieving a high level of sterility assurance in medical supplies, and has also been used as a food preservation technique. This technique has also been found effective as a pest disinfestation treatment of some agricultural commodities, such as fresh fruits, vegetables and cut flowers and is generally not phytotoxic at doses proposed for these purposes. This sterilization process that inactivates all forms of microbial life so that they are not able to reproduce, is very safe since it only involves the exposure of the products to gamma irradiation. There has therefore been increasing international interest in developing irradiation as a residue-free plant quarantine treatment. Unfortunately, irradiation which is being considered as an alternative to other quarantine treatments (chemical and physical) is very ineffective for the control of seedborne diseases of fungi, bacteria, nematode and viruses. The doses required to eliminate these pathogenic spores are by far higher than those required to kill the seed embryo. It has also been observed that the late stage of eggs and larvae of insects are resistant to radiation injury and may develop into adult. By far, fumigation and other routine quarantine treatments such as hot water treatment, cold treatment, heat treatment, fungicidal seed dressings etc. remain an excellent routine tools for disinfesting or disinfecting agricultural commodities and plant propagative materials from pests.

This paper discusses briefly routine quarantine treatments and considers irradiation as an alternative treatment, which has been used only for the cleaning of agricultural products and commodities and has been found to be very deficient in freeing seed borne pathogenic spores in plant propagative materials. The use of irradiation as a quarantine treatment requires further research in order to provide a standard dosage that can inactivate the pathogenic spore without killing the seed embryo.

Introduction

The movement of plants and plant products from one country to another, for purposes of crop improvement through germplasm exchange, germplasm conservation, trade, research and other human needs, have continued to be unavoidable means of disseminating exotic and dangerous agricultural pests (insects, pathogens and weeds) which have been known to pose serious threat to the agricultural economy of many nations (Black and Sweetmore, 1995; Singh and Manalo, 1985). Quarantine measures are established in accordance with the International Plant Protection Convention (TPPC) to check these pest movements and possibly prevent them from getting to areas where they do not already exist. One of these measures is the use of quarantine treatments; others being complete exclusion of infested/infected plant materials either through outright destruction and disposition or return to countries of origin.

A quarantine treatment is any action or treatment aimed at disinfesting or disinfecting exotic host commodities thereby guaranteeing the preservation of the good health and safety/security of indigenous host commodities. The application of treatments where possible before release encourages international trade which otherwise would have been stopped through prohibition or destruction of unsuitable materials for phytosanitary reasons.

Plant Quarantine treatments commonly in use include disinfestation by fumigating with various chemicals, cold treatments, heat treatment and hot water treatment, while disinfection treatments through use of chemicals are aimed at protecting plants from infection.

Irradiation on the other hand is an established, efficient and convenient industrial process for achieving a high level of sterility assurance in medical supplies and in food preservation techniques. It has also been found effective as a pest disinfestation treatment for some agricultural commodities and as such it is being developed as an alternative and residue free plant quarantine treatment.

This paper briefly discusses quarantine treatments commonly in use and examines irradiation as a complimentary means of effecting quarantine treatments.

Conventional Quarantine Treatments

(a) Disinfestation of plant materials and products

Disinfestation aims at destroying ectophytic and endophytic pests, notably insects, nematodes, molluscous and mites as well as any other undesirable animal organisms affecting the sanitary conditions of plant materials. Disinfestation is directed at eliminating most potentially destructive pests at the larva stage when they are most harmful. The treatments employed for this purpose include:-

i. Fumigation which entails use of chemicals (fumigants) with toxic substance that destroys any harmful pest present in any stage of development. Fumigation has the added advantage of being applied to large quantities of materials without opening the packages does not leave traces of toxic residue when properly applied. The fumigants commonly in use are Methyl Bromide (MB), Phosphine (PHS) and Ethylene dibromide (EDB).

ii. Insecticidal Bath e.g. cold insecticidal bath containing 0.2% Aldrin or Dieldrin or Heptachlor which has been found very effective in disinfesting bulbs and other dormant plant materials infested by insects and mites.

iii. Seed dressing using Aldrin, Dieldrin, Chlordan or Lindane (as dry or wet powder) at rates of 0.25 to 0.5% for various seeds.

iv. Heat treatment used mostly for vegetables and involves either immersion into a bath of water heated to a required temperature or subjecting the materials to steam heat in an insulated enclosure (bulbs inclusive) or dry heating at 121°C for 2 hours in an incubator or autoclave (especially for soil sterilization).

v. Cold treatment for the elimination of fruit flies from citrus and involves cooling fruit pulps close to freezing point and keeping the fruits at that temperature for a number of days depending on the species of fruitfly.

b. Disinfection

Disinfection on the other hand only aims at preventing the infection of plant materials by pathogens as no known chemical cure has been developed for the removal of pathogens from already infected plants, that would not destroy the host plant. Therefore most chemical quarantine treatments are applied to treat plants before they are infected with pathogens be they fungal or bacterial at doses toxic enough to destroy the pathogen without destroying the plant tissues. In the case of viruses however, heat treatment is employed.

Seeds infected by bacteria or fungal spores, however, can be given chemical and heat treatment before germination.

From the foregoing, it is clear that various treatment methods are required in quarantine depending on various circumstances of the nature of the pest and the host plant i.e irradiation treatment capable of providing the solution to quarantine pest eradication problems, as a substitute or is it to be used as a complimentary method? How effective and safe is irradiation treatment on plant propagative materials and at what cost?

Irradiation As A Quarantine Treatment: What it is

Irradiation is a process whereby substances are exposed to radiant or light energy with the aim of controlling or eliminating micro-organisms dangerous to the health or survival of higher organisms, be they humans, animals or plants. The various forms of irradiation techniques include: Sun tapping which relies on UV-radiation; infra-red radiation and microwaves used in baking or boiling and pico-waves, which could be produced from gamma rays, X-rays or electrons. This last group of irradiation is most commonly used in food preservation and each has the ability to penetrate tissues easily. The doses are often measured in kilorads (Sighn, 1987) but now in KGy (1KGy = 100 Krads).

General Usage of Irradiation

Irradiation is commonly used in the medical field for the sterilization of health care and disposable products through the exposure of the objects to gamma rays. This process inactivates all forms of microbial growths and stops reproduction.

Irradiation has also been used as a food preservation technique and a pest disinfestation treatment. For example, the technique has been used in the preservation of horticultural products. Shelf-life extension of onions and potatoes by inhibiting sprouting in countries like Japan and East Germany (Sighn, 1987) and garlic, chestnut and ginger in Malaysia (Sighn, 1987). In the agricultural sector, therefore, irradiation treatment appears justifiable in terms of reduced post-harvest losses and improved quality products (USA Dept. of Agric, 1973).

Possible Usage in Quarantine

The quarantine treatment of an agricultural commodity, be it for planting, decoration, consumption of manufacturing industry, moving from one country to another, aims primarily at eliminating pests (insects, nematodes, pathogens/disease organisms, weeds etc) capable of causing hazardous threat to the agricultural economy of a nation. The treatment should demonstrate the following qualities:- (Sighn and Manalo, 1985).

(a) Effectiveness against target pest species in the host organism, giving up to 99.9% control (i.e pest death, without destroying the embryo or growing part of the plant in the case of propagative materials.
(b) Freedom from adverse effects on quality, storage life and acceptability of treated products.
(c) No harmful residue or changes in the nutritional qualities of the commodity to consumers.
(d) Free of hazards to users in the immediate environment.
(e) Possibility of effecting treatment to packaged and unpackaged commodity and ability of treatment to prevent reinfestation and infection.
(f) That the cost of treatment is not prohibitive, thus rendering the final market price uncompetitive in the world market.

If irradiation has to be used as a quarantine treatment, it must be used in such a way as not to destroy the embryo of propagative materials, the main source through which pests are introduced to agricultural lands and which is the main focus of any plant quarantine outfit. Therefore, the destructive action of irradiation on cells of living organisms particularly above a certain level of radiation energy should be considered if it is to be used as quarantine treatment.

Irradiation and Commercial Consignments of Plant Produce/Products

Commercial consignments of plant produce/products involved in international trade are largely for consumption and the manufacturing industries and therefore any treatment aimed at preserving the commodities to ensure good quality of the products both for consumption and for the industry is very much welcome in quarantine. The sterilization of the growing parts of such commodity, which prevents germination of discarded parts like fruits and seeds is even more welcomed by the quarantine system as this removes the fear of planting seeds of plant materials meant for consumption. However, irradiation doses used for this purpose (preservation) are usually in the low to moderate range.

Radiations have been known to penetrate products slowly (depend on rate) and in totality, and the treatment has been found to be more uniform and in-depth than chemical treatment. It has, therefore, been used as an effective preservation technique for various plant produce including fruits and vegetables as earlier mentioned. Below is a summary of some recorded use of irradiation in agriculture:-

(a) Irradiation is used as an alternative to chemical fumigation for the control of fruitflies (at 1st half egg stage, early larva, 1st three day pupa) at between 0.3KGy and 3.0KGy Balock, et al. 1963.

(b) No targeted fungi (Fusarium spp and Cercospora spp.) grew when plated section of ripe and unripe banana on PDA (10 pieces per plate) were subjected to 4KGy irradiation for 30 minutes and plates incubated for 7 days at 280°C. The treatment eliminated all fungi on the treated banana and delayed ripening.

(c) High doses of irradiation have also been found to eliminate disease causing viruses by sterilization.

Irradiation doses are classified as follows:-

Low dosage:	Less than 1KGy
Medium dosage:	1KGy - 10KGy
High dosage:	10KGy - 50KGy (Singh, Maralo et al.1988)).

(d) Irradiation is not phytotoxic at doses (low to moderate) recommended for the purpose, when used for the preservation of fresh fruits, vegetables and cut flowers, (Burdilt, 1982). This success awakened international interest in developing irradiation as a residue-free plant quarantine treatment.

The doses recommended for preservation purposes which are usually applied to commercial consignments are usually low (and may not be effective enough to eliminate pests in dormant but living areas of propagative plant materials).

Irradiation and Propagative Plant Materials (Including Germplasm Exchange Development & Preservation)

Pests of agricultural importance are mostly introduced to a country through exchange of planting materials i.e seeds, cuttings, bulbs, tubers and rhizomes. To ensure that these plant materials are pest free for planting, the treatment used must be able to eliminate the pest and yet render the material viable for growth.

Irradiation when used in high doses has been known to cause serious disturbances in living cells, notably in the chromosomes constitution of the cells of growing germinating tissues, which could adversely affect the development of the plant in the field.

The spores of seed borne diseases like bacteria, bunts, smut and viruses, are very resistant to low levels of irradiation.

A higher dose of irradiation is required to kill the spores than required to kill the embryo, therefore, any attempt to eliminate the pests by irradiation automatically kills the embryo.

In view of this, irradiation as presently developed is not suitable as a quarantine seed treatment (Curtis 1985). Late stage eggs and late stage larvae are also known to be resistant to irradiation injury especially in low dosage, and may develop into the pupae or adults. This calls for caution even when used for preservation purposes

Implications of Irradiation As Quarantine Treatment

From the foregoing, irradiation may only be introduced as a quarantine treatment in Nigeria for purposes of promoting the sales of commercial consignments of plants and plant produce meant for consumption or industries in the world market. This service would be a partial one since consignments meant for propagation would not be catered for. This not withstanding, the full compliments of the resources (human, material and financial) required to be able to effect irradiation treatment would have to be put in place if the technique is recommended.

The resources required would be additional as existing facilities etc, would have to be retained and maintained to provide the needed service to the other critical area of plant propagative materials.

Facilities: The facilities and procedures to be provided must be of International Codex Alimentarius committees general standard and should be at strategic ports of entry/exit in the country. At least, 8 sets of such equipment would be required for a start.

Personnel: The personnel of the PQS as presently constituted are not equipped by training to operate irradiation facilities. Some existing specialists and staff of Plant Quarantine would need to be trained under the law of Nuclear Regulator Agency with well defined operations and dosimetry, while some specialists in the field of radiology would have to be recruited.

Costs: The employment of irradiation techniques as quarantine treatment by itself is a very expensive venture, let alone as an addition to an existing quarantine outfit. It will require a high initial capital cost. However, the operating cost of irradiation on the long run is relatively cheaper than other methods because of its low energy requirement.

CONCLUSION

Irradiation has been effectively and successfully used for the sterilisation of medical and personal care products. It has also been used for the preservation of agricultural produce and other commodities.

Although irradiation has been used in quarantine to treat non-propagative plant materials and commodities in marketable conditions, it has not been possible to treat infested/infected seeds and other propagative materials because the irradiation dose required to eliminate pest is so high that the viability of the seeds etc is destroyed.

The use of irradiation technique in quarantine can at present be only limited to agricultural commodities not requiring regeneration through cultivation. More research is required before irradiation can be developed to a point where it can be substituted for other quarantine treatments.

For now, irradiation may only be used selectively as a quarantine treatment if funds are available to establish irradiation unit of plant quarantine at strategic points nationwide.

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TECHNICAL SESSION III
Discussion: Questions, Answers and Comments

Questions on the 1st Paper

Question 1 - Mr. U. J. Ukpabi, N.R.C.R.I Umudike, Umuahia.
Why has the industrial sector not been utilizing information from NCRI on cassava starch? Have you looked into using the cassava starch from the factory at Ihiala instead of importing starch?
Why is data sparse on other roots and tubers as sources of raw materials.

Answer
I visited the starch factory in Ihiala last year and saw it closed down. The starch I have in mind must be detoxicated. I am looking into other points raised by you.

Comment:
(i) - Prof. E. U. Emovon, SHESTCO Abuja.
I will advocate that the industries bring in the universities and research institutes to the process of producing raw materials.

Question 2 - Mr. R. K. Omotayo, NAFDAC, Lagos.
Will the application of irradiation technology eliminate the problems of storage? I personally think there should be a national programme to address the issue of storage. Since irradiation will now ensure increased and regular availability of agricultural products for food and other industries, I think the need for adequate and proper storage should be addressed.

Answer
As SHESTCO Coordinator suggested yesterday, farmers should form cooperative societies as a strategy for central storage facility and consequently benefit from irradiation treatment. Cost implication of this extra input to harvested goods should however be considered as well as consumers preference to non-irradiated products. Also, NAFDAC regulation will require that irradiated foods should be so labelled.

Questions on the 2nd Paper

Question 1 - Dr. P. F. Olurinola, Faculty of Pharm. Sc. ABU, Zaria.
Is the 1.8m wall thickness as shield for the radiation source meant for the Co-60 sufficient in view of the high capacity of the irradiation plant?

Answer
The thickness of the concrete shield designed is very much adequate for the source to be used.

Question 2 - Dr. P. Onwualu, Agric. Div. Nig. Soc. of Engineers, UNN.
What is the effect of maintenance of equipment on safety given our low technological level and economic crisis?

Answer
Training is part of the project. Training will include maintenance of equipment. The foreign partners have experience of having installed such facilities in developing countries like Brazil, Indonesia where local engineers now maintain the equipment after series of training in Germany and Japan.

Question 3 - Dr. C. C. Ariahu, Univ. of Agric, Makurdi.
What are the safety measures to assure safety of radiation source at the ports of entry into Nigeria in view of the possibility of theft as a result of ignorance?

Answer
There are international regulations guiding transportation of radioactive sources. They protect against theft, fire etc. These will apply to this particular source.

Question 4 - Dr. A. J. Coker, SHESTCO Abuja.
Economy should not be allowed to undermine safety. I think it should be as low as reasonably achievable as Dr. Jimba said yesterday and not as low as economically achievable as you seem to be saying today.

Answer
There is no doubt that there must be economic consideration, but I agree that this should not be allowed to undermine safety.

Question - Dr(Mrs) O. Obodozie, NIPRD, Abuja.
What happens with post-treatment handling of irradiated food products viz-a-viz recontamination of irradiated materials and our food handling culture?

Answer
Pre-packing prior to irradiation should be encouraged so as to deter post-treatment recontamination

Question - Mr. G. A. Solabi
"The most affected flies are not those irradiated" Please explain further on the implications of this to the use of irradiation technology?

Answer
The flies are the infected and not affected.

Question - Mr. G. A. Solabi
The need to educate to alley fears and apprehension, who should do the educational programme: SHESTCO, AEC or Federal Ministry of Agriculture or Ministry of Petroleum Resources or Researchers?

Answer
You and I, all of us, every one including the stake-holders of the irradiation technology, the private sector should be involved.

Question - Mr. G. A. Solabi
If the scientific evidences internationally (FAO/IAEA/WHO/JECFI Joint Expert Committee) and naturally all show that the products of irradiation are wholesome, naturally balance and toxicologically safe (i.e quality and safety assured), why the demand on labelling requirements? would this labelling requirements not increase the consumers fears on safety?

Answer
It is a new method and with time labelling requirements may not be necessary. Also it is to prevent some importers bringing in products that may contain higher level of radioactivity.

Question
Are you considering the possibility of the effect of irradiation on the genetic complement of the irradiated plants during quarantine process?

