# PROCEEDINGS OF THE NATIONAL SYMPOSIUM ON FOOD IRRADIATION

Pretoria, Republic of South Africa
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* PLEASE NOTE:
These contributions, as well as all questions, answers and comments were compiled by the editors from verbatim tape recordings.

# PREFACE

Attending international and national symposia on subjects of interest to one's field of work has become an essential part of any scientist's activities. Apart from the knowledge to be gained, such gatherings offer singularly valuable opportunities for meeting fellow researchers active in the same and related scientific disciplines, and for discussing relevant problem areas on a personal basis. It was therefore a rare privilege for me to be invited to attend the National Symposium on Food Irradiation, organised by the South African Atomic Energy Board and the Department of Agricultural Technical Services at Silverton, Pretoria, and to be accorded the honour of being the guest speaker.

The timing of this symposium and the range of subjects covered were evidence of perceptiveness on the part of the organisers in correctly judging the growing importance of this not-so-new technology of food preservation in international trade. The scene had been set by the recognition accorded by the Codex Alimentarius Commission, through its advisory bodies, to irradiation as a technological process applicable to food. International standards for certain irradiated foods and the International Code of Practice for the Operation of Food Irradiation Facilities provide ample proof of the interest of many Member Governments of the Codex Alimentarius Commission in developing international trade in irradiation-preserved foods.

The symposium was well attended by many able scientists and researchers from the organising bodies and other South African Government departments and research institutions. Added to this high-powered assemblage was a representative collection of delegates representing a wide spectrum of food industry interests as well as delegates from overseas, evidencing clearly the international interest in the proceedings.

The program was divided into five sessions which dealt with the following subjects:

1. The general background of food preservation by irradiation with particular reference to the contributions made by South Africa. Papers were presented giving concise reviews of the effects of irradiation on the chemical constituents of treated foods and on the microbiological and nutritional aspects of this technology, particularly in relation to fruit, vegetables and meat.

2. The application of irradiation to the preservation of meat, fish and poultry products with special reference to parasitic infestation of meat and the problems facing South Africa's broiler industry.

3. The importance of irradiation in the preservation and quality assurance of subtropical fruits; the application of irradiation to increasing the storage life of vegetables.

4. The regulatory and marketing aspects of irradiated foods, including an appraisal of retailer and consumer responses and reactions to the sale of such foods.

5. A discussion of the costs, economics and design of irradiation facilities.

Because this introduction is followed by detailed accounts of the various excellent papers presented to the audience, it will suffice to restrict this note to highlighting a few aspects likely to become particularly important in the future development of this technology. In the light of today's worldwide energy crisis, the comments in the welcoming address of Dr J P Hugo, Deputy President of the South African Atomic Energy Board, were pertinent. Considerable savings in expenditure of conventional energy, such as heat or refrigeration used in food preservation, might be achieved by using as an alternative, the energy deriving from radioisotope decay.

The contribution of the irradiation technology to increasing the local food supply by preventing unnecessary losses from spoilage or infestation was a recurrent theme of many papers. Dr A Verster's discussion on the use of low-dose irradiation for the control of meat-borne parasites highlighted a particularly interesting aspect of enormous importance to developing countries struggling with overwhelming hygiene problems. Another interesting aspect, dealt with fully in clearly presented papers, was the question of marketing irradiated foods. The policy of linking high quality with a marker denoting that the product had been preserved by irradiation seemed to hold considerable promise for gaining consumer acceptance, even though irradiated foods could be slightly more expensive than foods preserved by more traditional means.

In general, the clear impression has been left with delegates that the symposium has fulfilled the objective of presenting an overview of the technology of food irradiation, it applications, advantages and drawbacks. The meeting has revealed the leading role played by the scientists and researchers of the Republic of South Africa in the basic as well as the applied research continuing in this comparatively new field worldwide.

Dr P S Elias
Director: International Food Irradiation Project
Karlsruhe
Federal Republic of Germany
October 1979

**ACKNOWLEDGEMENTS**

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## THURSDAY 4 OCTOBER

Morning

# OPENING SESSION

**SYMPOSIUM CHAIRMAN: DR W J DE WET**
*Director, Chemistry Division, Atomic Energy Board, Pretoria*

Ladies and Gentlemen!

Food irradiation is an exciting new technology and is beginning to arouse wide interest in South Africa, as well as all over the rest of the world. Prompted by the successes already achieved, in particular by the International Food Irradiation Project (IFIP) in conclusively clearing wholesomeness aspects of irradiated foods, and also due to considerable successes in our own research and development program, it was decided as early as 1976 that precommercial marketing investigations, eventually involving several irradiated commodities over a reasonable period of time, are most desirable for expediting eventual commercialisation of the process in this country. For authoritative reasons, a Coordinating Committee consisting of four State Departments was formed to guide our expanded efforts. The suggestion to hold this Symposium was also put forward by this Committee. The hope was expressed at the time that all interested disciplines be represented at the Symposium, which I am glad to announce, is indeed the case. A full program is offered in which all the facets of the technology will receive attention. The formal lectures will be rounded off with a panel discussion. We are indeed privileged to have Dr P S Elias, the Director of IFIP, with us at this Symposium and we look forward to his contributions.

Allow me to express the hope that the Symposium will prove stimulating and fruitful.

# WECOMING ADDRESS

**J P HUGO**

*Deputy President, Atomic Energy Board, Pretoria.*

The Atomic Energy Board's research and development program, initiated in 1959, rests upon four main themes, namely: nuclear raw materials, nuclear power, radioisotope and radiation applications, and supporting basic research. The topic of discussion at this National Symposium on Food Irradiation essentially involves the third theme, and more specifically the utilisation of radiant energy from intense radioisotopic sources, to achieve a broad spectrum of beneficial effects in a wide range of food products. I will consequently not explore this subject in any detail. However, I trust that it is not inappropriate at this juncture to briefly touch on a few aspects of this and the other themes.

We are currently in the throes of what has become known as the 'energy crisis'. The ultimate solution of these problems must be found in the development and use of alternative energy sources and in energy conservation. Energy requirements feature prominently in agriculture and the food industry, and a figure of about 15 % of the total energy consumption for a developed country for this sector is perhaps not a too unrealistic estimate. Radiant energy from radioisotopes for food preservation purposes could result in considerable energy savings as a result of the inherent efficient use made of radiant energy in such applications, apart from considerable savings in refrigerated storage and distribution energy needs which would otherwise have been required. Thus food processing by irradiation offers a positive contribution to the conservation of conventional energy.

The so-called oil crisis, which struck the world at the end of 1973 and precipitated the energy crisis, had a dramatic impact, particularly on the industrial countries of the western world. Nuclear power has emerged as the only proven alternative source of bulk energy in the medium term. As a result, the demand for uranium, as well as it's price, has risen strongly, the latter approximately five-fold. It is well known that South Africa is one of the world's major uranium producers and according to the latest estimates possesses about 16 % of the western world's reserves of low-cost uranium. In the interest of the country, and as a matter of high priority, research and development by the Atomic Energy Board (AEB) in this area of nuclear raw materials entail technical support to the exploration companies in their search for deposits of uranium and other nuclear materials, and the development of better and more economical extraction, refining and fabrication processes. These efforts have met with a large measure of success despite the fact that typical South African uranium ore is of a low grade. All this work is being done in close collaboration with the mining industry.

Analogous to energy requirements is the need for increased food production and the evident common factors for both are the world's population explosion at a rate of 2,2 % per annum, coupled with the relatively poor situation in developing countries with regard to food and energy production. Where it is at present estimated that almost a quarter of the world's population is underfed or undernourished and a smaller fraction even crippled by famine, it is clear that food production will have to be increased and food losses curbed. Nuclear energy and nuclear technologies (e.g. food irradiation) can, together with many other approaches already being pursued, alleviate such situations.