Answer
Plant quarantine is of the opinion that any treatment such as irradiation be targeted at pests and pathogens of quarantine importance but not to destroy the propagating materials or deform/change the genetic composition of the material; hence, we have not embarked on such technique. Plant quarantine welcomes such treatment that will check the pests or pathogen but maintain the genetic composition of the plant propagative material.

Question 1
The use of Co-60 may be quite improper as gauges and moisture content measurements. It would be better to think of low energy neutron gauges and β-sources for these facilities.

Answer- Mr. Badejo
There are custom-made γ-irradiators for measuring moisture contents.

TECHNICAL SESSION 4
IRRADIATION TECHNOLOGY FOR NATIONAL DEVELOPMENT

i. Dosimetry and Quality Assurance
U. Gohs and M. Frenzel - Gamma Service Produktbestrahnlung Germany.

ii. Comparative Study of Gamma Irradiation & Other Techniques in the Treatment of Pharmaceutical Products and Packages
Prof. C.O.N. Wambebe - National Institute for Pharmaceutical Research and Development, Idu Abuja.

iii. Radiation Sterilization of Pharmaceuticals, Cosmetics & Packages
a. Prof. Philip F. Olurinola - Faculty of Pharmaceutical Sciences, ABU, Zaria.

iv. Radiation Protection Requirements at A Commercial Irradiation Plant
by Dr. I. P. Farai - Federal Radiation Protection Service, Department of Physics, University of Ibadan, Ibadan.

v. Some Safety Aspects of Irradiation Technology
M. Frenzel - Gamma Service Produktbestrahnlung Germany.

DOSIMETRY AND QUALITY ASSURANCE

U. Gohs and M. Frenzel
Gamma-Service Produktbestrahlung GmbH, Leipzig, Germany.

Abstract

The determination of the radiation dose is necessary for radiation protection and for quality assurance purposes as well. The "official" personal dosimeters used for radiation protection purposes are film dosimeters. In addition electronic dosimeters, which indicate the dose value immediately can be used. For the determination of the dose of irradiated products several dosimeter systems can be used. The Gamma Irradiation Facility of SHESTCO will be equipped with an Alanine dosimeter system. One or a few Alanine thin films are irradiated together with each product unit (e.g. pallet) and then evaluated with an ESR-spectrometer. The dosimeter films keep their information for years and therefore can be evaluated as often as necessary. The dose has to be as high as required for the intended purpose but not lower than the sensitivity of the dosimeter. Therefore, the overdose ratio is an important quality parameter. It depends mainly on the distribution of the source rods in the source rack and the density and thickness of the irradiated material. The overdose ratio must be determined for each kind of product.

Introduction

Dosimetry

A drug has a favourable or a harmful effect on a person depending on the dose. The same can be said about ionizing radiation.

Ionizing radiation can be applied for cancer therapy and is widely used in the field of medicine. The malignant tissue has to get a radiation dose which is high enought to destroy it. On the other hand, healthy tissue must not be damaged (or at least not in a serious extent). It means its dose must be kept as low as possible.

In the field of industrial application of ionizing radiation for germ reduction, sterilization or cross linking we have a similar problem. A minimum dose must be applied to achieve the intended effect. If the dose becomes too high the product can be damaged. The other point is, that the application of doses higher than required is uneconomical. Thus, the plant does not work with the optima throughput.

These examples show, that the determination of the radiation dose is essential for radiation protection and for quality assurance purposes as well.

Dose Units

The dose is the quantity of radiation absorbed by a material. It can be defined by the number of ions produced in the material (ion dose) or the energy absorbed in a unit mass of the material. The unit of the absorbed dose in SI system is Gray (Gy). It is defined as

$$1Gy = \frac{1Ws}{1kg} = \frac{1J}{1kg}$$

For several considerations the dose rate D i.e dose per unit time, is important:

$$D = \frac{dD}{dt}$$

It is only in radiation protection that another dose is used. The name is equivalent dose H. The reason is, that different kinds of ionizing radiation (e.g.α-, β-, γ-radiation) are different dangerous for the human organism. The dangerousness depends on the Linear Energy Transfer-value of the radiation particles, i.e. on the energy loss dE within the path dz. If the LET-value is high, the density of radiation damages is high and the self repair mechanism of the living cells is obstructed. These differences are taken into account by the quality factor Q. The table shows how the quality factor depends on the LET-value.

LET-value in water [keV/μ m]	Q	Radiation
<3.5	1	β^-, β^+, γ, X
7	2	α, p, d, n, depending on particle energy
23	5	
53	10	
>175	20	

The unit for the equivalent dose is Sievert (Sv). It can be determined from the energy dose by the following equation:

$$H = D * Q$$

Dosimeters

Dosimeters for radiation protection purposes

Film Dosimeters

This type of dosimeters is mostly used as the "official" dosimeter for radiation protection in most countries. Although some countries now use thermoluminescence dosimeter (TLI) because it can be reused. Each person who is occupationally exposed to ionizing radiation has to wear a film dosimeter while working with radioactive materials or with other sources of ionizing radiation . Its main part is film of a similar material as used in photography. This film is enclosed in a thin light proof material. Therefore the film is not blaced by light. Ionizing radiation (β, γ-radiation) penetrates the lightproof material and causes the same chemical changes in the film as light. After development these changes are visible as blackening. By a calibration function the dose can be determined from the optical density. The film is enclosed in a plastic capsule with absorbers of different material (copper, lead) and different thickness. From the different blackening of the film behind the absorbers the type of the radiation and the energy can be determined. A good calibration for the particular type of film and that batch of films is required for the dose to be determined with high accuracy. The film dosimeters are changed and evaluated monthly or quarterly.

Electronic Dosimeters

The main disadvantage of the film dosimeters is, that the result is available only months after the irradiation. To keep the personal dose as low as possible a person who is occupationally exposed to ionizing radiation needs a quick information about the actual dose or dose rate during his work. Therefore electronic dosimeters are used besides the film dosimeters. Electronic dosimeters are available with different features. They should at least provide a dose rate proportional signal (beep) or a signal if the dose rate exceeds a certain limit and they should be able to determine the dose received in a day or during a particular working step.

Dosimeters for product dosimetry

Principles

The doses which are to be measured for product dosimetry are by a factor 10^6-10^8 higher than for radiation protection purposes. Therefore special dosimeter systems were developed.

The definition of the absorbed dose unit

$$1Gy = \frac{1Ws}{1kg} = \frac{1J}{1kg}$$

is a suggestion for the calorimetric dosimetry system. The energy absorbed in a material causes an increase of the temperature. If the specific heat capacity is known, no calibration is needed. The dose can be determined according to

$$D = \Delta T * c$$

Because heat exchange with the surrounding material during and after irradiatiion is very small, a minimum of dose rate of 10Gy/s is required. This system is used mainly in irradiation facilities with electron beams.

Calorimetric dosimeters with Graphite as absorber material may be considered as reference standard dosimetry system, requiring no calibration by other dosimetry systems, provided the heat capacity and its temperature dependence are known and the temperature sensors are calibrated accurately.

The most important group are chemical dosimeters. Chemical reactions are caused by ionizing radiation. If the following conditions are fulfilled, the system can be used as dosimeter.

(i) The products of the reactions induced by ionizing radiation are stable (at least for the time needed for irradiation and evaluation).
(ii) The quantity of reaction products depends on the dose only.
(iii) There is a convenient method for quantitative determination of the reaction products.

There are several methods for evaluation of the dosimeters.

(i) Thermoluminescence
(ii) Spectrophotometry
(iii) Electron spin resonance

Alanine dosimetry

An Alanine dosimeter system is planned for the gamma irradiation facility at SHESTCO. It has several advantages compared to other systems. Alanine, $CH_3CH(NH_2)COOH$, is an amino acid. It is used in polycrystalline form for dosimetry. No additives or dopants are required. Alanine is used mostly either compressed to discs or as coating on a plastic film carrier for easier handling. Under ionizing radiation radicals are produced:

$$CH_3-\underset{}{\overset{NH_2}{\overset{|}{CH}}}-COOH \qquad\qquad CH_3-\dot{C}H-COOH+\dot{N}H_2$$

For the determination of the radicals an electron spin resonance spectrometer is used. Electron spin resonance spectrometry is based on the absorption of microwave energy in the sample if it is placed in a magnetic field of a certain strength. For the evaluation of the spectrum a PC is used. The alanine dosimeter system can be used in the dose range from 0.001 kGy to 500 kGy. Dosimeters can be read out repeatedly and can be stored with very low fading. The alanine dosimeter system can be calibrated using a few dosimeters which were irradiated in a standard laboratory with a defined dose

Quality Assurance

Aim of Quality Assurance

Quality assurance in the irradiation technology means:

(i) make sure that each part of an irradiation unit (pallet, box) gets at least the minimum dose required.
(ii) make sure that the maximum dose is as low as possible (for sensitive products).

Dose distribution in the irradiated products

If an irradiation unit is irradiated in a gamma irradiation facility the dose distribution is inhomogeneous. The dose decreases with increasing distance from the radiation source. This is caused by two physical effects:

(i) absorption effect
(ii) geometry effect

Absorption effect means that the intensity of the radiation is attenuated by the product between the source and the point of consideration. For a given radiation energy the attenuation depends on the product of thickness and density (mass per square unit) of the product between source and point of consideration. The attenuation of the γ-radiation can be described in a first order approximation by the equation:

$$D_l = D_o e^{-\mu * \rho * l}$$

where

D_l .... dose behind a product layer with thickness l
D_o.... dose without product between source and point of consideration
μ .... mass attenuation coefficient, here about 0.06 cm^2/g
ρ .... density of product

l .... thickness of product layer

In addition the geometry effect must be considered. Even without absorption the dose decreases with increasing distance from the source. For the case of a point source this effect can be described easily by the quadratic distance law:

$$D = D_l * \frac{1}{r^2}$$

where

D .... dose at a point of interest

D_l ... dose in the distance l from the source

r .... distance of the point of interest from the source

Because the SHESTCO gamma irradiation facility will have a rectangular source with dimensions in the order of the distances, the quadratic distance law must be integrated over the source area:

$$D = \iint_{y,z} D_l (y,z) * \frac{1}{r (y,z)^2} \, dydz$$

where

y, z .... coordinates of the source rack

For the optimization of the source pattern these computations can be carried out using computer codes.

For a quantitative description of the dose inhomgeneity the overdose ratio ε is used:

$$\varepsilon = \frac{Dmax}{Dmin}$$

where

Dmax ... maximum of dose in the irradiation unit

Dmin ... minimum of dose in the irradiation unit

The dose distribution discussed above is the reason why the irradiation units (pallets) must be turned during irradiation. This is the easiest possibility to reduce the overdose ratio. If the irradiation unit is turned during irradiation the dose minimum is about in the centre.

Validation

Density specific validation

Validation of an irradiation facility means the determination of the ratio between dose and irradiation time. Due to the absorption effect, the dose distribution depends on the density of product. Therefore this validation must be carried out for all typical product densities. This validation can be done with product dummies. In the irradiation units dosimeters are placed in a certain pattern. Typical distances between the dosimeters are 20cm ... 30 cm. After irradiation over a certain time and in a certain operation mode of the plant, the dosimeters are evaluated. Then the dose distribution is known. The irradiation time for any other dose can be computed and the position or several positions for the routine dosimeter(s) can be fixed.

Product specific validation

For some products, especially medical products, a density specific validation is not sufficient. To make sure that the dose is at all points of the product above the lower limit and below the upper limit a product specific validation must be carried out. This must be done with original products. The dosimeters are placed in the material in a pattern with lower distances. The following steps are the same as for density specific validation.

Documentation

Documentation of all data concerning the validation is essential for quality assurance. The documentation has to comprise at least:

(i) date and source activity
(ii) source loading pattern
(iii) operation mode of the plant
(iv) description of the product (material, dimension, density, packing)

(v) position of dosimeters in the product
(vi) results of dosimeter evaluation.

APPENDIX

Dosimetry and Quality Assurance

1. **Dosimetry**
    - dose units
    - dosimeters for radiation protection
    - dosimeters for product dosimetry

2. **Quality Assurance**
    - dose distribution in the product
    - validation

Aims of quality assurance:

Make sure that

- minimum dose is achieved
- maximum dose is not exceeded at <u>all</u> points of <u>each</u> irradiation unit.

Units

1. **Energy dose (D):**

absorbed energy per mass $$D = \frac{dE}{dm}$$

unit: Gray (Gy)

$$1\text{Gy} = \frac{1\ Ws}{1\ kg} = \frac{1J}{1\ kg}$$

formerly used unit: Rad (rd)

$$1\ rd = \frac{0.01J}{1\ kg}$$

2. **Ion dose (J):**

electrical charge per mass $$J = \frac{dQ}{dm}$$

unit: Roentgen (R)

$1R = 2.58 * 10^{-4}$ C/kg (in air)

($1R$ = 1ecu/1cm^3)

3. **Dose rate** $(\dot{D})$

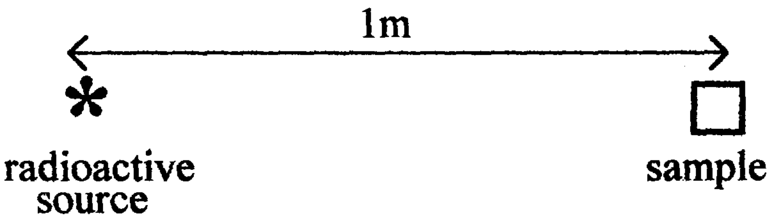
$$\dot{D} = \frac{dD}{dt}$$

dose per time

units: Gy/h (for energy dose)

R/h (for ion dose)

4. Dose rate constant (k)



dose per time dependent on distance, activity

Examples:

Co-60 $k\gamma = 0.351 mGy\ m^2\ h^{-1}\ GBq^{-1}$
Cs-137 $k\gamma = 0.086 mGy\ m^2\ h^{-1}\ GBq^{-1}$

5. Activity (A):
number of atoms decaying per time

$$A = \frac{dN}{dt}$$

unit: Bequerel (Bq)

$$1Bq = \frac{1\ decay}{1s}$$

formerly used unit: Curie (Ci)

$$1Ci = \frac{3.7*10^{10} decays}{1s}$$

6. Equivalent dose (Dq):
dose unit for radiation protection $Dq = D * Q$

unit: Sievert (Sv)

Q (quality factor) takes into account that different kinds of ionizing radiation are differently dangerous for the human organism.

Quality factor Q

LET-value

Linear Energy Transfer value (keV/µm)

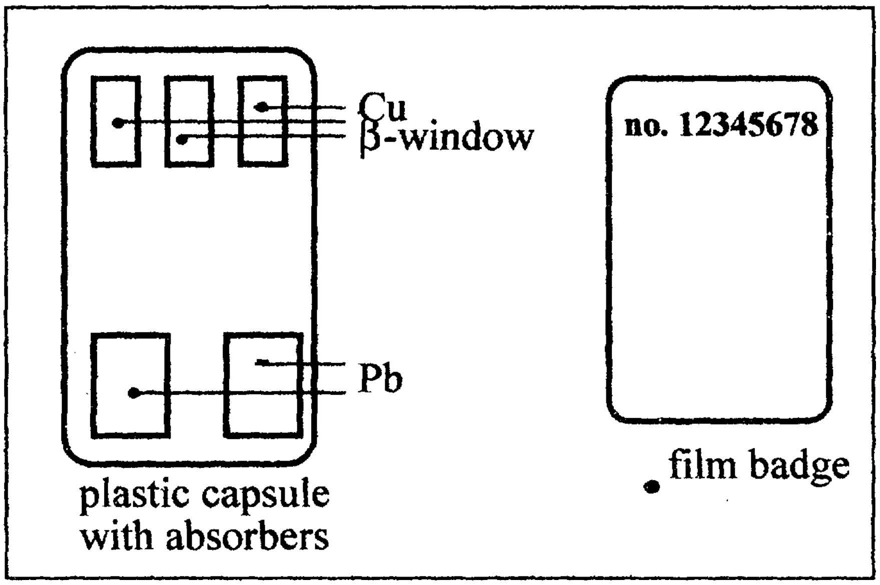
LET-value in water [keV/µm]	*Q*	*radiation*
<3.5	1	β^-, β^+, γ, X
7	2	*α, p, d, n,*
23	5	depending on
53	10	particle
>175	20	*energy*

usually used Q-values for particles with unknown energy

β^-, β^+, γ, X	1
n	10
α	20

Dosimeters for radiation protection
(low dose, µSv ... mSv)

1. Film dosimeters



Electronic dosimeters

Personal dosimeters (doserate, dose)

Hand held dosimeters (doserate)

Dosimeters for product dosimetry
(high dose, kGy)

1. Calorimetric dosimeter

$$D = \frac{dE}{dm} \approx \frac{\Delta E}{\Delta m}$$

This is a suggestion for a dosimeter

$$\Delta E = \Delta T * \Delta m * c$$

$$D = \Delta T * c$$

Advantages:

- no calibration required, direct method
- high accuracy

Disadvantages:

- limited sensitivity
- adiabatic system required

This system is a reference standard dosimeter.

2. Chemical dosimeters

They are based on chemical reactions, caused by ionizing radiation

Conditions for the use as dosimeter:

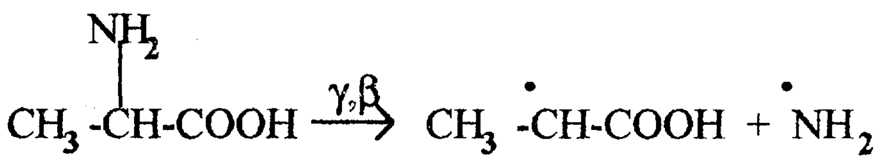
- stable reaction products (for the time of irradiation and evaluation)
- quantity of reaction products depends on the dose only
- convenient method for quantitative determination of reaction products

Methods of evaluation:

- thermoluminescence
- spectrophotometry
- electron spin resonance

3. Alanine dosimetry

Radiochemical reaction:



Principle of evaluation (ESR-spectrometry):

absorption of microwave energy in a magnetic field

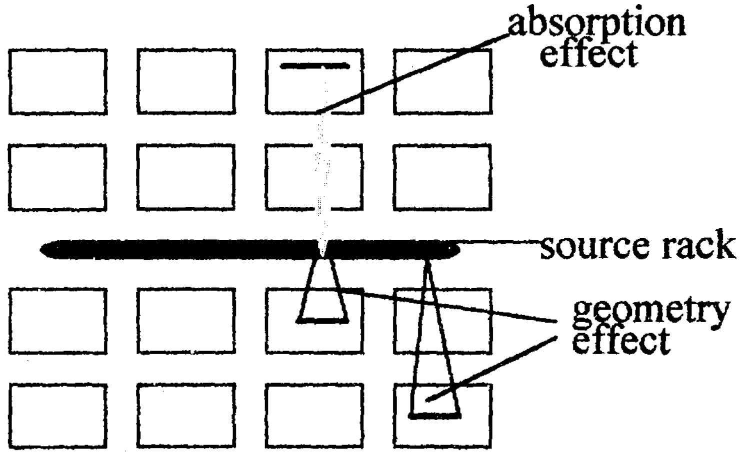
Features:

- dose range 10Gy to 500 kGy
- linear dose response up to 3kGy
- dosimeters can be read out repeatedly
- fading <1% per year
- temperature coefficient 0.176±0.005%/K
- total error of measurement 3%

Quality Assurance

Aims of quality assurance:
Make sure that
- minimum dose is achieved
- maximum dose is not exceeded at all point of each irradiation unit.

Reasons for inhomogeneous dose:
- absorption effect
- geometry effect



Overdose ratio (ε):

$$\varepsilon = \frac{Dmax}{Dmin}$$

Absorption effect:

$$D_l = D_0 e^{-\mu\rho l}$$

where

D_l .... dose behind a product layer with thickness l
D_o.... dose without product between source and point of consideration
μ .... mass attenuation coefficient, here about 0.06 cm^2/g
ρ .... density of product
l .... thickness of product layer
product r * l should be below $24 g/cm^2$ for good quality

Geometry effect (point source):

$$D = D_l * \frac{1}{r^2}$$

where

D .... dose at a point of interest
D_l ... dose in the distance l from the source
r .... distance of the point of interest from the source

Geometry effect (extended source):

$$D = \iint_{y,z} D_l(y,z) * \frac{1}{r(y,z)^2} \, dydz$$

where

y, z .... coordinates of the source rack

Validation

1. Density specific validation
- for all typical product densities and load patterns
- can be done with product dummies
- determination of the ratio between dose and irradiation time

2. Product specific validation
- for sensitive products (e.g. medical products)
- must be done with original products

3. Documentation
- date and source activity
- source loading pattern
- operation mode of the plant
- product description (material, dimension, density, loading pattern)
- position of dosimeters in the product
- results of dosimeter evaluation.

Decay correction

1. Decay law

$$D(t) = D_0 * e^{-\lambda t}$$

where

D(t) ... dose at the time, t
D_0 ... dose at the validation
λ ... decay rate,
for Co-60: $\lambda = 3.60 \times 10^{-4}\ d^{-1}$
t ... time since validation

2. Compensation

Adaptation for cycle time

$$t_c = t_0 * e^{\lambda t}$$

where
t_c ... cycle time
t_0 ... cycle time at time of validation

COMPARATIVE STUDY OF GAMMA IRRADIATION AND OTHER TECHNIQUES IN THE TREATMENT OF PHARMACEUTICAL PRODUCTS & PACKAGES

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Abstract

Sterilization process is an essential component in all aspects of modern-day pharmacy practice. The objective is to destroy all forms of viable organisms and ensure the safety of the numerous preparations and devices which could be potential sources of infection when used or administered. Different types of sterilization process are employed in pharmaceutical sterilization, and the choice of which procedure is used is determined by the physical, chemical nature of both preparation and packaging material. The pharmaceutical scientist has to handle a variety of products with different physical, chemical and biological properties, therefore no one sterilization process can be used across Board.

The manuscript examines the different sterilization process in sterilization of pharmaceuticals and compares them with the gamma irradiation process. The advantages in the suitability and potential applications of the gamma-irradiation sterilization technology for pharmaceuticals especially in industry, research and development, seem to outweigh the limitations.

This places it at a favourable position over most other pharmaceutical sterilization processes.

Introduction

An essential element in the practice of modern-day pharmacy is that of sterilizing pharmaceuticals and other materials and verifying that they are sterile. The objective of the sterilization process is to destroy all microorganisms in or on an object preparation and assure that it is free of infectious hazards or all demonstrable forms of viable organism. It is an orderly and total process proceeding to extinction of organisms and can be effected by physical or chemical agencies.

Why Sterilize?

Pharmaceutical preparation and materials are sterilized and supplied in a sterile condition when they are to be injected or applied to wounds or mucous surfaces because body fluids and tissue provide good substrate for the growth of many microorganisms. Preparations for injections may consist of sterilized solutions in their final containers or in case of limited stability, powders sterilized in containers to which water for injections can be added. Sterile liquids and gels may be required in surgery for irrigation of bladder, vagina, urethra or for lubrication of catheters. There may be need for sterile solids to be implanted under the skin, other preparation include eye-drops, surgical dressing, absorbable ligatures and sutures, antimicrobial powders.

Sterilization technology like all aspects of science and technology is very dynamic and not stagnant. The pharmaceutical scientist has peculiar problems in the sterilization process because he has to handle a variety of products with different chemical, physical and biological properties with a great deal of uniformity and consistency.

The new and improved technique in sterilization of pharmaceuticals that evolve constantly are due to changes and increase in the number of products requiring sterilization and also changes in the method of delivering health-care services. These lead to a subsequent revision in guidelines and requirements by regulatory bodies (in form of official standards) of processes and practices employed in sterilization.

The procedure to be used for sterilizing a drug, pharmaceutical and/or medical product depends to a large extent on the nature of the product. This is due to the fact that some products or their components may possess unique properties which may result in their destruction by a particular sterilization process or practice. Therefore it is almost impossible to apply the same sterilization technique universally across board. In choosing a sterilization method therefore, it is important to work according to certain guidelines for the use of the several types of industrial and hospital sterilization processes and evaluate each method experimentally if possible. Another factor to note here will be the need to understand the nature and level of expected contamination prior to sterilization. For example, while actively growing microbes are, generally vegetative forms, with little resistance to heat and disinfectants, some bacteria have the ability to assume a spore state that is highly resistant to heat and disinfectant. Therefore, the conditions required for a sterilization process must be lethal to the most resistant spores of microorganisms normally encountered, with additional treatment designed to provide a margin of safety. A design plan that includes elimination of the spores is very essential because, this is a form that preserves certain organisms during adverse conditions.

The task of providing sterile pharmaceuticals and hospital goods can be perceived as a system comprising a number of elements viz:

(a) Selection, handling of raw materials and subsequent compounding and packaging so as to achieve minimal microbial load.

(b) Selection of a packaging material that will withstand the sterilization process.

(c) Application of adequate and appropriate sterilization treatment that is compatible with both pharmaceutical and packaging.

(d) Other process involved would ensure the appropriate storage of sterile product in other to maintain sterility of product, sterility verification and delivery, opening and use of the product without contamination.

Briefly let us look at the sterilization processes of interest in modern pharmacy practice either for industrial or small scale purposes. These are basically classified into two groups; processes involving the use of:

Physical Process:

These may involve the use of heat in the presence or absence of moisture. The cause of death in these thermal processes differ. While dry heat at temperatures above 140°C probably kills bacterial spores by destructive oxidation, death by moist-heat is the result of coagulation and hydrolysis of cellular protein. The dry heat mechanism is of lower efficiency and therefore requires higher temperatures and longer exposure time.

Although saturated steam under pressure is not only the widely used method of sterilization, it is also thought to be the most efficient and effective. However, many-thermolabile pharmaceutical substances and packing materials like some plastics, paper and fabrics are damaged when exposed to temperatures above 110°C and/or moisture. Such materials therefore must be sterilized using other methods. These two processes will generally use either an oven or autoclave.

The second class of sterilization process is:

Chemical Processes

A gaseous chemical bactericide can be used in form of chemical vapours to sterilize articles unable to withstand the temperatures needed in autoclaving and dry heat sterilization. Many agents e.g. chlorine dioxide, ozone, propiolactone, chloropicrin, peracetic acid, methyl bromide are available in this group but only ethylene oxide and formaldehyde have proved to be generally suitable for medical product sterilization but then only when such critical conditions like relative humidity, temperature, exposure time and concentration of agent have been strictly adhered to and carefully controlled. For example, ethylene oxide which has a high penetrating power can kill all bacteria including spores, but at the presence of moisture. Thus products to be sterilized require a relative humidity of 33% to 60% before exposure to the gas. This operation is usually carried out at percentage at temperature range of 40°C to 60°C, therefore its low boiling point of 10.7°C is ideal.

Formaldehyde similarly requires a high relative humidity of about 80% to 90% and because of its low penetrating power, requires longer exposure time. Protective matter like sputum, pus, serum can seriously hinder its effectiveness on bacteria.

Propylene oxide has also been used and behaves similar to ethylene oxide although easier to handle because of its higher boiling point of 34°C it is less effective, requiring about twice the concentration to achieve some results as ethylene oxide.

Although this method of sterilization is used widely in industry, particularly in the sterilization of heat labile medical devices, in view of the critical nature of gas sterilization procedures, it is inadvisable to use them if more certain methods are available. Some of its shortcomings include, difficulty in controlling the sterilization cycle and conditions, control of the gas residues and by-products in treated materials and exposure level of employees. These two points are very important because some of the gases e.g. ethylene oxide have been classified as mutagens and potential carcinogens, with high toxicity. Without adequate aeration after treatment (to allow for dissipation) ethylene oxide residues create the largest potential hazard in hospitals and small laboratories where materials may be used soon after sterilization. Many of these gases are also explosive to handle, therefore they are used as 10% to 20% concentration in CO_2 and are also very reactive. A major advantage of ethylene oxide that sold it to pharmaceutical industry, is that products can be sterilized already packaged for shipment, because due to its high penetrating power, the gas can permeate sealed plastic films and cartons, and dissipate from the material simply by exposure to air.

For plastic materials used in packaging pharmaceuticals, gas sterilization is a practical method

It is believed that ethylene oxide exerts its lethal effect upon microorganisms by alkylating essential metabolites affecting particularly the reproductive process. This alkylation probably occurs by replacing an active hydrogen on sulphydryl, amino or carboxyl or hydroxyl group with a hydroxyethyl radical. Since the altered metabolites are not available to the organism, it dies without reproducing.

Such chemical reaction can also occur with drug molecules in pharmaceutical preparation especially in a liquid medium, therefore the use of ethylene oxide in sterilizing pharmaceuticals is limited to dry powders, substances shown to be unaffected including rubber goods, delicate optical instruments, stainless steel, parenteral administration sets and hypodermic needles.

Surface Disinfection:

Another type of a chemical process is surface disinfection. Most often than not, the application of chemicals in solutions to places like skin surfaces, utensils, surgical equipment does not produce sterility. The use of chemical disinfectants in pharmaceutical industry is designed primarily to reduce the microbial population i.e. microbial decontamination so that asepsis can be maintained in a controlled and limited area. Since most disinfectants do not destroy spores during any reasonably contact period, they do not sterilize a surface, only vegetative forms of micro-organisms can be expected to be killed. The effectiveness of the agent will depend on the number of organisms present and their sensitivity to the agent, the nature of the surface (hard smooth surface are easier to disinfect than rough porous ones). A large number of disinfectants are commercially available. Usually a general guideline for the use of disinfectants assumes that a 2% solution of one of the phenolic germicide-cleaners is adequate for floors and walls, 1:1000 concentrations of quaternary ammonium compounds (QAC) solutions or 1% to 2% solution of phenolic germicide for smooth hard surfaces. A metallic object will require a 0.2% sodium nitrite to be added to the QAC solution and 0.5% sodium carbonate to the phenolic germicide to prevent rusting.

We would not dwell much on this process since it does not produce sterility.

Mechanical Process:

A third class of sterilization process is <u>Filtration</u>. Filtration is a nonthermal process and can be considered to be a mechanical process because the organisms here are not killed in situ but removed by filtration. To be effective, filters must remove micro-organisms from the solution while permitting the passage of the desired components of the solution and imparting no undesirable components from the filter. The filters usually are composed of various materials e.g. asbestos or cellulose, diatomaceous earth candles, sintered glass candles or discs, porcelain candles. The filtrations mechanisms of these depth filters is random adsorption or entrapment of the microbes in their matrices. Also some filters function by electrostatic effects due to opposite charge attraction to the surface of the passage ways within the filter or charge repulsion preventing passage through the pores. Usually, most filters employ a combination of the various mechanisms. Pore size of filters is a very important consideration. The smallest viable bacterial particles are spores which may have a diameter of 0.5 micron or slightly smaller, vegetative bacteria rarely are found to be smaller than 1 micron. Therefore a filter should have pore size small enough to prevent micro-organisms from moving through the filter. Membrane filters of 0.2 μm pore size are employed as sterilization filters while 0.45μm pre size filters are used to sterilize antibiotics or steroids in organic vehicles prior to aseptic process.

The process involved in sterilization by filtration can be said to consist of:

(a) Passage of the solution to be sterilized through a previously sterilized filter-unit.

(b) Aseptic transfer of filtrate to sterile containers which are then sealed aseptically.

(c) Tests for sterility are compulsorily carried out.

(d) Since there are a number of hazards in sterilization by filtration, a bacteriostatic agent is included in the solution to increase the margin of safety.

The advantages of this process include the:

(i) absence of heating, thus it is suitable for thermolabiles.

(ii) removes all bacteria and fungi and often clarifies the solution.

(iii) It is useful for sterilization of large volume solutions.

(iv) It is useful for eye-drops, as drops bottles do not withstand heating process well.

However, its disadvantages outweigh its advantages.

These include:

- Aseptic technique required. And highly trained staff, sterile equipment and facilities are necessary for asepsis.
- Sterile tests are always required, issue and use of products are not permitted until tests are carried out.
- Deterioration can occur within the required seven days and the products have a short shelf-life.
- Viruses and filtrable forms of bacteria and their products like toxins, pyrogens may not always be removed.
- Filters may break down suddenly or gradually in use and may not be detected.
- There could be a leak in the filtration unit, permitting entry of non-sterile air.
- There could be adsorption of drug components to some filters e.g. candles and fibrous pads.
- Clogging of filters could occur with prolonged filtration, and bacteria could grow on some filters.
- Though this is a disadvantage, but it has become a unique feature (for membrane filters) that can help with regulating the extent of use of filters. This is because for membrane filters beyond a certain challenge level of micro-organisms, usually 10^9 organism per cm^2, the filter clogs.
- Filters could shed some filter materials into the filtrate.
- It cannot be used for suspensions or some multi-phase solutions containing molecular aggregates (e.g. emulsions) or solubilized systems with droplets larger than filter pore-size.

Radiation Sterilization

This is a physical sterilization process. Two types of radiation are commonly used in sterilization:

(a) electromagnetic - comprising ultraviolet and gamma radiaton.

(b) particulate - involving high energy electrons.

The basis of the lethal action of radiations on micro-organisms is the production of ionizations and less importantly, excitations, when radiation transverses the cell. Ultraviolet radiation involves low energy, short wavelength emanations in the UV range of 240 to 280nm, and has limited use in sterilization. Maximum microbicidal activity is at 253.7nm where it is non-ionizing but produces excited molecules within the cell, resulting in damaged intracellular chemical reactions which may lead to cell death, if extensive enough. When a high intensity is maintained for a long time, it can kill vegetative and sporing microbes. UV light has poor penetrating power because it is extensively absorbed by substances like plastics, turbid liquid glass. It is suitable for the sterilization of air, water in thin layers, hard impermeable surfaces.