Regarding the second theme mentioned above, namely, nuclear power, the AEB has over a number of years been working on the economic evaluation of nuclear power in South Africa in collaboration with ESCOM and other state departments. It has been shown that nuclear power will be an economical proposition in the Western Cape from 1982 onwards. In 1976 ESCOM entered into a contract for the supply of two pressurised-water reactors of 921 MW(e) each for the Koeberg power station. The first of these units is scheduled for commissioning at the end of 1982 and the second in 1983. The AEB is further involved in other projects related to nuclear power, in addition to being responsible for the statutory licensing of nuclear installations.

Returning to the third theme of the AEB's program, namely radioisotopes and radiation applications, the AEB has a dual function, namely excercising statutory control over the safe use of all radioisotopes in South Africa, and the promotion of radioisotope and radiation applications. These activities have required the development at Pelindaba of a considerable infrastructure. Research and development in the four main areas of application, namely, general research, agriculture, industry and medicine, have been actively pursued from the early sixties, in many instances in close collaboration with outside organisations. These efforts are further backed by training, guidance and advice whenever possible. The number of authorised users of radioisotopes is close to 500, a figure which is still increasing at a satisfactory rate.

Apart from uranium mining, activities in radioisotope and radiation applications are at present the most important applied nuclear technological realities in the country. Based on cost and the number of consignments of radioisotopes, nuclear medicine features most prominently among applications of radioisotopes. In 1967, soon after the SAFARI-1 Research Reactor became operative (1965), the AEB initiated a reactor radioisotope production program. Despite very limited processing facilities available at the time, considerable progress has since been made. A large percentage of the diagnostic radiopharmaceuticals used in the country is locally manufactured to a quality on a par with imported equivalents. In the middle sixties the Council for Scientific and Industrial Research also embarked on cyclotron production of radioisotopes. More recently a R3 million isotope production complex has been commissioned at Pelindaba, comprising adequate hot-cell facilities for the production of a wide range of processed radioisotopes.

The industrial uses of radioisotopes in the form of tracers or devices for physical measurements are also well developed and are fulfilling very useful purposes in addition to saving considerable sums of money in many instances. The uses of solid radioisotopic sources of low to medium activity are equally well established in industry as well as in therapeutic medicine. Research applications of radioisotopic tracers are furthermore quite extensive in many disciplines, including agriculture.

The highly commendable role of the International Atomic Energy Agency (IAEA) in promoting the wider use of isotopes, should also be mentioned. Since the advent of nuclear reactors in the late forties, which made available large amounts of radioactive material at relatively low cost, considerable benefits have been forthcoming from radioisotope and radiation applications. Although these benefits are not always easy to quantify in accurate figures, some of the successes achieved in areas such as insect and pest control, plant mutation breeding of economically important types of crops, efficient use of fertilizers and several other areas, have been very significant, particularly in developing countries. The efforts of the IAEA, FAO the OECD (NEA) as well as the WHO and a number of member countries, in resolving the question of wholesomeness of irradiated food will be discussed by Dr Elias. The progress made by one or more of these agencies in establishing general standards for the international trade in irradiated foods and a code of practice for the operation of food irradiation facilities, is certainly of great significance and will undoubtedly also contribute to the commercial introduction and future use of food irradiation technology.

Since 1971 the AEB has been actively engaged in radiation technological development work. This does not only relate to a food irradiation program executed in collaboration with the Department of Agricultural Technical Services (ATS), but also to a non-agricultural program. As regards the latter, a package irradiation facility was commissioned in 1971 for establishing the gamma sterilisation technology for disposable medical items. This activity has since made impressive progress to the extent that it is at present rendering a sterilisation service to about 50 clients with a combined throughput of about 40 tons per week. The cobalt-60 load in the facility (initially 50 kCi) is already in excess of 1 Megacurie. It is gratifying to be able to report that this sterilisation service has reached the stage of viability where it is to be taken over and operated on a fully commercial basis by the private sector within about two years from now. This serves as a lucid example of where the AEB had to take the initiative in introducing an applied nuclear technology into the country, as no single private company had been in a position to have done so at that stage and time.

The remaining part of the non-agricultural program entails research and development on grafting, plastic modifications, polymer synthesis as well as a number of diverse investigations such as the pasteurisation of sewage sludge done in collaboration with the Johannesburg Municipality. For some of these applications electron accelerators are already in use in large overseas countries and the introduction of accelerator irradiation technology into South Africa is possibly not too far distant.

Finally, as regards the food irradiation program, it is appreciated by the AEB that it is very important that the initiative is not lost at this critical stage when a breakthrough in final acceptance of the technology appears very promising. A significant sum of money has been spent to date, but considerable successes have been achieved both with the local program and through international collaboration. At this point in time the AEB is indeed very optimistic about the future of food irradiation, but is also convinced that its large-scale implementation should not be unduly rushed. Food irradiation may well develop into the largest single application of radiation technology, which if it materialises, will surely be of enormous benefit to the country as a whole.

With these few words, I have great pleasure in formally welcoming you all to this Symposium – in particular those of you from outside our borders. May I wish you all interesting and fruitful deliberations.

ZA8000312



# GENERAL INTRODUCTION ON NEW TECHNOLOGIES IN AGRICULTURE AND FOOD SUPPLY

D W IMMELMAN

*Secretary for Department of Agricultural Technical Services, Pretoria.*

Food shortages, and in many parts of the world outright famine, are today commonplace.

The population explosion, especially in the underdeveloped countries of the world, causes a geometric progression in the scale of this problem. If we do not do something about it immediately, we will have a global catastrophy threatening us by the turn of the century. Man's fecundity has become the greatest threat to progress and even survival in certain areas of the world.

However, modern technology, as developed in the industrialised nations of the world, has not only given us vastly improved methods of increasing food production from traditional sources, but has also opened up a whole new spectrum of natural and synthesised foods from sources never dreamed of before. And yet all our modern technology and discoveries may not be sufficient to stave off starvation and death in the 21st century. This threat of outright famine has focused man's attention on, and emphasised the necessity to reduce all unnecessary and avoidable waste of food. It has been estimated that food losses in the world today, accountable to rodents, insects, bacteria and fungal attack, amount to a staggering one third of total world production — this notwithstanding the application of numerous established and acceptable food preservation methods. It is essential therefore that we find not only better methods of preserving food but also ways and means of producing better quality products with an extended shelf life.

It would be good at this stage to look very briefly at the major causes of losses in quality and yield of our foodstuffs:

According to figures of the Food and Agricultural Organisation of UNO, 30 % of all apples which could be harvested are lost as a result of pests and diseases. Even in the most advanced countries, losses are very heavy in spite of modern methods of crop protection. Farmers in the United States lose R2 000 million in farm products annually through pests and as much again as a result of plant diseases. In South Africa, farmers lose approximately R12 million per year as a result of diseases which attack deciduous fruit and table grapes before and after harvest. Post-harvest losses alone amount to R5 million annually. Post-harvest diseases are responsible not only for direct crop losses, but they also indirectly undermine the confidence of overseas' consumers of South Africa fruit, leading to a loss in foreign exchange earnings. I could quote many examples where diseases and pests are responsible for very big losses of harvested fruit and vegetables. However, these are not the only or necessarily the most important losses.