Gamma Radiation

Gamma rays are high energy electromagnetic emanations with a wavelength in the range of 1 to 10^{-4} nm and energy values of $10^6$to 10^{10} eV. When they are absorbed within the cell, they cause ionization of the cell contents, free radical formations and excited molecules and this leads to disorganisation of enzymes and DNA of the nucleus or nuclear apparatus. Gamma radiation is emitted from radiostopes like cobalt-60 or cesium-137 and it is the most frequently-used form of radiation sterilization. The effect of gamma radiation is cumulative, divided doses being as effective as a single dose of same duration and magnitude. All microorganisms including viruses are affected by gamma radiation, although there could be relative resistance of microorganisms to sterilization by gamma irradiation. It is generally agreed that vegetative forms of organisms are the most sensitive, followed by moulds, yeast, viruses and spore formers. The unit of the absorbed dose is the Gray = J/kg. It is accepted that a radiation dose of 25kGy is usually sufficient, although higher doses may be needed with heavy microbial loads encountered in some products like foodstuff. Some of the factors affecting radiation sensitivity of microbes include, the species, innoculum level, gaseous environment, degree of hydration, temperature, state of cell division and protective and sensitizing agents etc. Protective agents include reducing agents (e.g. thiourea, DMSO, cysteine etc), alcohols, complex foodstuffs and proteins.

Modern gamma sterilization facilities used by pharmaceutical and medical-device firms generally hold up to 4 million curies of Co-60 or 30 million curies of cesium-137 radioactive source material.

The Pharmacist probably has little use of radiation sterilization facilities in hospitals and small labs, however many industrial sterilization procedures use radiation with the result that most materials processed throughout the world is sterilized by ^{60}Co irradiation. Many pharmaceutical and surgical products which are thermolabile with high demand are sterilized by this method including disposable rubber gloves, adhesive dressings, plastic disposable surgical equipment, sutures, plasma tissue, tissue transplant, protheses, vitamins, antibiotics like penicillin and streptomycin, steroids, hormones, chloramphenicol ointment tetracycline group antibiotics, cannulae, dialysis units, starch glove lubricating cream, oxygenators for heart lung machines.

Some of the limitations of gamma-irradiation sterilization process include the fact that radiation dosages of this level can adversely affect many pharmaceutical substances. Biological products like heparin, insulin, some alkaloids, barbiturates, sulphonamides may lose a great deal of their potency when in solution. Irradiation of products may also result in colour changes and brittleness in soft glass and plastic materials.

Due to this continous emission of gamma rays from the source, it is only economically suitable for production of large volume of items. Elaborate housing and safety precautions are required to protect operators from radiation effects, while the operations require expert supervision and control .

It's advantages include

(i) It is highly effective

(ii) Treatment time may be very short

(iii) Materials may be irradiated in dry or frozen state in the presence or absence of oxygen.

(iv) Sterilization is in the final container after packaging. This reduces risk of re-contamination.

(v) Thermolabile products can be sterilized since it is a cold process that does not appreciably induce rise in temperature.

(v) It is suitable for large quantities of products since it is a continous process.

(vi) It is independent of heat sensitivity or resistivity of the material.

(vii) It cannot induce radioactivity.

(viii) Low maintenance cost e.g. ^{60}Co source replacement is at a rate of 12 $^{1}/2$ % per annum.

(ix) Reliable constant energy output.

(x) The process can be controlled and monitored accurately.

Which Process?

The question of the economics of the various sterilization processes is probably not as important as has been implied, in the choice of sterilization process. There are undoubted differences in the cost of the various processes. e.g. cost of ethylene oxide sterilization is about 60% that of radio-sterilization. However, while the increasing utilization of ^{60}Co irradiation is resulting in reduced costs, the general inflationary trends have caught up with some other processes. Sometimes sterilization may account for only a small percentage of a manufacturers price, so the cost difference in the different processes will not have appreciable effects in manufacturing .

I think that the real consideration should be which sterilization process is most suitable for the materials concerned and its ability to impart an appropriate degree of security. The chosen method if suitable should not cause any undesirable change in the materials so that they remain fit for the purpose.

Another factor that determines which sterilization process is used, is the suitability and potential applications to specific needs of the recipient and/or user of the technology. For a large consumer of pharmaceuticals, like most developing countries, vigorously pursuing self-reliance in the development and sourcing of pharmaceuticals and pharmaceutical raw materials, the ability to sterilize large quantities of raw materials like Talc, Bentonite, Kaolin, Starch, and a host of other natural products (which could have high microbial load) becomes paramount. Gamma-irradiation sterilization process will invariably seem to be most suited here.

As at 1996, there are over 150 pharmaceutical companies manufacturing in Nigeria. Plastics, glass and cardboards are the main packaging materials and Gamma-irradiation facility should become useful and cheaper in sterilizing them, thereby reducing cost.

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RADIATION STERILIZATION OF PHARMACEUTICALS, COSMETICS AND PACKAGES

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Abstract

Irradiation technology, as applied to pharmaceuticals have gained prominence and much better public acceptance in the last ten to fifteen years. Two types of radiation are used for sterilisation: electromagnetic (ultraviolet and gamma) and particulate (high energy electrons). Ultraviolet radiation is unsuitable for sterilisation of pharmaceutical dosage forms because of its weak cell lethality and low material penetrability.

Gamma radiation from (1) a suitable radioisotopic source, such as cobalt-60, and (2) electrons energised by a suitable electron accelerator are officially recommended and widely accepted radiation for sterilisation. Sterilising dose of 25 KGy is generally accepted, based on its high inactivating factor of up to 10^7 and 10^{10} for the standard test bacteria species *Bacillus pumilus and Streptococcus faecium* respectively. The USP, B.P. and other relevant authorities have given allowance for use of lower or higher doses, if validated.

The pharmaceutical products sterilised by irradiation processes are mostly thermolabile products in their final containers and packages, including: injectables, antibiotic powders for injection, ophthalmic ointments and solutions, topical ointments and creams, multicomponent parental units, and packages.

Some details of this technology, its processes and application are discussed.

Introduction

Several types of radiation have found some application in the manufacture of pharmaceuticals and medical products. Two types are used for sterilization purposes, particulate (high energy electrons) and electromagnetic, in form of gamma rays and ultraviolet light. The latter, (U.V) is unsuitable for the sterilization of pharmaceutical dosage forms because of its poor material penetrability and its weak lethal activity against microbial cells. Its use is, therefore, limited to sterilization of air in aseptic rooms, hard impermeable surfaces and water in thin layers.

Irradiation sterilization has gained prominence and much better public acceptance in the last 10-15 years. It has become a superior alternative to ethylene oxide sterilization, of which there is an increased awareness of its ecological and toxicological problems. Besides, there has been legislative breakthroughs in acceptance of food items irradiated to various levels of radiation energy by the World Health Organisation (WHO), and the United States Department of Health and Human Services, covering fresh fruits and vegetables, dry or dehydrated vegetables, wheat and potatoes processing, herbs, spices and pork (Jacobs, 1991). Irradiation has now heen recognised as a highly effective and reliable sterilization process for heat-sensitive (thermolabile) materials.

In this paper, prominence is given to gamma radiation sterilization, though some information is given on electronbeam irradiation.

Antimicrobial Activity

The mechanism of antimicrobial activity for both gamma (γ) rays and electron-beam irradiation is believed to be by ionization and free radical production, the target being the microbial DNA. Vegetative bacteria are the most susceptible [except for Deinococcus (Micrococcus) radiodurans] followed by moulds, yeasts with bacterial spores and viruses (Denyer, 1992) . The extent of DNA damage required to cause cell death can vary, and this together with the ability of the organism to carry out effective repair largely determine its resistance to radiation.

Figure 1 illustrates the effect of radiation on the viability of some food microbial contaminants. Among the eleven tested micro-organisms, *Pseudomonas aeruginosa* and *Escherichia coli* are the two most susceptible, while *Clostridium botulinum* and *Micrococcus radiodurans* are the two most resistant.

With both radiations, destruction of a microbial population follows the classic survivor curves (figure 2). From such a curve, a D-value, that is in this case, the radiation dose required to reduce the microbial population to one-tenth of the initial product population, can be established, especially for standard bacterial spores of *Bacillus pumilus*, and subsequently a suitable sterilizing dose calculated.

Radiation Equipment and Operation

Radiation sterilization equipment is of two main types: electron accelerators and gamma radiation sources. The latter is by far more popular.

Electron Accelerators

High energy electrons are usually generated by direct current (DC) machines, generating 1-3 MeV electrons, or the microwave linear accelerators, generating 3-15 MeV electrons (Jacobs, 1991). Van de Graaff machine and Dynamitron(^{R}) are examples of D.C. machines. Figure 3 is an illustration of a Dynamitron(^{R}). The machine generates high energy electron beam by accelerating electrons from a hot filament down an evacuated tube under high potential difference. A horizontal conveyor belt system usually carries the product to be sterilized, through the electron beam, which may be scanning. The sterilizing dose is delivered rapidly, usually within a few seconds or minutes. The articles to be sterilized have to be in small packs because of low energy penetration (usually mm or cm) into the product. Varying levels of shielding based on size of accelerator, are necessary to protect the operators from the X-rays generated by the bremsstrahlung effect.

Gamma-rays sources

Gamma-rays for sterilization purposes are usually derived from a cobalt-60 (^{60}CO) source, with a half-life of 5.25 years. Caesium-137 (^{137}Cs), with a half-life of 30 years may also be used, but is much less popular. Each ^{60}Co atom on disintegration emits radiation at two energy levels of 1.33 and 1.17MeV.

In a typical industrial gamma radiator, the Cobalt-60 isotope is encapsulated and packed in stainless steel rods ranging between half a metre to one metre in length, and 1 to 2cm in diameter. Each rod may contain isotopes whose activity is up to 20kci (740 x 10^{12}Bq). Hundreds of these rods are arranged in a rectangular plane or source rack. A typical installation may contain lMCi to 2MCi of activity. A model of a Cobalt-60 irradiation plant is shown in figure 4. For safety reasons, the irradiation source is housed within a reinforced concrete building with walls some 2m thick, usually stored in a sunken water pool, 5-8m below and raised into the irradiation chamber only when required. Safety control devices operate to ensure that the source is raised only when the chamber is locked and that it is immediately lowered if not in use or there is a malfunction in a component or device. Radiation monitors are continually used to detect radiation leakage during operation or source storage, and to confirm return to normal background levels in the irradiation chamber after operation.

Packages of materials to be sterilized are passed through the irradiation chamber on a conveyor belt (as in figure 4), or on monorail system (as in the schematic diagram shown in figure 5). They are moved around the raised source, a few times to ensure that all the packages are irradiated to the same extent and from both sides. The total dose received by a product is an accumulation of doses received (dose rate x time) at each point of dwell along the irradiation field. Figure 6 illustrates a step in obtaining uniformity of depth dose distribution by using two-sides radiation. When the products are automatically removed from the irradiation chamber to the unloading and storage area.

Selection of Sterilization Dose

The selection of the radiation doses required for the sterilization of various pharmaceutical and medical materials depend on a number of factors including: the nature, variety and abundance of the contaminating microbial species and their radiation resistance level under the sterilizing environment. Among these factors, knowledge of the most resistant species present and its population are two most important factors. Many times the exact nature and variety of all the contaminants are not known. So it is impossible to determine their D-values and the inactivation factor (IF) required to determine appropriate sterilizing dose.

A radiation dose of 25kGy has generally been accepted as suitable for sterilization. The choice is based on the radiation response of the bacterial spores of radiation resistant *Bacillus pumilus*, the biological indicator for radiation sterilization. Its D-value is 3 kGy. It is considered that an IF of 10^7 should provide a satisfactory sterility assurance level (SAL) for the worst contamination experience of most of the materials prepared for sterilization by radiation. Hence, the justification for the choice of 25kGy as a standard sterilization dose.

The United States Pharmacopoeia (USPXXII) while approving the historically selected 25 kGy dose, encourages use of lower doses for devices, drug substances, and finished pharmaceutical dosage forms, and higher doses when justified. Use of lower doses should be validated by prior determination of the magnitude of the natural radiation resistance of the microbial population of the product. The U.S.P. further suggests estimation of the desired sterilization dose by use of one of the four methods laid down in the Guidelines for Radiation sterilization by the Association for Advancement of Medical Instrumentation (AAMI, 1983). These methods are attempts to obtain some knowledge of the microbial load of the product to be sterilized, through which a dose can be set based on the desired sterility level.

The Parenteral Drug Association (PDA) another USA body in 1989 has suggested two close setting procedures, one of which is based on the use of biological indicator overkill method. This advocates a sterilization dose of at least double the radiation dose needed to achieve 10^6 inactivation of *B. pumilus*. In practice the sterilization dose arrived at is similar to the classical 25kGy.

The British Pharmacopoeia (B.P 1993) recommends a minimum absorbed dose of 25kGy, but allows use of other doses provided they are validated. For lower doses, additional micro biological monitoring of the product is required before irradiation.

The International Atomic Energy Agency (IAEA) which earlier on (1986) approved 25kGy dose "when no information on the pre-irradiation microbial load is available provided the product is manufactured under CGMP conditions, has recently (1990) suggested a "rational selection of a sterilizing dose based on knowledge of resistance of the natural microbial population present on the product to be sterilized and on a reasoned selection of a maximal SAL. Thus, it can be deduced from all the above that although a radiation dose of 25kGy is generally accepted, the preference seems to favour the use of a maximal sterility assurance level dose based on a knowledge of the resistance of the natural microbial population of the materials to be sterilized.

Good Irradiation Practice

Radiation sterilization as a process must comply with appropriate code of Good Manufacturing Practice (GMP). Codes of practice have been adopted by the I.A.E.A. and some national pharmaceutical/medical bodies, which (codes) are essentially similar. The codes regulate radiation processing with some emphasis on irradiation commissioning, process validation. routine process control and facility organisation.

Applications

Radiation sterilization is generally applied to pharmaceutical and medical articles which are dry and thermolabile, including: drug powders for injection, such as the semi-synthetic penicillins and cephalosporins, tetracycline and streptomycin; ophthalmic and topical ointments; medical and laboratory appliances, such as surgical instruments, endotracheal tubes, prostheses, hypodermic syringes with needles; surgical dressings, petri dishes, rubber gloves and disposable plastic materials; packaging materials, such as plastic films, laminates and aluminimum foils (Table 1).

In recent times the process has been extended to sterilization of thermolabile parenterals (both aqueous and oily), eye drops e.g. of Atropine sulphate; ophthalmic and topical creams, implants; multi-component parenteral units such as one in which a drug powder and solvent are compartmentalised until the time of administration.

Radiation sterilisation, especially of powders for injection and eye ointments in their final containers have proved very valuable, and provided a great relief from the burden of separate sterilisation of such powders before aseptic preparation and packaging into final containers, which had been the case till recently. Another great value is the possibility of handling large volumes of pharmaceuticals in a continuous process.

The standard sterilization dose for all these materials is 25kGy, unless there is sufficient justification based on the initial microbial load of the material for a lower or higher dose. Irradiation processing is also usefully applied to many naturally sourced raw material powders in pharmaceutical and cosmetic industries. Such materials are usually heavily contaminated with microbes. They can be decontaminated with lower irradiation doses ranging from lkGy to 10kGy. Examples include tragacanth, kaolin, and talc powders. Some food items, especially vegetables, fruits and pork have been similarly treated (Jacobs, 1991).

An important area of weakness is the degradation of some materials when irradiated. Prominent in this group are aqueous solutions. Their irradiation results in radiolysis products such as H_2O_2 and H_2 in addition to water which may be present in such products resulting in damages. Radiolysis effects can, however, be minimized by choice of appropriate treatment conditions, such as irradiation in anoxia, at low temperatures, or/and incorporation of suitable non-toxic, drug compatible and medically inert additives. This may be done by use of -SH containing molecules, scavengers of radiolysis products of water, or reagents that convert radiolysis products to the parent compounds.

Another area of products concern was on the beta-lactam antibiotics, their tendency to hydrolyse, especially at elevated temperatures, and necessary cores of aseptic processing to prepare them as sterile products. Some teams of researchers tackled the problem radiosterilizing these antibiotics at 25kGy and 50kGy in their final packs, and thereafter subjected the post-irradiation sterilization products to several analyses, comparing them with un-irradiated controls. Their results are illustrated in table 2. The products compared favourably well with un-irradiated controls.

This led them to radiosterilize a number of other betalactam antibiotics. The results are shown in Table 3.

Such a determined and thorough investigational approach on specific groups of compounds may provide open doors to areas of application hitherto unknown.

Advantages of Radiosterilization

The advantages of radiosterilisation are many, the major ones are as listed below (Table 4).

1. It is very effective
2. Treatment time may be short.
3. It is a continuous process suitable for long runs and large quantity of packaged materials at a time.
4. It is a cold process and therefore suitable for thermolabile materials.
5. Materials may be irradiated in dry or frozen state and in the presence or absence of oxygen.
6. Products are sterilized in final containers after packaging and so are unlikely to be contaminated until used.
7. The process may be controlled and monitored accurately.

Concluding Remarks

Radiation sterilization is an advanced technology which has progressively gained prominence and public acceptance in recent times. Through it a very wide variety of pharmaceutical and medical materials can now be effectively sterilized. In nations where it is well operated it is already making life easy especially for the manufacturers of pharmaceutical products which previously had to be separately sterilized before final preparation by aseptic processing.

Purchase and installation of a radiation sterilizer such as a cobalt-60 plant by the Nigeria government is a worthwhile investment if properly commissioned and run in accordance with the international code of practice it should prove a valuable service and high revenue yielding venture especially if indigenous pharmaceutical industries are given conducive incentives for manufacturing various pharmaceutical dosage forms.

Acknowledgement

The author is grateful to the organizers of this symposium for the privilege of presenting this paper; to Dr. W. B. Jimba, CERT. Ahmadu Bello University Zaria for his technical advice, Mr. I. Ameh, Faculty of Pharm. Sci., A.B.U. Zaria for typing the manuscript, and to Mr. A.R. Fagbemi of the Dept. of Physics A.B.U, Zaria for his assistance with the graphics.

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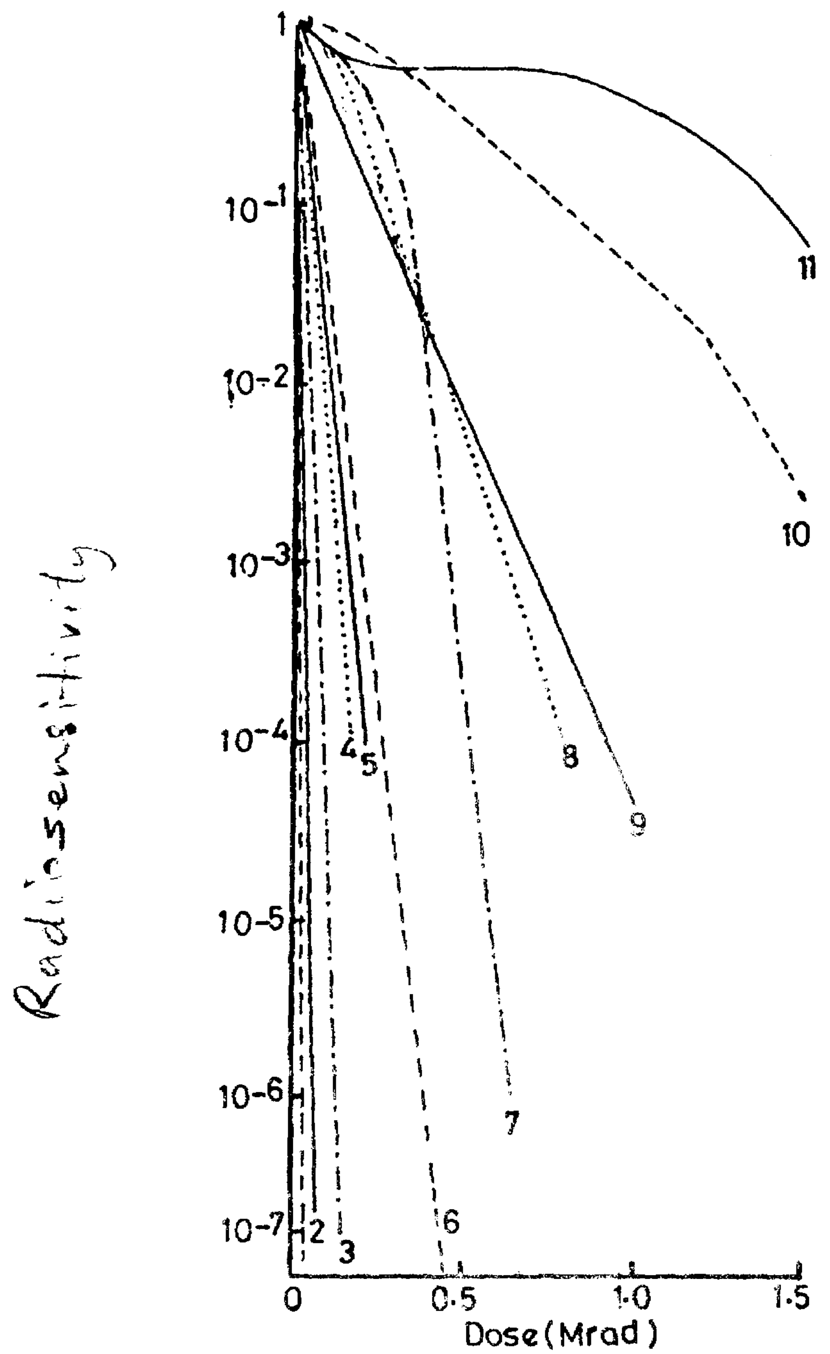

Fig·1 : The radiosensitivities of some food spoilage micro-organisms.(1)Pseudomonas spp; (2)Escherihia coli;(3)Salmonella typhimurium in buffer;(4)Torulopsis famata;(5) Bacillus brevis; (6)Salmonella typhimurium in liquid egg; (7)Streptococcus faecium strain R53;(8)Bacillus megaterium spores;(9)Clostridium welchii spores; (10)Clostridium botulinium type A spores;(11)Micrococcus radiodurans [From Rawlins E A(1977)]

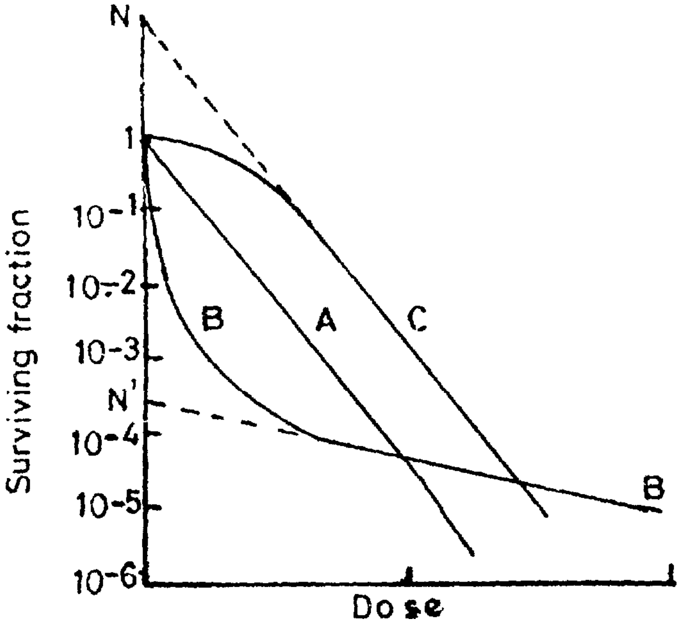

Fig.2: Types of log survivor-dose curves. Type A, exponential (single hit). Type B, curve showing (1 or more strands) tailing. Type C multitarget (sigmoidal) curve.
[From Rawlins E A (1977)]

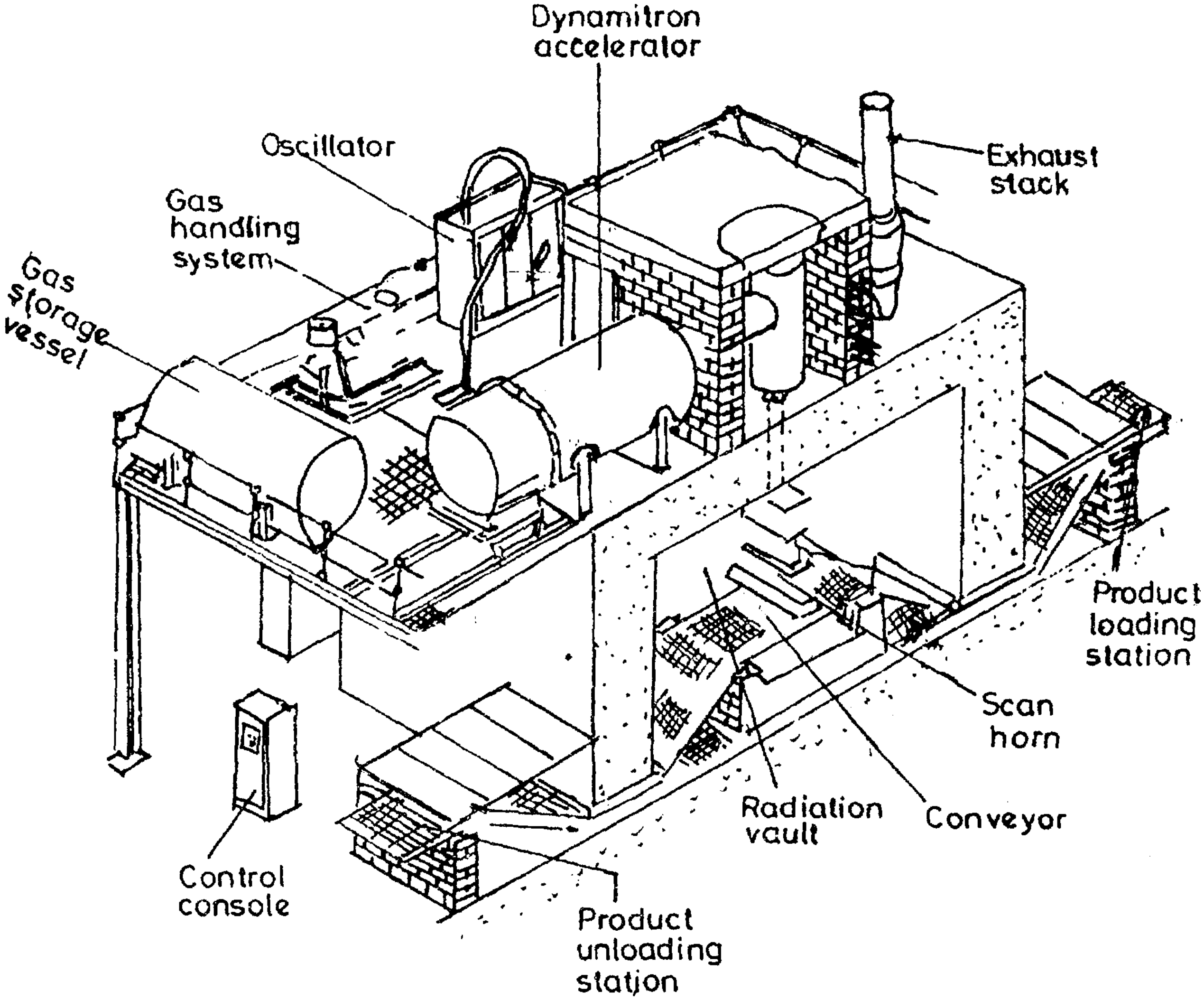

Fig3i: Typical layout of a Dynamitron electron beam processing facility
(From Morganstern, 1978)

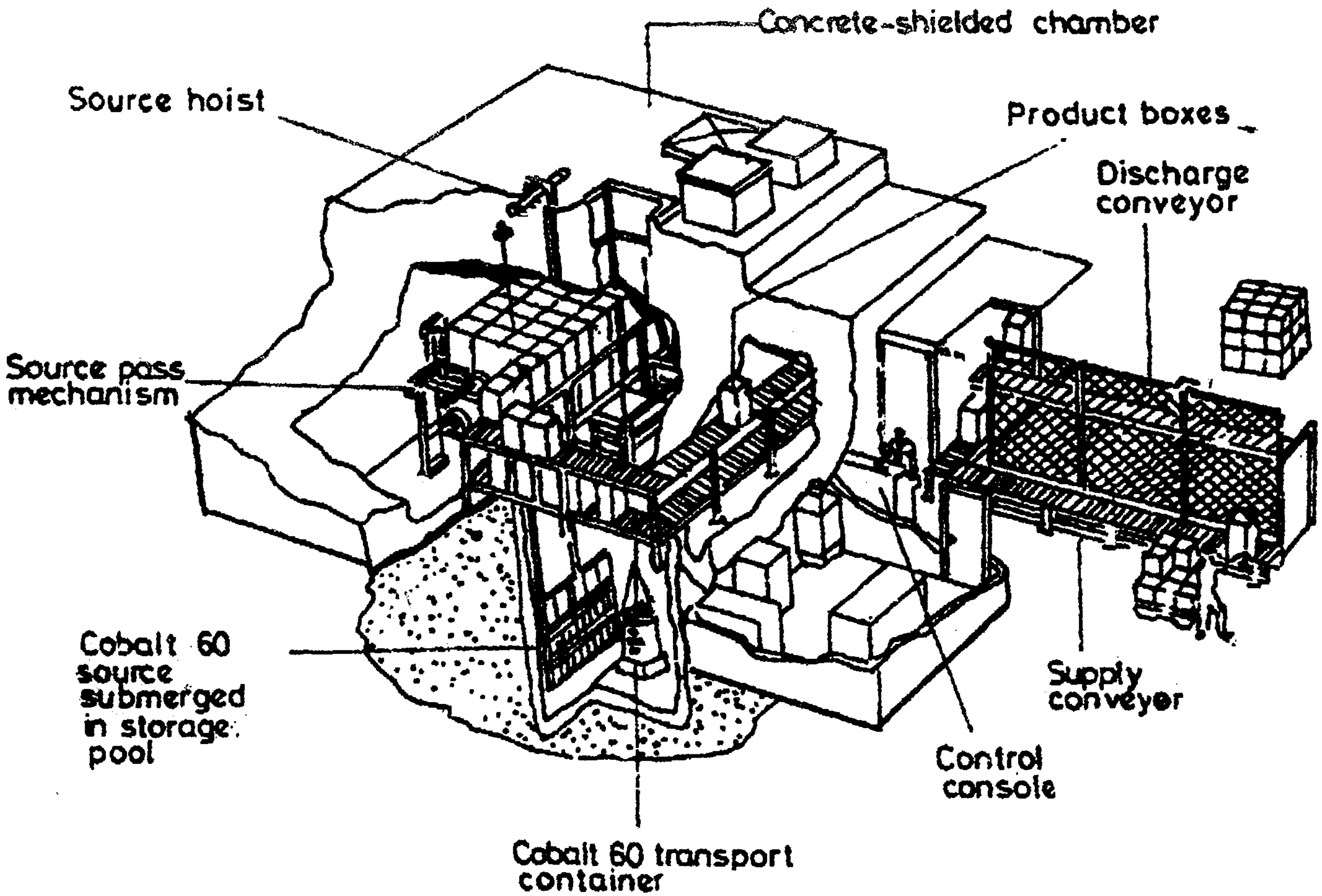

Fig 4: Diagram of a typical cobalt-60 irradiation plant
(From Hugo and Ruesel, 1991)

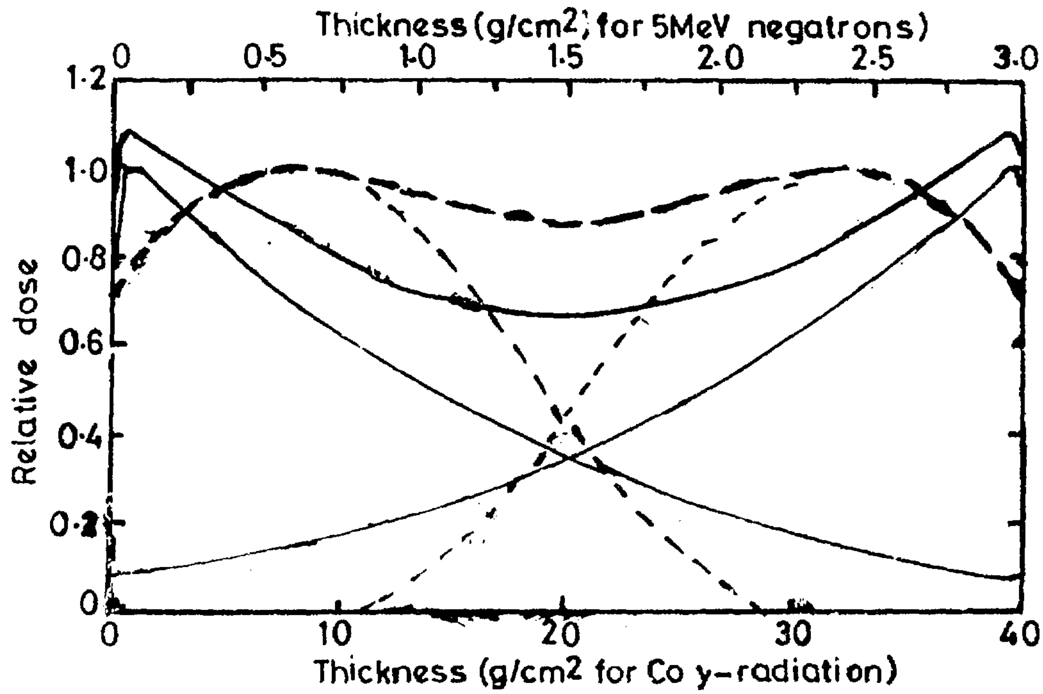

Fig.5: The variation of dose with adsober thickness for y-radiation and negatrons. Solid lines, ^{60}Co y-rays, mean energy 1·25 MeV; broken lines 5MeV negatrons; thin lines, single sided irradiations; heavy lines, double sided irradiations. [From Rawlins, EA (1977)]