Equally important, because they are losses which are incurred in sound, good quality fruit and vegetables, are losses which occur during storage or in transit to markets. Cold storage has for a long time been one of the important methods to prevent or minimise decay and losses of perishable products. However, physiological deterioration and micro-biological decay still occur during this process. Both of these may be minimised by correct cold storage techniques. This implies cold storage under optimal conditions of temperature and relative humidity. The quality of most deciduous fruits and many vegetables may be maintained by storage at a temperature of minus 0,5 °C and a relative humidity of 90 to 95 %. Deterioration in quality will be rapid if the product is not stored under these specific conditions and the product will ripen and eventually become senescent . Decay will develop much faster than at the recommended low temperature. If the relative humidity is too low, the product will lose moisture and shrivel. Subtropical and tropical fruits cannot be stored at temperatures below 4 °C because these are sensitive to low temperatures. Loss of quality is therefore much faster than with deciduous fruit. Cold storage slows down the rate of deterioration, but cannot prevent it. A wide range of chemicals such as anti-oxidants and fungicides, have in modern times been introduced to complement cold storage and to reduce losses, but at this stage losses cannot be completely eliminated.

Losses also result from microbiological decay. These losses are estimated either by marketing surveys, or by withdrawing samples from commercial consignments and noting the extent of decay after a predetermined period of storage at a specific temperature. The second method is used in South Africa. Relative losses can also be estimated from figures supplied by fruit inspectors at points of export. All export fruit is inspected after packing and containers of fruit which are unacceptable are rejected. These rejections represent an immediate loss of approximately 2 %, or R3,5 million in foreign currency. During cold storage and marketing these losses may increase to a total of R5 million. Such statistics do not reveal the entire economic impact of post-harvest losses because several important aspects have not been taken into consideration. These include:

(a) The loss of considerable investment in harvesting, packaging and transportation;

(b) partial or total loss of containers which contain a single or only a few affected fruits;

(c) the acceleration and uncontrolled ripening of fruit in a container, due to ethylene which is given off by the diseased fruit;

(d) loss in consumer confidence in fruit from a specific source. An excellent example of this is core-rot in apples.

Unfortunately, an affected fruit can often be identified only when it is cut or bitten into, and the consumer is the first person to realise the problem.

Losses are not only confined to fruit which is exported. Apples are stored for seven to nine months during which period decay can take place. If the correct post-harvest treatment is not applied and optimum storage conditions are not maintained, very high losses may be expected. A survey of apples stored for a period of five and a half months revealed losses of 11,5 % as a result of fungal decay.

Large quantities of fruit and vegetables are cold-stored for canning at a later date. Most of these products (such as pears, peaches, pineapples and tomatoes) have a relatively short storage life and if care is not exercised considerable losses may occur and a 10 % loss of our fresh produce is not unrealistic.

A brief examination of insect pests reveals that pome fruits are attacked by a complex of 23 insect and mite pests, stone fruit by 22 and table grapes by a complex of 14. If these pests are not controlled, approximately 87 % of the fruit crops can be destroyed in a single season. This would cause the complete collapse of the South African deciduous fruit industry. Consideration of only three of the 23 pests attacking pome fruits reveals the following:

(a) If uncontrolled codling moth will infest about 85 % of our apple and pear crop, and in terms of last year's total crop of R98 million would cause losses of about R80 million

(b) fruit flies would infest at least 90 % of the apricot, peach and plum crops, causing a loss of more than R23 million in terms of the 1977/78 season's crop

(c) vine mealy-bug would infest about 88 % of our table grape crop, i.e. a loss of about R40 million in terms of the last season's table grape crop which was valued at R45 million.

However, the highly effective chemical control program carried out on South African farms has kept overall losses down to between 1,5 % and nil percent of the various crops, before marketing. Rejections of packed consignments of those deciduous fruits which I have mentioned, still occur as a result of pest infestation. This is due however to ineffective sorting at the point of packing and does not reflect true losses. Such rejections are often based on a single infested fruit in a small number of cartons per consignment. Rejected consignments are usually re-packed and losses due to infested fruit in such consignments are actually part of pre-harvest losses.

At this stage I would like to repeat two statements which I made in my opening paragraphs. Firstly, it is estimated that food losses as a result of rodents, insects, bacteria and fungal attack amount to 30 % of the total world production. Secondly, I would like to repeat that better methods of food preservation must be developed not only to reduce these losses, but also to supply a better quality product with a longer shelf life.

The discovery of X-rays and radioactivity during the closing years of the last century was followed by investigations into their biological effects. The principles of food preservation by ionising radiation were established soon afterwards. Since 1970, South Africa, together with 24 other countries, has participated in an international project on the wholesomeness of irradiated products. This project is under the control of the Food and Agricultural Organisation, the International Atomic Energy Agency, the Organisation of Economic Co-operation and the World Health Organisation.

To date 26 different irradiated foodstuffs have been cleared for sale in 19 countries. South Africa has taken the lead in pre-commercial marketing investigations where, since August 1978, appreciable quantities of irradiated produce have been retailed through several outlets in the Johannesburg–Pretoria area. Items cleared for sale in South Africa to date include potatoes, onions, garlic, mangoes, papayas, chicken and strawberries.

Food preservation by means of irradiation may be achieved through one or more of the following effects:

(a) Micro-organisms which cause deterioration of foodstuffs may be controlled;

(b) insects which contaminate and destroy stored products may be killed;

(c) parasites, such as measles in meat, may be inactivated;

(d) natural changes in certain fresh products may be either slowed down or halted, e.g. sprouting may be inhibited or the ripening of fruit delayed.

Before I proceed to give specific examples of these applications, two unique advantages which irradiation offers over other methods of processing should be noted. Firstly, gamma rays penetrate materials such as plastics and some metals and it is therefore possible to treat packaged products. The elimination of contaminants embedded within a foodstuff may be achieved and not just a surface treatment. The second advantage lies in the virtual absence of an increase in temperature in the irradiated product. This enables the treatment of commodities such as fresh fruit and vegetables or the elimination of harmful bacteria from frozen products, without thawing. Two further advantages are the extremely low demand for expensive electrical energy and the reduction in the need for insecticides and fungicides, with an accompanying reduction in environmental pollution.

Before closing I would like to run through a number of specific examples which will serve to demonstrate how irradiation may help to reduce food losses in local consumption and also allow some commodities to be successfully exported.

Firstly subtropical fruits: A mango may fail to reach the consumer for one or more of three reasons:

(a) The mango weevil which develops inside the pip may emerge, bore its way through the flesh and cause serious damage to the fruit;

(b) fungal disease may spoil the fruit during prolonged storage; and

(c) fruit may ripen too quickly and become over-ripe.

Very mild doses of radiation combined with a short heat treatment controls all three causes of wastage, and much wider markets, both locally and abroad, can therefore be reached.

Papayas and strawberries are also spoiled by fungal contaminants which can be controlled by a combined heat and irradiation treatment, prolonging the keeping time by up to several days. Another fruit which may be successfully treated is the avocado. Although avocados have a low tolerance towards irradiation, progress has been made using very low doses in order to slow down the rate of ripening in the fruit of the *Fuerte cultivar.*

As for vegetables, irradiation prevents sprouting in potatoes, onions and garlic. Irradiated potatoes kept under refrigeration were still edible after more than a year in storage. The export potential of onions to countries where onions are stored at room temperature for lengthy periods can now also be realised. A further beneficial effect of irradiating potatoes is the delay in greening. Greening which results from the formation of chlorophyll, is associated with solanin production which, besides being a known toxin, imparts a bitter taste to the potato. Non-irradiated potatoes kept in supermarkets are rejected after 3 to 4 days as compared with irradiated tubers which have a marketable life of 8 days or more.

The next example is meat: The present method of storing detained measly carcases requires that they be kept under deep-frozen conditions for several days. These carcases could be used immediately after being subjected to low doses of irradiation. The cysticerci inside the muscles are inactivated and cannot develop if eaten by the intermediate host (man). The shelf life of chilled meat and poultry can be extended considerably by applying relatively mild doses of radiation. Bacteria which cause spoilage are reduced and pathogens such as salmonella are eliminated, resulting in a product with excellent keeping quality and high standards of hygiene. If much higher doses are given to enzyme-inactivated meat in appropriate packaging, a sterile product with a shelf life of several years at room temperature can be obtained. The same treatment can be applied to certain seafoods such as shrimps and fish.

My fourth example is wheat: The irradiation of wheat and wheaten products is a highly effective method of insect disinfestation. Fungi on products such as bread are also effectively controlled.

And finally, I must mention spices: The use of ethylene oxide to sterilise spices is causing serious concern. This gas is suspected of possessing carcenogenic properties and may also leave toxic residues after treatment. Radiation sterilisation of spices seems to be an attractive alternative solution to the problem.

Those feeling that progress in the field of food irradiation should be much faster should remind themselves that man is generally quite conservative where his food is concerned. After Nicholas Appert discovered his "principle" for conserving food by heat sterilisation, it took 25 years before heat sterilised foods were marketed in quantity. A patent on the freezing of fish was issued as far back as 1842 and yet more than a century was to pass before this technique of food preservation was applied commercially. It took 30 years before "controlled atmosphere" storage was generally adopted by the fruit and vegetable trade. So, food irradiation is not doing so badly by comparison. Research in food irradiation started in the USA in the early fifties, but more extensive programs in America and Russia only started towards the mid-fifties. During the sixties uncertainties regarding the wholesomeness, i.e. safety and nutritional aspects, were raised but these are being progressively cleared through the efforts of the International Food Irradiation Project.

As this exciting new technology is beginning to arouse wide interest in the Republic as well as all over the world, it was decided to organise this symposium in order to disseminate knowledge regarding the state of the art and future prospects of this science. Special reference is made to the wide range of applications of irradiation in extending the shelf life of a variety of commodities, thereby minimising storage and distribution problems. Also to be considered is the effect of irradiation in reducing hazards relating to food-borne diseases, without adversely affecting the wholesomeness of these products.

Prospects for the irradiation of food on a commercial scale in the eighties appear to be very promising indeed for South Africa. In particular, as will become evident from the rest of the program for this symposium, this technology could be of considerable benefit to South Africa and the world at large.

ZA8000313



# THE AIMS AND ACHIEVEMENTS OF THE INTERNATIONAL PROJECT IN THE FIELD OF FOOD IRRADIATION

P S ELIAS
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## SAMEVATTING

Aan die einde van die sestigerjare, is 'n groot verskeidenheid voedselprodukte vir bestraling oorweeg. As gevolg van die potensiële belangrikheid van bestraling, die koste van biologiese toetse en die voorkoming van onnodige duplisering van navorsing, het internasionale samewerking wenslik geword. Die Internasionale Voedselbestralingsprojek (IVBP) is in 1970 gestig en 25 lande is tans verteenwoordig.

Doelstellings van die Projek

Die basiese funksie is om met die objektiewe evaluering van die voedsaamheid van bestraalde voedsel behulpsaam te wees. Daar word nie beoog om die proses te bevorder of die ekonomiese moontlikhede daarvan te verbeter nie.

(a) Voedsaamheidstoetse

Bestraalde aartappels, graan en graanprodukte is aanvanklik bestudeer. Bykomende voedselsoorte is op grond van sekere faktore gekies. Die gekose voedselsoorte het vis, rys, speserye, mango's, dadels en uie ingesluit. In geeneen van hierdie studies is betekenisvolle effekte waargeneem wat aan die voer van bestraalde voedsel toegeskryf kan word nie.

(b) Metodologiese Navorsing

Die IVBP het baie aandag aan die hersiening en instandhouding van hulle prosedures geskenk. 'n Voortdurende studie van wetenskaplike literatuur en publikasies van regulatoriese liggame is met praktiese navorsing in IVBP-laboratoriums en met raadpleging van deskundiges in toksikologie verenig.

(c) Inligtingsbedrywighede

Die resultate van wetenskaplike navorsing wat deur IVBP geborg word en inligting van algemene belang word gepubliseer.

(d) Hulp van Nasionale en Internasionale Owerhede

Die IVBP beoordeel nie die aanvaarbaarheid van bestraalde voedsel nie. Hy is egter gewillig om inligting en advies, op versoek, aan regulatoriese liggame te verstrek wat vir sodanige besluite verantwoordelik is.

## ABSTRACT

By the end of the 1960's a large number of food items were being considered for irradiation treatment. Because of the potential importance of the process, the cost of biological tests and the danger of unnecessary duplication, international collaboration became desirable. The International Food Irradiation Project (IFIP) was established in 1970. Membership at the present time numbers 25 countries.

Objectives of the Project

The basic function has been to facilitate the objective evaluation of the wholesomeness of irradiated foodstuffs. It is not concerned with promoting the use of the process or with assessing or improving its economical feasibility.

(a) Wholesomeness Testing

Studies were initiated on irradiated potatoes, wheat and wheat products. Additional foodstuffs were chosen on the basis of certain factors. Products chosen included fish, rice, spices, mangoes, dates and onions. In none of these studies was any significant effect observed which could be attributed to the feeding of irradiated food.

(b) Methodology Research

IFIP has devoted considerable attention to reviewing and up-dating its testing procedures. A continuous study of the scientific literature and the publications of regulatory bodies has been linked with practical research work in IFIP's laboratory and consultation with many experts in toxicology.

(c) Information Activities

The results of scientific investigations sponsored by IFIP, as well as information of more general interest, are published.

(d) Assistance to National and International Authorities

IFIP does not judge the acceptability of irradiated foods. However, when requested by regulatory bodies responsible for such decisions, IFIP is willing to provide information and advice.


## 1. INTRODUCTION

The potential of irradiation as a means of food preservation has been recognised for many years. However, because ionising radiation is itself widely known to be dangerous to man, the irradiation of food has always been regarded with suspicion. Although much mistrust of the process is based on misunderstanding of the physical properties of radiation, it has to be accepted that the possibility of radiation-induced effects on food quality or safety can only be excluded definitely by means of thorough scientific investigation. Irradiated foodstuffs have been under study for a long time. The early work in this field, however, involved testing methods which later came to be regarded as inadequate. In 1964, an Expert Committee set up jointly by the Food and Agriculture Organisation of the United Nations (FAO), the International Atomic Energy Agency (IAEA) and the World Health Organization (WHO) made recommendations which were adopted internationally as the basis of acceptable procedures for testing irradiated food. The recommended procedures involved the feeding of large numbers of animals, of at least two species, for a period of about two years. The animals were to be studied for any adverse effects on health or reproductive capacity. Studies which complied with these recommendations were expensive, time-consuming and required extensive facilities and trained staff.

By the end of the 1960's, interest in food irradiation was being expressed in many different countries and a large number of food items were being considered for treatment. Because of the potential importance of the process, the cost of biological tests and the danger of unnecessary duplication of effort, international collaboration on food irradiation became highly desirable.

One international project had in fact been set up in 1964 at Seibersdorf, near Vienna, Austria. Called the International Program on Irradiation of Fruit and Fruit Juices, the project was organised by the Österreischische Studiengesellschaft für Atomenergie G.m.b.H., the Nuclear Energy Agency (NEA) of the OECD*, and the IAEA. Although limited in scope and running for only three and a half years, this project laid some of the groundwork for a more comprehensive international program.

After detailed discussions between the Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture, the NEA, and interested countries, the International Project in the Field of Food Irradiation was set up on 14 October 1970 by an International Agreement. Organisations, usually the Atomic Energy Agencies, in 19 countries signed the agreement to set up a project for 5 years from 1 January 1971. The First Extension Agreement was signed at the Board of Management meeting in Paris on 17 December 1975 on behalf of 23 participating organisations for the three years 1975–1978. The Second Extension Agreement was signed at the Board of Management meeting in Paris on 20 December 1978 on behalf of 24 participating organisations for the three years 1979–1981. Membership has now grown to 25 countries since 1978. The other international organisations with interest in IFIP are the Bureau Eurisotop of the Commission of the European Communities (since 1972 an observer at the Board of Management) and the Division of Geophysics, Global Pollution and Health of the United Nations Environment Programme (UNEP) (since 1976 the Division Director was been an observer at the Scientific Program Committee).