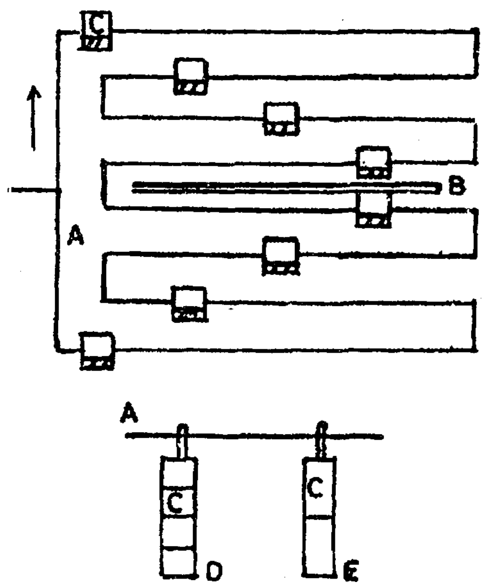

Fig. 6: Monorail system for sterilisation by gamma radiation

A – monorail
B – source plaque
C – package (shown at only a few positions on the rail) — one side is shaded to illustrate exposure of opposite faces on the two sides of the source
D & E – tiers of 4 and 2 packages respectively

Table 1: Some pharmaceutical applications of radiation sterilisation

Application	Materials	Usual Radiation dose
Microbial decontamination	Raw materials active and adjuncts e.g	
	e.g. Tragacanth	5kGy
	Fresh fruits and vegetables*	1kGy
	Food*	10 - 30kGy
Sterilisation	Injectables, implants, multicomponent parenterals	25kGy
	Drug powders for injection e.g. semi-synthetic beta-lactams and tetracycline.	25kGy
	Eye ointments and drops e.g tetracycline eye drops	25kGy
	Topical ointments and creams e.g starch glove lubr. creams	
	Medical/lab. appliances: surgical instruments, dressings, hypodermic syringes with needles, rubber gloves, lubr. petri dishes, transfusion assemblier.	25kGy
	Packing materials e.g plastic films, aluminium foils, laminates.	25kGy

Table 2: Analytical Data for Gamma Irradiated Cephalosporins in Powders
(Details of the methodologies are to be found in the original papers)

Drug (ref)	Dose (kGy)	UV* absorbance E% 1cm	Chemical assay (±sd)(%)	Specific optical rotation* (°)	TLC Rf values	Microbial assay (±sd)(%)	HPLC* assay (%)
Cefazolin	0	244	100**	-16	0.70	100**	
sodium	25	244	98.4(0.4)	-15	0.70	91.7(6.2)	
(3)	50	244	98.7(0.6)	-14	0.70	94.5(2.8)	99.5
Cefadroxil	0	220	100	+155	0.62	100	
monohyd	25	218	101.3(0.1)	+1.55	0.62	101.3(1.4)	
(3)	50	216	99.0(0.1)	+1.55	0.62	97.1(1.5)	n/a
Cefoxitin	0	275	100	+195	0.72	100	
sodium	25	275	101.7(1.2)	+188	0.72	97.4(3.6)	
(2,4)	50	275	100.0(0.1)	+187	0.72	100.0(0.4)	97.9
Cefroxadine	0	182	100		0.62	100	
dihyd	25	182	100.2(1.4)		0.62	101.3(3.4)	
(3)	50	184	100.4(1.1)		0.62	96.7(0.7)	n/a
Cephalothin	0	327	100	+114		100	
sodium	25	315	100.0(0)	+111		90.6(3.0)	
(1,4)	50	318	97.8(2.2)	+119		89.8(1.6)	94.9
Cephradine	0	198	100	+16	0.53	100	
monohyd	25	178	87.7(6.1)	+16	0.53	89.0(2.9)	
(3)	50	178	71.0(1.0)	+15	0.53,0.48	67.0(0.1)	n/a

*Means of not < 2 determination within 15%
** Unirradiated sample used as standard and taken as 100%/n/a data not available
( ) References to original data:
(1) Jacobs 1980: (2) Jacobs 1981; (3) Jacobs 1983; (4) Jacobs Dobrilovic Coombes and Raghavan 1986
[From Jacobs (1986)]

Table 3: Beta - lactam antibiotics displaying varying levels of degradation following 25kGy gamma-radiation sterilisation

A. Antibiotics displaying greater than 5% degradation

Azlocillin sodium	
Carbenicillin sodium	cephapirin sodium
Carindacillin sodium	cephradine monohydiate
Epicillin	
Mezlocillin sodium	

B. Antibiotics displaying less than 5% degradation

Amoxycillin	cefadroxil monohydrate
Ampicillin sodium	ceforanide
Flucloxacillin	cefotaxim
Mecillinam	cefoxitin sodium
Methicillin sodium	cephalexin
Nafcillin sodium	cephaloridine monohyd
Oxacillin sodium	cephalothin sodium
Phenethicillin potassium	
Piperacillin	
Ticarcillin disodium	

Table 4: Advantage of Radiosterilization

1. Very effective.
2. Treatment time may be short.
3. Continuous process; suitable for long runs and large quantity.
4. A cold process suitable for thermolabile materials.
5. Materials may be sterilised in dry or frozen state and in the presence or absence of oxygen.
6. Products sterilised in final containers after packaging unlikely to be contaminated until used.

RADIATION PROTECTION REQUIREMENTS AT A COMMERCIAL IRRADIATION PLANT

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Abstract
A gamma irradiation plant contains a large amount of radioactivity (10^{12}-10^{18}Bq) which will deliver a lethal dose to man within seconds of accidental exposure or cause large scale contamination of the environment in case of damage to the source. There is therefore the need to achieve a high degree of safety and reliability of the facility. Though the safety record of the industry has been very good, the probability of an accident is always finite. The safety level can be enhanced and possibility of accident reduced to its bearest minimum by good quality control together with careful design, manufacture, installation, operation and eventual decommissioning. The criteria for safety in all these aspects are discussed, paying particular attention to the wet storage irradiator type, a pioneering facility in Nigeria.

Introduction

Radioactive nuclides are unstable nuclides which seek stability by transforming into other nuclides. The process of transformation, called radioactive decay, usually involves the emission of either alpha (α particles or beta β) particles of either sign. In most cases, the transformation leaves the daughter nucleus in some excited state. It goes to the ground state by the emission of another type of radiation, gamma (γ) rays, which have similar properties as x-rays but with much more energy and penetrating power than x-rays. After successive collisions in matter, alpha particles, which are a stream of He ions, lose their energy (4-9MeV) and become absorbed within 10cm (in air) or a few μm in a solid matter. Beta particles, a stream of electrons, will lose their energy (0.01-5MeV) and become absorbed within a few metres in air or a few mm in solids. Gamma rays and x-rays (photons) are far more penetrating. They lose their energy (0.01-2MeV) progressively and become reduced in intensity, obeying the attenuation equation $I=I_0e^{-ux}$ when they traverse a distance x in a material of attenuation coefficient μ.

When any type of radiation interacts with matter, it transfers part or all of its energy to the medium. If the energy transfer is in a biological medium, the structured molecules which are essential to life may be damaged or killed, depending on the dose. It is therefore possible and it is increasingly being practiced, to kill living cells or organisms (bacteria) with a gamma irradiator. A gamma irradiator is a facility in which matter may be deliberately and safely irradiated, or exposed, to large dose of gamma radiation. The process has been successfully applied in
sterilization to:

(i) reduce spoilage of a great variety of food stuff (20-70kGy).
(ii) prepare medical products ready for single use (1 5-20kGy).
(iii) render male pest insects infertile before releasing as a means of population control (10-100Gy) etc.

The dose ranges in the above and other applications are delivered using radiation sources that produce very high dose rate (as much as 25kGy/hr). Radio-nuclides with high gamma factors, particularly Co60 (up to 500TBq) and Cs-137 (up to 750TBq) are utilized. These sources will deliver lethal dose to man (<lOGy) in seconds of accidental exposure or cause extensive contamination in case of accidental release. There is therefore the need to maintain absolute safety culture in an irradiator facility. The intention of this presentation. is to highlight some of the basic safety requirements.

Containment and Storage:

The radioactive material is usually encapsulated in special form sealed sources and one or more of such capsules are given secondary containment within metallic tubes called source pencils. Each pencil has a serial number and it is provided with a unique identification. A number of pencils are mounted within a flat or cylindrical module and arranged to provide uniform irradiation of the product. The modules are assembled onto a source rack ensuring that the pencils cannot be removed.

A commercial irradiator is usually category IV type in which the irradiation room contains a deep water filled pool into which the radiation source (an insoluble material) is lowered by remote control when it is not in use. The water acts as a shield and interacts with gamma emissions producing a visible, harmless, bright blue underwater glow (cerenkov radiation) in the vicinity of the source. The water is recirculated through treatment plant where it is deionized, filtered and chilled to minimize potential corrosion of the pool liner, source pencils and source rack and to keep the pool clean. The source is exposed within the radiation volume that is maintained inaccessible during use by an entry control system.

Safety Functions

The design, installation and operation of an irradiation facility are based on the ALARA principle taking into account any additional dose constraints that may have been specified for the purpose by the national competent authority. From records, it is possible to design and operate irradiation facilities with sources delivering as much as 25kGy/hr, and have the exposure of workers significantly less than 5mSv per year. This is a feat which is achieved by following three levels of defence in terms of equipment and procedures. They are aimed at preventing accidents or mitigating the consequences in the event that prevention fails. These levels of defence are:

i. The aim of the first level is to prevent deviation from normal operation. This requires that the facility be soundly and cautiously designed, constructed and operated and that an appropriate quality assurance program be established and maintained at all stages.

ii The aim of the second level of defence is to detect and respond to deviations from normal operating conditions to prevent anticipated operational consequences from escalating into accident conditions. This is in recognition of the fact that radiation incidents can occur during the service life of an irradiation facility, despite the care taken to prevent them at the first level.

iii. The aim of the third level is to mitigate the consequences of an accident particularly through the achievement of stable and acceptable conditions. This level also requires the provision of additional equipment and procedures.

The above levels of defence are adequately planned for in a well designed, well installed and well operated irradiation plant through the provision and proper functioning of such devices as

i. Personnel access door interlocks
ii Product entry/exist port interlocks
iii Fixed radiation monitor with alarms
iv Source status and exposure system interlocks
v Water Treatment System Monitor
vi Control console
vii Radiation room safety-delay timer
viii Automatic water-level control
ix Fire protection devices
x Power failure management arrangements
xi Ventilation/Ozone level monitor
xii Warning Signs and Symbols, etc.

The above safety devices and many others must as a rule be in place and functioning before commissioning. After commissioning and during the service life of the irradiator, a good radiation safety program must be designed and implemented to incorporate the safety features into each and every day operation. The strategy is to fortify in order to remain always, at the first level of defence. This is the safest and the cheapest option.

Radiation Safety Program for Irradiators

The International Atomic Energy Agency (IAEA) through a number of publications (Safety Series No. 9, Manual on Panoramic Gamma Irradiators, Training Course Series No.2 etc.) has given very useful guidelines on how to maintain a safe radiation protection regime in a gamma irradiator.

To start with, the operating organization responsible for possession and use of the irradiator (i.e SHESTCO in this instance) shall obtain from the competent authority (the appointment of which is in the offing in

Nigeria) any approvals, permits, or authorization necessary for the acquisition, storage, and use of the irradiator. The authorization is upon the satisfaction of the competent authority that the operating organization has adequate infrastructure (man power, equipment, discipline etc.) for all of these purposes. The operating organization shall be responsible for the operation of the irradiator in accordance with the conditions attached to such approvals, permits, or authorizations.

The operating organization should appoint, at least two radiation protection officers whose duties should include ensuring that the written administrative procedures are implemented. The radiation protection officers play a supervisory role in assisting the organization to comply with the requirements of the approval or regulations. They should be directly involved with the work with ionizing radiations, preferably in a line management position that will allow them to exercise close supervision to ensure that the work is done in accordance with the written administrative procedures. At least one of the officers has to be available at all times. No person should be appointed as a radiation protection officer unless he/she:

(a) knows and understands the requirements of the approval and the written administrative procedures (or code of practice) as they affect the work they supervise.

(b) commands sufficient respect from the people doing the work as will allow them to exercise the necessary supervision of radiation protection; and

(c) understands the necessary precautions to be taken in the work that is being done and the extent to which these precautions will restrict exposures.

Because qualified operators usually have the closest association with particular irradiators, day to day responsibility for safe operation is generally theirs. Operators' training, experience, attitude, and competence will establish the degree of safety associated with operation of the irradiator.

Each operator should hold an appropriate certificate of competence and approved training which is recognized by the competent authority, and should be familiar with the basic design, operation, and preventive maintenance of the irradiator; the principles and practices of radiation protection; biological effects of radiation; the written procedures for routine and emergency irradiator operation; and the requirements of the competent authority.

Each operator shall know the exposure rate at all areas around the irradiator. Operators shall be familiar with area security safeguards such as locks, posting of signs, warning lights, audible and visible signals, and interlock systems.

Each operator shall be familiar with the radiation detection instrumentation which is used and the requirements for personnel dose monitoring as specified by the competent authority.

Each operator shall demonstrate competence to use the source of radiation and its related components, and to maintain the required operation logs and records. Operators shall be familiar with the overall organizational structure pertaining to management of the irradiator, including specific delegations of authority and responsibility for operation of the irradiator.

Training of Personnel

The operating organization shall ensure that those of its employees who are engaged in work with ionizing radiation receive such information, instruction and training as will enable them to conduct that work in accordance with the requirements of the written local rules.

Examples of the topics in which they should be trained include:

a) The nature of ionizing radiation;

b) The health hazard from such radiation;

c) The basic principles and methods of protection (shielding etc.);

d) A basic understanding of how to measure radiation fields and the units of measurement;

e) A clear understanding of the plant safety systems and the warning signs and signals and any actions to be taken;

f) A clear understanding of how to operate the plant safely.

g) A clear understanding of the actions to be taken in emergencies.

Training must be reinforced regularly and updated when necessary. An annual review of staff training should be undertaken. Arrangements should be made to ensure that all new staff receive the required training and that the training needs of staff affected by any internal reorganization are reviewed.

It is the role of the radiation protection adviser to provide advice on staff training needs and how best those needs may be satisfied. Qualified and experienced personnel of say, the Federal Radiation Protection Service, FRPS, Ibadan can be consulted from time to time for this purpose. In many cases he (the adviser) should be able to provide much of the training that is required. The training discussed above is in addition to that required to operate the facility safely which will in general be provided by the manufacturer or supplier. It is believed that an appreciable number of SHESTCO personnel have undergone this kind of training.

Personnel Dosimetry:

All workers entering controlled areas shall carry appropriate personal dosimeters. In addition, at least one audible personal alarm shall be carried by person(s) entering controlled areas. The monitoring of workers including the type of dosemeter and the frequency of replacement should be chosen in consultation with the radiation protection adviser. FRPS, Ibadan is adequately equipped in terms of personnel and material, to provide TL dosimetry services.

The results of personal monitoring measurements shall be recorded and reported as required by the competent authority. When visitors are permitted to enter the irradiator, they shall be escorted by a qualified operator who shall have surveyed the area immediately prior to the visit and the visitors should have electronic dosimeters to record possible exposure during the visit.

Quality Control:

The operating organization shall ensure that all components and devices are regularly tested by setting up a formal program of maintenance and testing to ensure the continued safe operation of the facility.

Particular attention must be given to **regular testing of safety interlock components** for correct operation, according to the instructions of the equipment manufacturers. These tests shall be carried out by appropriately qualified persons and should be undertaken in the presence of a radiation protection officer.

Portable radiation **meters shall be calibrated** before they are first used, after repair and at intervals specified by the competent authority. The pre-use test should include a test of the instruments overload performance i.e, it should operate correctly up to the maximum credible doserate it may encounter. By the courtesy of IAEA, FRPS has just acquired a secondary standard calibration laboratory. The services of this national Centre will certainly be of immense advantage to SHESTCO when its operations start.

Periodic **examination of the hoist cable and guide** cable shall be done and they shall be replaced as required by existing national regulations or at intervals recommended by the manufacturers.

Periodic **leak test of the radiation sources** in a manner and at a frequency determined in discussion with the source supplier and plant manufacturer and in accordance with national requirements.

The following tests should be carried out weekly:

Check that the continuous radiation monitoring device on the pool water circulating system is functioning correctly.

Analysis of **samples of pool water** taken from the circulating system by a well regulated national laboratory (a less frequent analysis may be appropriate if experience allows this).

Check the **water filter** for correct operation and contamination.

Check the **emergency stop button** on the control console, emergency stop device inside the radiation room, door interlock, water level control, low pool water interlock, and water treatment system for correct functioning.

Attempts should also be made to operate the irradiator after **deliberately violating the approved start-up procedure** to ensure that the interlocks and sequential controls are functioning correctly.

The following additional but separate tests should be carried out monthly:

Test that the radiation room monitor is functioning properly by exposing the monitor probe to check source until the alarm sounds.

Check, in accordance with the manufacturers instructions, the **safety control systems** that prevent access to the radiation room when there is any radiation present.

With the irradiator operating, test that the **product exit monitor** is functioning properly by exposing the monitor probe to a check source until the alarm sounds. The product exit conveyor shall stop and the source shall automatically become fully shielded.