## 2. PROJECT ADMINISTRATION

The Project is supported by contributions from the participating organisations. The participants can choose between two levels of contribution, depending on the extent to which they wish to exercise control over the Project's activities. An annual contribution of not less than US $5 000 is required for participation and this entitles the member country to send a representative to the Board of Management. Countries contributing US $25 000 or more are also entitled to individual representation on the Scientific Program Committee (SPC). Participants paying US $5 000 have organised themselves into groups of five countries, each of which is represented by one delegate at the SPC, often in rotation. As an alternative to financial contributions, participants may offer supplies or services required by the Project at a suitably reduced cost as an "in kind" contribution.

Matters of general policy are decided by the Board of Management while scientific policy is the responsibility of the Scientific Program Committee. Both these bodies meet twice each year. All scientific results originating from Project activities as final reports are freely available; interim reports and results are available only to the Signatories and certain international agencies, including WHO.

The day-to-day administration of the Project is the responsibility of the Project Director who, with a Scientific Officer, Information Officer and their assistants, is based at the Federal Research Centre for Nutrition in Karlsruhe, West Germany.

The Federal German authorities, in addition to their financial contribution, generously provide the Host Centre facilities free of charge. These include offices, laboratories and the services of the Project Director's secretary and a laboratory assistant. The salary and expenses of the Project Director are provided for by the IAEA and the secretariat is provided by OECD.

**TABLE 1**
**PARTICIPANTS AND CONTRIBUTIONS TO IFIP**

| | | | |
|---|---|---|---|
| France | | $ 27 500 | |
| Germany, Federal Republic of | | $ 27 500 | |
| Iraq | | $ 27 500 | |
| Netherlands | | $ 27 500 | |
| South Africa | | $ 27 500 | |
| United Kingdom | | $ 25 000 | |
| Austria | | $ 5 500 | |
| Belgium | | $ 5 650 | |
| Brazil | | $ 5 500 | |
| Denmark | approx. | $ 12 750 | (Dkr. 70 000) |
| Finland | | $ 5 500 | |
| Ghana | | $ 5 500 | |
| Israel | | $ 5 000 | |
| Italy | | $ 10 000 | |
| Japan | | $ 5 000 | |
| Norway | | $ 5 500 | |
| Portugal | | $ 5 500 | |
| Spain | | $ 5 500 | |
| Sweden | approx. | $ 11 700 | (Skr. 52 000) |
| Switzerland | | $ 5 500 | |
| Turkey | | $ 5 000 | |
| United States | | $ 6 500 | |
| | | $268 100 | |
| Contributions in kind: | | | |
| Hungary | | $25 000 | |
| India | | $ 5 500 | |
| | | $30 500 | |

*Nuclear Energy Agency (NEA), formerly the European Nuclear Energy Agency, of the Organisation for Economic Cooperation and Development (OECD)*

## 3. OBJECTIVES OF THE PROJECT

The task of the Project were defined in 1970 and although some reorientation of these aims has occurred, they are basically still valid today.

The objectives laid down in 1970 were thus:

(a) Wholesomeness testing of irradiated foods.

(b) Research on and investigations into the methodology of wholesomeness testing.

(c) Dissemination of information resulting from the work undertaken and other information concerning wholesomeness testing of relevance to the program.

(d) Assisting national and international authorities in their consideration of the acceptance of irradiated food.

The First Extension Agreement of 1975 redefined the objectives as follows:

(a) completion of wholesomeness-testing studies under way or planned (re-irradiated wheat, fish, rice, spices and mangoes),

(b) wholesomeness testing and related studies on other products or groups of products to provide the required additional data,

(c) systematic review and evaluation of the relevant data in the scientific literature to identify the nature of chemical changes induced in foods by irradiation and assessment of the possible toxicity which might result,

(d) preparation of comprehensive data files on the wholesomeness of individual irradiated foods and groups of foods for consideration by the national authorities of the Signatories, Joint FAO/IAEA/WHO Expert Committees or other national or international authorities,

(e) investigation of more practical research procedures for determining the effects of irradiation on the wholesomeness of foods,

(f) other studies as may be determined by the Scientific Program Committee,

(g) dissemination of information resulting from the work undertaken and of other information concerning wholesomeness testing of relevance to the program,

(h) assisting national and international authorities in their consideration of the acceptance of irradiated food.

The publication of the Report and of the Recommendations of the 1976 Joint FAO/IAEA/WHO Expert Committee on the Wholesomeness of Irradiated Food, and the acceptance by the Codex Alimentarius Commission in 1978 of a Draft General Standard on Irradiated Foods in international commerce as well as a Draft Code of Practice for the operation of Irradiation Facilities Used for the Treatment of Foods led the Signatories of the Second Extension Agreement to reorientate the program of the Project as follows:

(a) provision of the necessary data to permit the 1980 JECFI to recommend acceptance of foods processed by irradiation at dose levels not exceeding 10 kGy (1 Mrad) as being, in general, safe for consumption by man,

(b) provision of the additional toxicological data requested by the 1976 JECFI in relation to irradiated onions, rice and fish together with other foods investigated by the Project including totally irradiated food composites simulating human diets.

(c) assembly of surveys on the effect of using irradiated laboratory-animal diets on the natural incidence of disease and cancer in laboratory species compared to heat-sterilised laboratory animal diets,

(d) in-house methodological research into the application of short-term mutagenicity studies to irradiated foods as a screening system for biologically active radiolytic compounds complemented by outside contracts for techniques not available at the Project laboratory,

(e) updating the review of radiation chemistry data and provision of further radiochemical information supporting the extrapolation of safety data within major classes of foods and between various classes of foods,

(f) coordination of current national programs in radiation chemistry whatever the food or food components involved, in order to fill the existing gaps in information (CORC program).

It should be stressed that the basic function of the Project has always been to facilitate the objective evaluation of the wholesomeness of irradiated foodstuffs. It is not concerned with promoting the use of the process or with assessing or improving its economic feasibility.

## 4. ACHIEVEMENTS

4.1 As mentioned above, the accepted method of testing irradiated foodstuffs, was in 1970, the long-term animal feeding study. Because such experiments required extensive facilities, which were already available in a number of countries, the Project decided to carry out its wholesomeness testing on a contract basis, using established and experienced laboratories. The details of the test procedures, however, were worked out by members of the Project.

As a first priority, studies were initiated on irradiated potatoes, wheat and wheat products which has been recommended a temporary (5 year) clearance in 1969 by the first Joint FAO/IAEA/WHO Expert Committee. Additional foodstuffs were chosen on the basis of four factors:

(a) Interest in the product as a staple food entering into international trade;

(b) The interests of developing countries;

(c) The extent to which the product lends itself technically and economically to irradiation treatment;

(d) The desirability of giving priority to products to be irradiated at low or medium doses.