Test the **source exposure mechanism,** the ventilation system, and similar hardware which contribute to the safe operation of the irradiator and its related product positioning mechanism.

Check that other main items of equipment associated with the source movement and control function properly and show no signs of potential failure.

Check that all product containers are in good and undamaged condition.

NOTICE: **If any of the checks indicates fault or interlocks do not function properly, the irradiator must not be used until repairs are accomplished.**

On a semi-annual schedule (or at other approved intervals) inspection of the source movement and suspension system should be carried out.

Record Keeping:

A log book or file shall be kept in which all tests, maintenance tasks, modifications, or changes to the irradiator shall be recorded. All uses of the irradiator shall also be recorded in a log book or file. The results of all the above tests must be recorded on a formal check list signed by the radiation protection officer who has witnessed the tests.

Since failure of the safety systems could cause radiation exposure to personnel, the **compliance inspectors** from the competent authority will pay particular attention to these records. The records should be kept for such periods of time as are prescribed by the competent authority. The operating organization shall notify the competent authority and supplier and obtain approval from the competent authority prior to any modifications which may cause a radiation hazard. Some examples are:

a. Modifying operating procedures.
b. Modifying the safety control system.
c. Major modifications of the irradiator.
d. Source loading: replenishment, removal or redistribution.
e. Changes in supervisory personnel or advisors.

Emergency Response Planning:

Accidents have occurred in irradiation facilities (China-1962, Italy-1975, Norway-1982, El Savador-1988, etc). Fatalities (>12), and injuries (hundreds) of workers and the public **have been reported**. When an accident occurs, depending on its characteristics, workers and members of the **public** may be exposed to radiation and other health hazards.

Adequate written emergency procedures shall be prepared and this can only be done after a formal assessment of hazards has been carried out (Gale, 1987). The final responsibility for preparing the procedures lies with the operating organization. The operating organization is also responsible for liaison with emergency authorities and other bodies who are quoted in the procedures. The purpose of this liaisons is to ensure that all parties understand the hazard and are aware of the requirements of the emergency procedures.

In the event of an accident it is the duty of the operating organization to initiate the emergency procedures and co-ordinate the initial response of the emergency services and other bodies and to inform the competent authority and the radiation protection advisers. Experience has shown that the most likely events leading to significant radiation exposure and/or contamination are:

(a) A jammed source with the source assembly failing-to-return to its shielded position.

(b) Part of the source assembly detached and left in an unshielded position.

(c) Malfunction or deliberate defeat of the safety control system

(d) Leakage of the source.

(e) Fire inside the shielded room.

The most significant accidents can occur when a worker enters or remains in the irradiation room when the irradiation process is going on (El Savador, 1988). Very severe injury or death must be expected as a consequence of such an accident.

In the case of gamma facilities, the possibility of accident situations due to contamination must also be considered. In those cases, although the over exposure may be less severe it may involve many more people, mainly workers, but also members of the general public.

Following an accident it is necessary to:

(a) Limit radiation exposure, both individual and collective.

(b) Regain control of the situation in order to restore the site to its normal conditions.

(c) Treat the injured and over exposed. Many doctors in Nigeria have benefited from the FRPS annual workshop on management of radiation over exposed persons.

Emergency procedures should be written for each type of emergency that may reasonably be foreseen. These should be concise, easily followed instructions. They should describe what will be indicative of a situation requiring emergency action, specify the immediate action to be taken to minimize radiation exposure to persons in the vicinity of the irradiator, and allow for the development of the written contingency plan for effecting entry to the irradiation room.

They should also include names and telephone numbers of the person(s) to be notified to direct remedial action. For example, police, fire brigade, company doctor, hospital, radiation protection advisers, competent authorities and manufacturer. The procedures should also include the names and location of an employee who is responsible for communication with the media and the public. The list of these names and telephone numbers should be displayed in a prominent location adjacent to the irradiation facility (Barry, 1987).

Any incident shall be reported to the competent authority according to a time schedule to be fixed in the approval depending on the severity of the incident. Incident reports should be evaluated by the competent authority so that any lessons can be learnt and if necessary, improvements made to safety at all existing facilities. Special attention should be given to precursor events that have the potential to lead to more severe incidents.

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SOME SAFETY ASPECTS OF IRRADIATION TECHNOLOGY

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Abstract

Several safety aspects are to be considered at the planning, construction and operation of each equipment or plant. Main topics are: safety of staff, safety of environment and safety of goods (produced or treated in the plant).

The risk arising from the ionizing radiation is to be taken into account too in the case of an irradiation facility with radioactive sources. At the SHESTCO gamma irradiation facility, safety will be achieved primarily by technical means which are in effect independent of people. All systems will remain in or go into the safe position in the case of a technical fault. In the paper some of the most important safety functions and measures will be explained such as shielding to protect the staff from radiation; barrier system to prevent persons from entering the irradiation room when the source barrier rack is in the irradiation position; barrier system to protect goods and environment from radioactive contamination; control system for the source rack (lifting and lowering);barrier system against theft of radioactive material.

The safety systems ensure that an unintentional exposure of persons to ionizing radiation is not possible. In addition a basic training of the staff in the field of radiation protection is absolutely necessary and should be repeated regularly.

Introduction

Each technical process and each machine have a residual risk for persons and for the environment. If it is low enough it can and must be accepted. Otherwise no production, no traffic, etc would be possible. To make the technical risk as low as possible is an important task in the planning stage.

Safety can be achieved by different means:

i. technical means which are in effect independent of the staff
ii. technical means which are to be used by the staff.
iii. regulations, restrictions which are to be followed by the staff.

The effectiveness of these means decreases in the same order.

Safety demands for the industrial application of radioactive materials are higher than in other fields of technology. The reasons are probably

i. ionizing radiation is invisible and man does not have a sense organ for it, one cannot smell, see or feel it directly.
ii. safety aspects are of particular public interest in this field.

This results in specific regulations and instructions which are to be followed during planning, construction, commissioning and operation of a plant.

Safety considerations for a gamma irradiation facility have to include the following points:

i. safety of staff (protection against irradiation)
ii. safety of environment (protection against radioactive contamination)
iii. safety of goods, treated in the plant (protection against radioactive contamination and overdose).

In the following chapters the safety measures will be explained which will be implemented at the SHESTCO gamma irradiation facility.

Protection of the staff against radiation

Shielding

The concrete walls of the irradiation room have to provide a sufficient attenuation of the g-radiation from the Co-60 source. It must be ensured that work can be carried out in the hall without danger even if the source is in the irradiation position. The following maximum doses (according to German regulations) have to be considered.

person	**dose per year (mSv)**	**doserate for 2000 working hours per year [µSv/h]**
occupationally exposed to ionizing radiation (under medical and dosimetric supervision)	50	25
working in the plant (not under supervision)	5	2,5

In addition, the basic radiation protection rule must be taken into consideration. Independent on dose limits, the dose should be as low as reasonably achievable (ALARA Principle) e.g. economical means possible.

Therefore, the concrete walls of the irradiation room will have a thickness of 1.80m. Computations show that an average doserate of 0.5µSv/h can be expected at the outer wall surfaces for concrete with a density of 2.3g/cm^3 and for the case that no goods are in the irradiation room. The doserate will be lower at other points in the hall. The annual doses of the staff under these conditions will be far below the limit set by regulation.

The irradiation room will have a maze for the conveyor system. The maze can be left by radiation only after at least 3 scattering processes. Each scattering process reduces intensity and energy of the radiation. The computations show that the dose rate will not be higher at the inlet and outlet of the maze than at the outside walls of the irradiation room.

A water pool will be built in the irradiation room. If no radiation is required, the source rack will be stored in the water pool. This is the safe position of the source. At this position, the irradiation room can be entered by staff. There are several safety conditions which release the movement of the source into the water pool (see next chapters). Manipulations at the sources are possible in this position (e.g. loading and unloading of sources, changing the source pattern in the source rack, etc). Manipulators will be used for this works. The depth of the water pool is 8m. Because the source rack is about 3m high, the water layer above the upper source rods is about 5m. During manipulation works, the source frames must be lifted into and out of the source rack. In this case the thickness of the water layer above the highest sources will be reduced to 4m. The attenuation factor of 4m water for the γ-radiation of the Co-60 sources is 10^{-9}. Even if a source frame with an activity of 100 kCi (3.7 PBq) is lifted up to 4m below the water surface, the doserate will not be higher than 0.1µSv/h in the irradiation room above the water pool. Of course the staff must pay attention that the sources are not lifted up too high. They have to complete a training with source dummies and have to wear dosimeters during work.

Measures to prevent persons from unintentional entering of the irradiation room

Only skilled staff will work in the hall under normal conditions. They know the danger which arises from the radioactive source. It can be assumed that they will not try to enter the irradiation room while the source is in the up position. Nevertheless, an extended locking system is foreseen as additional safety system.

There are 3 different ways to enter the irradiation room. The first one is the way through the shielding door. This is the normal way into the irradiation room for service works. The following safety measures will be taken against unintentional entering through this door:

i. A red light, which is controlled by the SPC (stored program control) indicates, that the source is not in the safe position.
ii. An independent second red light, which is controlled by a dosimeter indicates, that the source is not in the safe position.
iii. The door is locked and can be unlocked only with a special key. The handling of the key will be fixed in the radiation protection instructions. It will be kept safe in the process control room.
iv. The door is locked by a second independent electromechanical system which is controlled by the SPC. The SPC will release the door only under the following conditions:
    a. The sensors at the winches indicate that the source is in the safe position.
    b. The sensors at the water pool indicate that the source is in the safe position.
    c. The dosimeter in the irradiation room indicates that the doserate is at the background level.
    d. The operator in the process control room releases the door.
v. If the door is opened and the source is still in the unshielded position (what is in principle impossible) it will be released to move down into the water pool.
vi. According to radiation protection instructions a person who enters the irradiation room has to wear besides his official film dosimeter, his personal electronic dosimeter and in addition a portable dosimeter.

The second way into the irradiation room is the way through the maze. it cannot be barred because the trolleys with the irradiation goods have to pass it. On the other hand this way is not the normal way to enter the irradiation room. Therefore it is not likely that anybody will try to enter the irradiation room using this way.

Persons are prevented from unintentional entering of the irradaition room by this way by the following measures:

i. A fence around pallet handler and conveyor system keeps persons away from the maze inlet and outlet.
ii. Red lights at the maze inlet and outlet indicate that the source is not in the safe position.
iii. Photoelectric barriers are installed at the maze inlet and outlet. They are active if the source is in the up position. If a photoelectric barrier is interrupted, the source is released to move down into the water pool. If a trolley moves into or out of the maze, they get inactive a few centimetres before the trolley and get active a few centimetres after it.
iv. Safety gates at the maze inlet and outlet and in addition in the maze prevent persons from entering. If somebody tries to open a sefety gate forcibly, the source is released to move down into the water pool These gates open only if a trolley passes.
v. Mats are installed in the maze. If anybody steps on one of them, the source is released to move down into the water pool.

The third way to enter the irradiation room is the plug in the ceiling. It can be opened only using the crane. The following safety measures are taken:

i. The crane is locked and can be used only with permisssion of the plant operator.
ii. The upper plug of the three plugs is locked too. The handling of the key will be fixed in the radiation protection instructions. It will be kept safe in the process control room.
iii. If the upper plug is lifted the source will be released to move down into the water pool.

These measures make sure that unintentional entering of the irradiation room is in principle impossible. If it is tried the source is released to move down in the water pool.

Barrier system to protect people, goods and the environment from radioactive contamination

Besides the protection of persons from irradiation the aim of irradiation protection is the protection of the environment from radioactive contamination. It must be made sure that no radioactive material will be released. Therefore a multistage barrier system is planned:

i. The radioactive Co-60 is in the sources in metallic form. It will be released only gradually even in the case of a leak in the source capsules.

ii. The radioactive material is double encapsulated in stainless steel. The capsules are leak tested at the end of the production process. These capsules are very reliable even under stress conditions.

iii. If the source is in the irradiation position it is not in direct contact with the goods. A sheeting of the source rack is an additional barrier against radioactive contamination.

iv. If the source is in the water pool the Co-60 which is released by a possible leaking source (probability is nearly zero) will be dissolved in the water. The wate rin the pool will be pumped permanently through a mixed bed ion exchanger. All dissolved substances will be deposited in the ion exchanger. Therefore the water will not contain radioactive material in a high concentration. A detector for ionizing radiation will be installed at the ion exchanger. It will register any increase of radioactivity. This is a permanent leak test of the sources.

v. The water pool with its liner of stainless steel is waterproof.

vi. If a trolley which is going to leave the maze carries radioactiv material, the conveyor system will be stopped.

Lifting and lowering of the source rack

The control system for lifting and lowering of the source rack has to make sure that no persons are irradiated and goods are not irradiated with an overdose. There are several safety conditions which must be fulfilled before the source rack may be lifted. On the other hand, it must be lowered if only one of these conditions is violated. Some of these conditions are mentioned in point 2.2

Concerning the safety in the irradiation room two different situations are possible:

In the situtation "service" the shielding door is released. The irradiation room can be entered for service and inspections. The source is in the water pol and cannot be lifted.

In the other situation, it can be called "irradiation", no person may be in the irradiation room and all safety measures mentioned above must be active. In this situation, the source rack can be lifted for irradiation.

i. After service or inspection work all staff members leave the irradiation room.

ii. An acoustic signal indicates that the irradiation room will be closed and that all staff members have to leave the irradiation room.

iii. An authorized member of staff makes a safety round of the irradiation room. He has to press some buttons within a defined time. These buttons are installed in the irradiation room at places which guarantee that he can look into all corners.

iv. After leaving the irradiation room he has to close and to lock the shielding door within a defined time.

If all steps are done without failure the plant is ready for irradiation i.e the source rack can be lifted, provided no other safety conditions are violated (e.g light barriers). Otherwise all steps must be repeated.

Lowering of the source rack is the most important safety function. It is the only possibility to switch off the radiation for radiation protection reasons or to prevent goods from overdose irradiation. Therefore it must work whatever happens. The sheeting of the source rack prevents it in the case of a jam from mechanical influences by the irradiation goods. An emergency power supply for the winches makes sure that the source rack can be lowered even in the case of a power failure.

Barrier system against theft of radioactive material

It is one of the obligations of the owner of radioactive material to take care for a safe storage of it. This includes the protection against theft. During irradiation works, when staff is present, theft of sources is not possible. Outside working time, when staff is not present, the source rack is in the water pool. All safety gates in the maze, the fire doors at the inlet and outlet of the maze, and the shielding door are closed. The burglar alarm system is active. If somebody tries to enter the building of the irradiation plant, burglar alarm will be released. Then the burglar has to open one of the ways into the irradiation room. This is not possible in a short time. When the burglar is in the irradiation room he has to lower a source container into the water pool. This is not possible without the crane, which is locked. For unloading the sources into the source container manipulators are needed. The manipulators are stored in the irradiation room, but from each of them an important part (manipulator head) is removed and stored at a safe place (e.g operator room). To overcome all these barriers takes enough time to make sure that guards, called by burglar alarm, can take measures needed.

APPENDIX

Some Safety Aspects of Irradiation Technology

1. Protection of staff against irradiation
   - shielding
   - measures against unintentional entering of the irradiation room.

2. Barrier system against radioactive contamination.

3. Lifting and lowering of the source rack.

4. Barrier system against theft of radioactive material.

Safety can be achieved by different means:

- technical means, in effect independent on the staff.
- technical means, to be used by the staff.
- regulations, to be followed by the staff.

High safety demands for radioactive materials because of:

- ionizing radiation is invisible
- one cannot feel it directly
- particular public interest in this field.

Safety considerations for a gamma irradiation facility have to include:

- safety of staff (protection against radiation)
- safety of environment (protection against radioactive contamination)
- safety of products treated in the plant (protection against radioactive contamination and overdose)

Safety of Staff

1. **Dose limits**

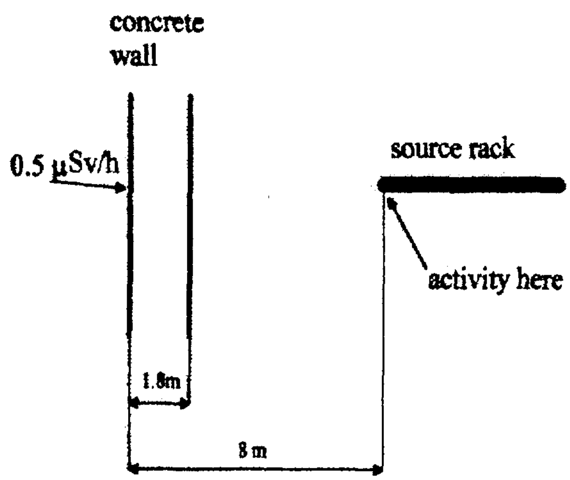
person	dose per year [mSv]	doserate for 2000 working hours per year [µSv/h]
occupationally exposed to ionizing radiation (under medical and dosimetric supervision)	50	25
working in the plant (not under supervision)	5	2,5

for comparison:
natural radiation background about 0.2µSv/h

a basic radiation protection rule:
Dose should be as low as by economical means possible!