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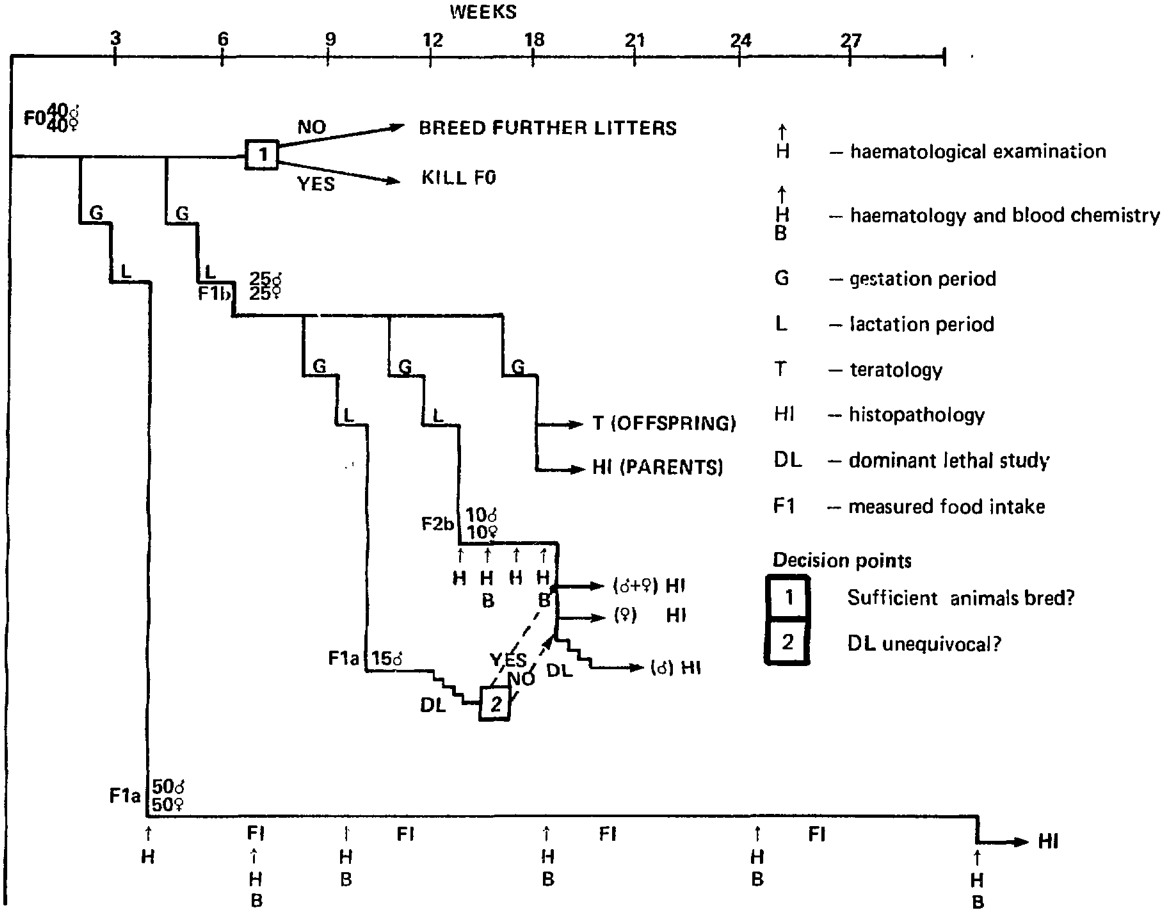
The products chosen included fish, rice, spices, mangoes, dates and onions.

**TABLE 2**
**PROTOCOL FOR ANIMAL STUDIES ON IRRADIATED MANGOES**




The methods used for wholesomeness testing have varied somewhat from study to study but have all involved the incorporation of the foodstuff under test into the diet of laboratory animals. Groups of animals fed on a diet containing the irradiated product have been observed over a long period of time and their health and reproductive capacity compared with that of animals receiving a standard diet containing the unirradiated foodstuff. Some of these studies have been continued for 2 years, while others have been of only 90 days duration. Many different factors have been taken into account in assessing the effects of the irradiated food, including rate of growth, incidence of disease (including cancer), changes in haematological and biochemical parameters and chromosomal abnormalities. During the studies, the animals have been allowed to breed and several generations have been studied for changes in fertility and abnormalities in the offspring. At the end of the tests, tissues have been examined microscopically for signs of disease.

In none of these studies was any significant effect observed which could be attributable to the irradiation treatment received by the food administered to the laboratory animals.

Recognition of the likely validity of the arguments put forward by the Project regarding the relative insensitivity of animal feeding tests for detecting subtle effects due to a few ppm of radiation-induced products, the obscuring of toxicological effects by the adverse effects of the gross dietary alterations consequent upon incorporation of a high percentage of food components into the laboratory animal diet, and the precipitous escalation of the costs of animal feeding studies enabled the Project to abandon this unprofitable objective and to gain acceptance of the view that only a few animal studies are needed in future for wholesomeness purposes. These would provide very specific but essential data.

4.2 A considerable effort aimed at identifying areas of insufficient knowledge of radiation-induced changes in major food components culminated in the publication of the monograph "Radiation Chemistry of Major Food Components" in May 1977.

4.3 The preparation of the appropriate working papers and monographs for the 1976 (September) meeting of the Joint FAO/IAEA/WHO Expert Committee, as well as the carrying out of the secretarial work related to the preparation of the Report of the meeting could be regarded as another achievement of the Project.

4.4 As a consequence of the successful outcome in terms of international acceptance of the wholesomeness of certain irradiated foods, the Project became the official representative of OECD at the sessions of the Codex Committee on Food Additives under the joint FAO/WHO Food Standards Program. The Project, jointly with the IAEA, was instrumental in preparing the Draft General Standards on Irradiated Foods and the Draft Code of Practice for the Operation of Irradiation Facilities Used for the Treatment of Foods and in getting these Drafts accepted at Step 8 of the Codex Alimentarius Procedure for developing internationally accepted standards for items in international trade.

4.5 It was recognised very early on in the Project's work that it would not be practicable either within or outside the Project, to carry out long-term animal feeding studies on every individual food item which might be considered for processing by irradiation. This problem could only be alleviated by the use of other test methods, the simplest of which dealt rather specifically with genetic effects. It was clear that some reliance would have to be placed on generalisations drawn from the results of a limited number of wholesomeness tests. Since the effects of radiation on a foodstuff depend on its composition and structure, the changes occurring in closely related types of products would be expected to be similar. The biological effects, if any, of irradiated foodstuffs of similar composition e.g. different types of grain, or lean meat from different species of animal, would therefore be expected to be comparable. However, no two foodstuffs are identical in composition and in order to prove the validity of extrapolating the results of wholesomeness tests, it has been necessary to study in some detail the chemical changes induced in different foodstuffs by irradiation. The Project has commissioned little practical work in this field but has engaged expert consultants to write reviews on many aspects of radiation chemistry and through its Coordinated Program on the Radiation Chemistry of Food and Food Components has organised meetings and discussions.

The international coordination of radiation chemical research was essential, if a substantial body of relevant information of the safety of the irradiation process were to become available for the next Joint Expert Committee. The Project successfully designed and managed this coordinated program (CORC program) by holding regular meetings of participating research laboratories. A comprehensive review of these efforts will be submitted to the 1980 JECFI as a basis for predicting with confidence the effects of the irradiation process on food.

4.6 Finally it behoves me to review the efforts of the Project in regard to *methodology research.*

Scientific methods and ideas are constantly developing and the type of data required by regulatory authorities tends to change accordingly. The effects of such developments were felt in the food irradiation field well before the International Project was set up. A large number of wholesomeness studies carried out in the 1950's, using protocols which were then considered adequate, were by 1964 regarded as incomplete and unacceptable. To avoid the recurrence of such problems, the Project has devoted considerable attention to reviewing and up-dating its testing procedures. A continuous study of the scientific literature and the publications of regulatory bodies has been linked with practical research work in the Project laboratory and consultation with many experts in toxicology.

The results of this work are reflected in the careful design of the Project's animal feeding studies and in a diversification of the testing methods used. In the Project's own laboratory, the effects of irradiated food on the immune system of the rat have been studied and several genetic tests using cultured mammalian cells have been employed. In recent years, the advent of a number of simple, short-term and highly sensitive tests for mutagenicity has opened up new possibilities for the detection of possible genetic effects of irradiated foods. The Project has investigated these new test systems and has adapted them where necessary to its own specific requirements. A comprehensive program of mutagenicity testing, involving many different methods, and carried out in the Project laboratory and elsewhere under contract, is underway at present.

The procedures developed by the Project for testing irradiated foods by short-term mutagenicity screens to detect the presence of carcinogenic or mutagenic products possibly derived from the irradiation processing, have applications beyond the wholesomeness aspects of irradiated foods. The methodology is of a general nature and can be used to investigate the effects of any form of food processing on the toxicological qualities of the treated food.

A large body of data on the radiation chemistry of foods has now been collected which is of great value not only in assisting extrapolation but also in its own right. The identification and measurement of chemical substances produced in foods after irradiation is extremely useful in assessing the possible health hazards of consuming irradiated foods. See Figs. 1 and 2.

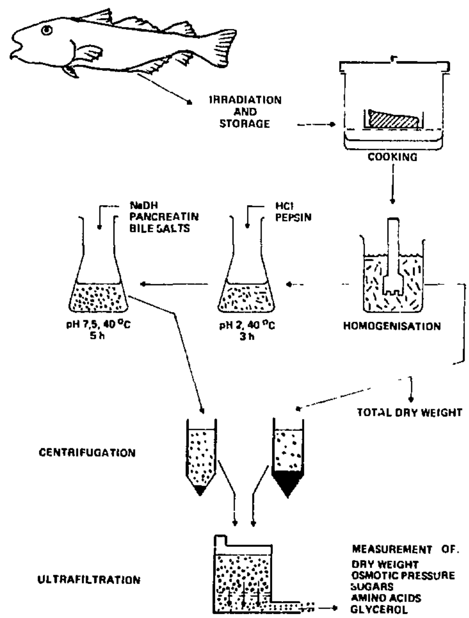



*Fig. 1*

*Preparation of food samples for testing* in vitro *e.g. fish*

p2p6

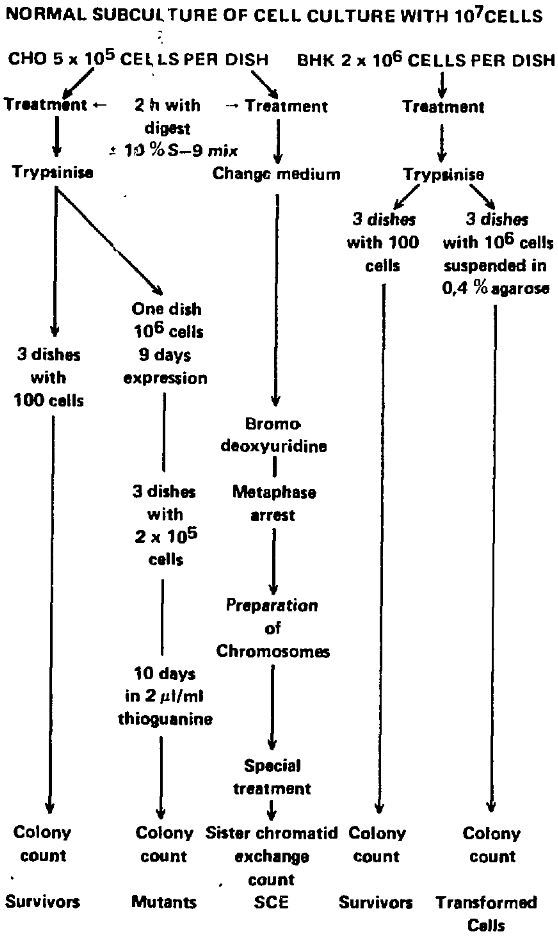



*Fig. 2*
*Treatment and testing of cells with food samples*

## 5. INFORMATION ACTIVITIES

The results of scientific investigations sponsored by the Project are published in Project Technical Reports which now number over 50. Information of more general interest, including reviews and reports from other organisations, is published in the Project bulletin "Food Irradiation Information" which appears at approximately yearly intervals and is distributed throughout the world.

In addition, the Project's Information Section stores and collates reports published in the field of food irradiation and is at present involved in processing for computer storage much of the earlier published information which has not previously been available in this form.

## 6. ASSISTANCE TO NATIONAL AND INTERNATIONAL AUTHORITIES

It is not the function of the Project to judge the acceptability of irradiated foods. However, when requested by the national and regulatory bodies responsible for such decisions, the Project is always willing to provide information and advice.

## 7. THE FUTURE

The Project is due to be terminated in 1981. The present program of work will of course continue until this time. In October 1980, however, a Joint FAO/IAEA/WHO Expert Committee will meet once again to consider the acceptability of the irradiation processing of food. The outcome of the meeting will be crucial for the future of the process. The Project is thus presented with the clear objective of bringing together the results of its entire work program as an aid to the deliberations of this Committee.

## 8. CONCLUSION

The wholesomeness of irradiated foodstuffs has been studied for a long time by very many workers throughout the world. The International Project in the Field of Food Irradiation has played a significant role in the accumulation of wholesomeness data and has acted as a valuable forum for discussion and coordination of effort between nations interested in this new technology.

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## DISCUSSION

**Question:** Would you please explain the principles applied by the expert committee in judging wholesomeness based on the data presented to them? What weight will the judgement carry because with the exception of South Africa it seems that very few other countries have responded positively to the findings of the 1976 committee? As a result of the findings six to seven products have been unconditionally cleared in South Africa.

Answer: I am afraid the system of having an expert committee judging irradiated foods is a legacy which has burdened us since the project started. (I think even before that.) It arises, in fact, out of the American legislation and it's a cross, I think, that irradiated food has to bear. It is a present that was given to us way back in 1950. In the American Food and Drug Act, processing is treated as an additive. This is legal for America and we just have to face the fact. It is for this reason that, in the early stages, food irradiation processing was considered an additive to the food. Since way back in the early fifties food additives have always been assessed on an international basis by a Joint Expert Committee of FAO and WHO. This Committee has been looking at the safety of additives regularly year after year for the last 25 years. This Expert Committee acts as an advisory committee to the Codex Alimentarius Commission on the safety of these additives as to whether or not these additives should be incorporated into international standards. The idea is that if an international codex standard is prepared, all the member states of Codex, there are over 180 of them, should abide by it. A country should not refuse to accept the food of another country. If the food complies with the Codex standard it should be acceptable.

The earliest committee to judge the safety of irradiated foods was therefore set up as an exact mirror of the Food Additives Committee which advises on Codex standards. That is how the first Joint FAO/IAEA/WHO Committee came about. This Committee met in 1964, 1969 and 1976 and I hope will meet for the last time in 1980. It took from 1964 to 1976 to satisfy those concerned with the toxicological aspects that food irradiation was a process and not an additive. The minute this happened, it lifted the whole problem out of the additive approval procedure into a process approval procedure.

Now many countries have long lists of approved additives which they change every so often, depending on the results of the Joint Expert Committee sitting in Geneva. I think the same thing has happened now. Those countries which can treat processes in their legal systems can accept the decision of the 1976 Committee and allow irradiated goods to go on the market as processed food. We have similar legislation in the United Kingdom. The handling of irradiated foods by legislation around the world is basically very simple. The process is forbidden and then exceptions are made. It is stipulated exactly what food may be irradiated under what conditions after which it may be marketed. It is a very easy device designed by legislators to make their lives less cumbersome. It also has the advantage, if I may say so, of absolute control. If legislation worked the other way round, by negative legislation, certain commodities would be forbidden leaving a wide open field with everything else uncontrolled. There is long experience with this form of legislation.

This legislation is the reason why one will find that in some countries nobody has yet approached the government to make the exception to this legislation. There are a number of these applications at the present time, e.g. in Canada, the United States, on various commodities to the FDA and there are possibly, I hope, several to come in the United Kingdom. The committees will then have to decide on the advice they will give the governments on whether or not they could permit the marketing of irradiated food. But it is a matter of applying to the government for permission.