2. Shielding

thickness of concrete walls: 1.80m
density of concrete: 2.3 g/cm^3
===> attenuation factor: 1.2 * 10^8
===> geometry factor: 64
===> dose rate: 0.5 μSv/h



Measures to prevent unintentional entering of the irradiation room

at the shielding door:

- 2 independent red warning lights
- special key needed for unlocking

- electromechanical locking system releases door only if
  - sensors at winches and in the water pool indicate that the source rack is in the safe position
  - dosimeter indicates doserate at background level
  - operator in the process control room releases the door
- if the door is opened the source will be released to move down
- staff has to wear hand held dosimeter and personal dosimeter.

Measures to prevent unintentional entering of the irradiation room at the maze:

- fence around pallet handler
- red warning lights
- photoelectric barriers
- safety gates
- safety mats

at the plug in the ceiling:

- crane is locked
- upper plug is locked
- if upper plug is lifted source rack moves down.

Barrier system against radioactive contamination:

- Co-60 in metallic form
- double encapsulated in stainless steel
- sheeting of source rack
- water purification system
- detector for ionizing radiation at the ion exchanger (permanent leak test)
- water pool with liner of stainless steel
- detector for ionizing radiation at the outlet of the maze

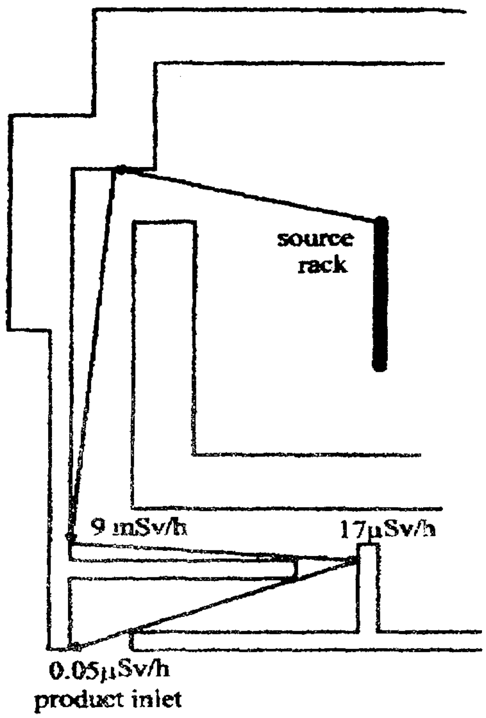
Lifting of source rack:

- all staff members leave irradiation room
- acoustic signal
- safety round, press buttons
- close and lock the shielding door

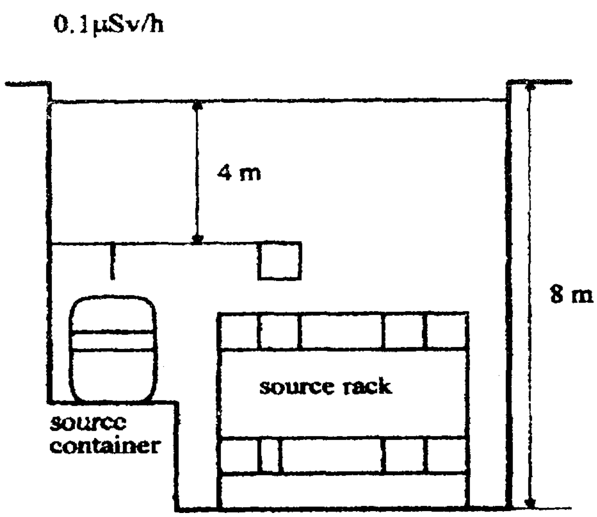
Barrier system against theft of radioactive material:

- burglar alarm
- safety gates and fire doors are closed
- crane is locked
- manipulator heads are removed.

3. The maze



4. The water pool



TECHNICAL SESSION IV
Discussion: Questions, Answers and Comments

Questions on the 2nd Paper

Question 1 - Dr. B. O. Ajagbonna, N.I.T.R, Vom Jos.
Does the ethylene oxide used for the chemical sterilization have any effect on the ozone layer?

Answer
No effect on the ozone layer is known to us.

Question on the 4th Paper

Question 1 - Dr. P. C. Onyenekwe, IAR/ABU, Zaria.
Why do you have to deliberately violate safety conditions knowing the consequences of such an action?

Answer
This is part of the emergency preparedness programme to test the efficiency and proper functions of the safety devices put in place.

Question 2 - Mr Martins Ogharandokun, Energy Commission of Nigeria, Lagos.
I think there is need for FRPS and NAFDAC to cooperate on issues of verification of food integrity particularly the measurement of radioactivity content. Don't you think so?

Answer
This cooperation existed before and may now change for the better with the implementation of the nuclear safety and radiation protection Decree 19 of 1995.

Questions on the [illegible] Paper

Question 1 - Dr. S. O. Olabanji, CERD, OAU, Ile-Ife.
Boron Neutron Capture Therapy (BNCT) complements the techniques discussed, is it not so?

Answer
Yes that comment is appreciated, however BNCT requires the use of nuclear reactors to produce the required thermal neutrons.

POTENTIAL CONTRIBUTIONS OF FOOD IRRADIATION TO POST-HARVEST MANAGEMENT OF ROOTS AND TUBERS IN NIGERIA

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Abstract

Nigeria, the world's largest producer of cassava (Manihot esculenta) and yams (Dioscorea spp.) loses up to 40% of the harvested crops to post-harvest spoilage. This situation is not much different for other locally cultivated roots and tubers such as cocoyams (Colocasia esculenta and Xanthosoma sagittofolium), sweet potato (Ipomea batatas), Irish potato (Solanum tuberosum) and ginger (Zingiber officinale). Low dose irradiation has been shown to extend the shelf-lives of yams, potatoes, ginger and the dried products of roots and tubers. This paper, therefore, tries to elaborate on the potentials of food irradiation in post-harvest management of roots and tubers produced in Nigeria. It also shows the major contributing factors to the present high post-harvest losses of these crops in Nigeria.

QUALITY CHANGES IN IRRADIATED TROPICAL PERIWINKLE (Tympanostomus fuscutus) DURING ICED STORAGE

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Abstract

The effects of gamma irradiation on the quality of shucked periwinkle meat were assessed. The periwinkles were packaged in sterile self-sealing polyethylene bags and irradiated at 0, 0.5, 1.0 and 1.5 kgy followed by iced storage over a period of 18 days. Changes in cooked flavour, appearance, mouthfeel/chewiness, tyrosine value (TV), total volatile bases (TVB), non-protein nitrogen (NPN), pH and bacterial flora were evaluated. The periwinkles showed decline in organoleptic quality during storage with concomitant increases in TV, TVB, pH and bacterial counts, the effects being more gradual with increase in doses of irradiation. The dominant bacteria flora were Bacillus and Staphylococcus species in the irradiated samples. The shelf-life limit for the shellfish was 6 to 8 days for the unirradiated samples and 14 to 16 days for the irradiated periwinkles.

SHELF-LIFE EXTENSION OF TOMATO FRUITS DUE TO GAMMA IRRADIATION

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Centre for Energy Research and Development,
Obafemi Awolowo University, Ile-Ife.

Abstract

Tomato, (Lycopersicon esculentum), an essential food composite in the diets of infant and adult in Nigeria was studied so as to improve our capacities to increase its seasonal availability through an increase in its shelf-life. The tomato fruit which were cultivated in and harvested from the teaching and research farm of the College of

Agriculture of the Ogun State University, Ago-Iwoye were subjected to gamma radiation doses of 0.0, 0.5,1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 KGy and stored at an ambient temperature and humidity of (25°C; 60-80%). Monitority was carried out at 3 days interval and percentage rot recorded. A maximum shelf-life extension of 15 days was recorded for a gamma radiation dose of 1.0 KGy; representing the optimum dose.

CAPACITY BUILDING IN IRRADIATION TECHNOLOGY IN AGRICULTURE IN NIGERIA

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Abstract

Nigeria became a member state of the International Atomic Energy Agency (IAEA), in the early 1960s and has since set up various organs involved in the research, application and monitoring of the use of nuclear technology. A brief review of the application of nuclear technology to agriculture in Nigeria reveals that the nation is lagging far behind. Factors militating against the rapid and wide application of these technologies in the country are highlighted. In order to join other nations of the world that have reaped significant benefit from the application of nuclear science, especially irradiation technologies in agriculture, Nigeria must rapidly build up its capacity in terms of national awareness and commitment, scientific expertise, research facilities and infrastructures as well as an effective legal environment, all of which are essential requirements for active participation. Strategies that could be adopted for this programme of capacity building are briefly discussed.

PHYSIOLOGICAL AND MICRONUTRIENT COMPOSITION OF LOW HEAT AND GAMMA IRRADIATED 'JULIE' AND 'MABROUKA' CULTIVARS OF MANGO DURING STORAGE

Efe Onwirhiren[1], P. C. Onyenekwe[2] and G. H. Ogbadu[3]
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[3]Biochemistry Department, A.B.U, Zaria.

Abstract

The effect of γ-radiation and low heat treatment on the physiological and chemical composition of two cultivars of Mango (Mangifera indica L) (Julie and Mabrouka CVS) was studied.

The physiological weight loss (PWL) for the Julie cultivar was significantly higher ($P \leq 0.05$) than Mabrouka cultivar and it was not affected by γ-irradiation and low heat treatment. Decay was significantly reduced at dose of 250Gy for both cultivars. γ-irradiation has no effect on peel colour development but ripening was significantly delayed in both CVs.

Total solids, ascorbate content, protein, ash, crude fibre were unaffected by γ-irradiation but lipid content was significantly reduced ($P \leq 0.05$) by γ-irradiation and low heat treatment. Flavour preference was highest for non-irradiated cultivars. In general, γ-irradiation and low heat treatment has no significant effect on the physiological and chemical composition of mango fruit. The results are discussed in relation to the use of γ-irradiation and low heat treatment to delay ripening and extend shelf-life.

RADIATION THERAPY EQUIPMENT FOR MEDICAL APPLICATION

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Abstract

Shortly after Wilhelm Roentgen discovered the X-Ray in 1895, Scientists realized the biological effects of ionizing radiation on both malignant and non-malignant conditions. During the period between 1899-1920, ionizing radiation was used to treat many afflictions ranging from acne to malignant skin cancers.

Medical science first began using radiation to treat specific types of cancer in the early 1920's. It was in 1922 that two scientists (Coutard and Houtant) presented findings that advanced laryngeal cancer could be managed through the use of radiation. Scientists learned over the next few decades that more and more types of cancer could be treated with radiation. They required machines that could produce higher and higher energies. Machines using radioactive cobalt 60 were developed and became commercially available in the 1950's. This enabled scientists and physicians to treat a larger variety of disease, but even higher energy units were needed.

The development of radar during the second world war provided science with the answer. A machine that could accelerate electrons faster than a conventional X-ray machine and convert them into photons. It was then possible to treat deep seated tumors in patients without significant side effects. Since the photon particle carries a higher amount of energy, radiation could be deposited in a tumor deep inside a patient without causing extensive damage to the surrounding tissue. This same basic principle is still used today in all modern linear accelerators. They have become more sophisticated and provide the user with a very high level of control.

Siemens has been a part of this process from the very beginning. Many of the X-ray tubes used by Dr. Roentgen in the late 1890's in his lab in Wurzburg, Germany were provided to him by the company you now know as Siemens Medical. Siemens began supplying equipment to the medical community for radiation therapy in 1911 with orthovoltage and superficial machines. Siemens also provided commercial cobalt units starting in the early 1950's. More than 100 of these units are still in clinical use today in various countries around the world. The first Mevatron medical linear accelerators arrived on the market in the late 1960' s from the company now known as Siemens Oncology Care Systems.

Today, Siemens provides the most comprehensive line of linear accelerators available. In the 1920's, one of the most powerful machines available could provide a maximum energy of 200Kv (200,000 volts). Today, Siemens manufactures linear accelerators that can produce up to 25MV(25,000,000 volts). We also provide machines that can produce a variety of energies in between. In addition, Siemens has Simulators (used to simulate a treatment before it is delivered), Treatment planning computer systems. and the most widely used networking system in radiation oncology. Together, these advantages add up to the best alternative for the Patient, the Physician and the Hospital.

PROBLEMS, PROSPECTS AND POTENTIALS FOR FOOD PRESERVATION BY IRRADIATION IN NIGERIA.

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Chairman, Agricultural Engineering Department
University of Nigeria, Nsukka.

Abstract

The basic concepts of the use of ionizing radiations such as electrons, gamma and X-rays, as well as microwaves in food preservation, are presented. The factors affecting the

efficiency of food irradiation are identified to include intrinsic properties of the food material, nature of microorganisms and enzymes, and absence or presence of oxygen. The applications in food preservation include inhibition of sprouting through enzyme inactivation, and general sterilization to achieve the destruction of common agents of deterioration like insects, moulds, yeasts and other microorganisms. Also, baking, cooking, curing, drying and heating of food products, which in their own rights are common unit operations in food preservation, readily lend themselves to the use of microwaves.

The problems facing the introduction and sustainable use of food irradiation technology in Nigeria are identified to include the exotic nature and sophistication of the technology, safety considerations, cost, equipment and maintenance, wholesomeness and storage stability of irradiated foods. The paper notes that, although food irradiation may have high prospects and potentials for food preservation in Nigeria, the concern of human exposure to radiation and the mix up of possible contamination of food products with radioactive or carcinogenic substances is a very critical problem that must be addressed along with attempts to introduce such technologies in a developing country like Nigeria. Nigerians need to be educated about the safety of irradiated foods.

PRACTICES FOR AREA-WIDE ERADICATION OR CONTROL OF TSETSE AND TRYPANOSOMIASIS WITH EMPHASIS ON THE STERILE INSECT TECHNIQUE (SIT)

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Abstract

Control of trypanosomiasis in man and animals in Africa is still a very tasking problem which has continuously attracted international interests. In Nigeria, records on trypanosomiasis and the tsetse fly vector existed from early periods of the colonization of the territory. However, intensive control programmes were not available until during the early 1950s when aerial spraying of organochlorides was used to reduce tsetse populations in the regions to enhance development and encourage increased economic and agricultural productivity. Today much advancement has been made in the efforts to control tsetse and trypanosomiasis through integrated methods. These include improved mechanical trapping, use of baits and attractants, impregnated screens and barriers and the biological control using sterile insect technique (SIT). In this method, irradiation-sterilized male tsetse flies were released in large numbers in an area infested with tsetse. The infertile matings with wild female flies over a specified period greatly reduced the fly population to very low levels. In the specific studies cited in this presentation, the authors have used different trapping methods in determining tsetse populations to monitor the effectiveness of the SIT programme in Nigeria. This method was also extended to Southern Nigeria to determine prevalence and abundance of tsetse in the areas to decide on feasible agricultural projects including modern livestock production.

SYMPOSIUM ON IRRADIATION TECHNOLOGY FOR NATIONAL DEVELOPMENT
OCTOBER 16 - 17, 1996
organised by
SHEDA SCIENCE AND TECHNOLOGY COMPLEX (SHESTCO)
Abuja, Nigeria.

COMMUNIQUE

A two day national symposium on Irradiation Technology for National Development was held at the permanent site of the Sheda Science and Technology Complex (SHESTCO), Abuja, Nigeria, between October 16 - 17, 1996. The symposium was declared open by the Honourable Minister for Federal Capital Territory, Abuja. The symposium attracted many participants from government, universities, research institutes, regulatory agencies, the industry and the electronics and print media. Papers were presented by experts on different aspects of the uses of irradiation technology in agriculture, medicine and industry. The areas covered included preservation of foodstuffs and agricultural products, mutation in plant for high yielding and disease resistant varieties, sterilization of medical, pharmaceutical and cosmetic products, improvement of mechanical, thermal and electrical properties of plastics through radiation induced cross-linking and vulcanization of natural rubber latex.

The participants

1. observe that :

(a) there are immense benefits derivable from the application of irradiation technology;

(b) some research work are being done in Nigeria on the application of irradiation technology in agriculture, medicine and industry

(c). these research efforts need to be properly coordinated, practically demonstrated and used for the socio-economic development of our country :

(d). the Federal Government has promulgated Nuclear Safety and Radiation Protection Decree No.19 of 1995 to ensure safe operation of the irradiation facilities among others ;

2. commend :

(a) the Federal Government for establishing SHESTCO as a research and development institution in high technology and

(b) for acquiring irradiation technology facility for application in agriculture, medicine and industry.

3. urge :

the Federal Government to fund SHESTCO adequately to enable effective utilization of the irradiation technology among others and

4. recommend that :

(a) the Federal Government implements the Nuclear Safety and Radiation Protection Decree No.19 of 1995 ;

(b) a close collaboration between researchers in our national research system and the industries be enhanced to reap maximum benefits from irradiation technology and other research results in Nigeria

and(c) SHESTCO should organise awareness programmes on the benefits of irradiation technology in agriculture, medicine and industry through the media, educational institutions, conferences, seminars, symposia and workshops.

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