**Question:** I understood that there has been a submission to Congress in America to change the additive amendment in the Food, Cosmetic and Drug Law which would assist in furthering the application of irradiation to food. Could you perhaps tell us something about this?

**Answer:** I know the submission is going in. But what does it really involve? The Food and Drugs Act in America would have to be changed which is a major political effort. No country is going to change its basic Food and Drugs Act unless there is a lot of time and the politicians are willing to do it. At the moment the situation is that irradiation is still classified as an additive. The Federal Register gives a long list, about six pages, of all the things required of an additive. Because it is classified as an additive, irradiated food must exhibit all the characteristics of an additive given on the list. Every item on the list must be checked. That is why we have been condemned to do these rather expensive and really unprofitable feeding experiments. The experiments do not tell us anything except that the rat does not like so much fish or too much potatoes or papayas. Nothing else. This is not the normal food of the rat, they do not have 40 to 60 % of their diet consisting of papayas. I'm not surprised that they don't like it and die earlier than they should. The idea was to try and pick up the presence of 1 ppm of maybe an aldehyde or ketone or some supposedly toxic compound in the food. One feeds the food to a group of fifty rats and hopes that after two years something can be seen. One spends ½ million dollars and observes nothing.

**Question:** As somebody interested in nutrition as a fundamental approach to the treatment of all kinds of disease, I think you will agree that we are being bedevilled for a long time by food processing procedures which have certainly very adversely affected mineral and many other aspects in food, particularly mineral calcium, as an example. There is one area which is very badly neglected (I think that in this field your approach is going to come pretty close) and that is the question of enzymes and co-enzymes. These are very difficult to detect even in animal experiments because they are notoriously often not applicable to human conditions. Your close relationship between enzyme and trace elements is, I think, a vitally important factor. I am wondering whether during the procedures this aspect will be touched upon. I think it is going to be a vital factor in our ultimate assessment of the irradiation of foods.

**Answer:** Well, my technical friends tell me that enzymes are in fact pretty insensitive to irradiation. Please do remember I am interested particularly in getting clearance for the process up to 10 kGy. I do not wish to go beyond that because that dose limit will cover 99 % of the technological applicability in developed and undeveloped countries. Special areas where higher doses must be used are more difficult, but these, I think, are not for general release of irradiated food. Most of the doses are all below 10 kGy and at that level (a) no radioactivity is induced – the energy is far too low, and (b) no major changes are induced in the constitution of the proteins, no amino acids are destroyed although a couple of peptide bonds may break, but that is all. Carbohydrates are not changed except that some of the chains are broken down. Not much happens to the fats either. Basically, the nutritional quality is not affected. However, some of the vitamins are radiosensitive and some of the vitamin content is destroyed. That is not such a problem because the whole diet is not irradiated. Therefore, if some vitamin is lost in one food, it can be made up for in another. Furthermore, vitamins can always be added to the food if one feels that a major supply of the vitamin is being lost. This has been done with bread and margarine where the vitamins are added automatically.

**Question:** What are your own views on the outcome of the Joint Expert Committee meeting next year, i.e. of actually clearing the process up to 10 kGy?

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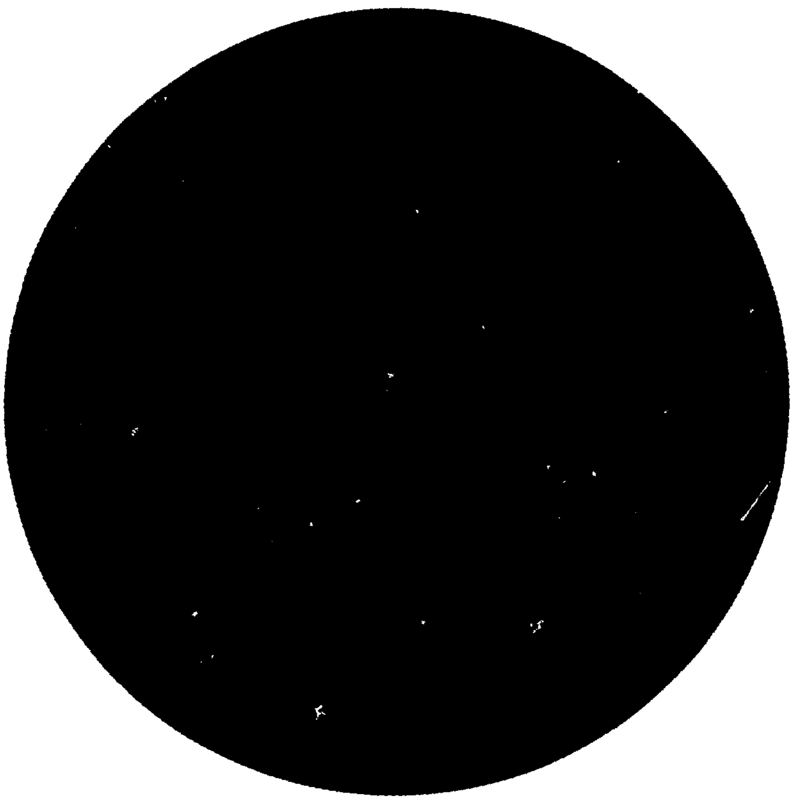
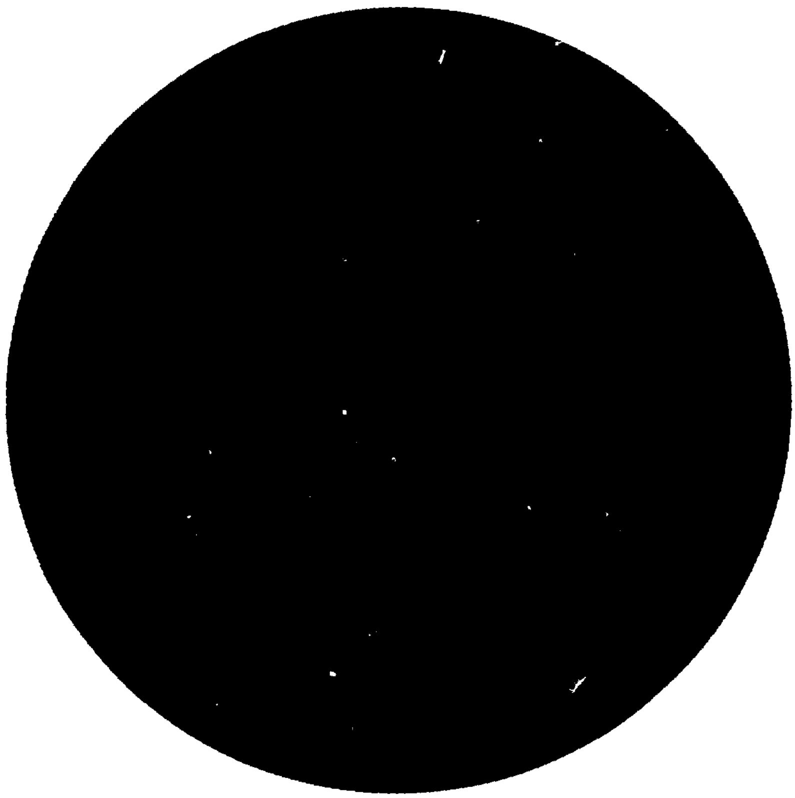
**Answer:** We have attempted to provide a methodology to pick up what people are concerned about in irradiated food — the induction or production of materials which could produce cancer or have a mutagenic effect. We can now use these procedures to screen irradiated food. Just as other commodities are checked for carcinogenicity and mutagenicity, irradiated food can now be checked quite quickly. On the other hand, if ordinary traditional cooking procedures are applied and the cooked food is tested, it is unfortunately found that they give positive results in the short-term tests while the irradiated foods don't. Well, I can't say that one can use this as an argument. All I can tell you is that every day some American discovers a new mutagen in his hamburger, or broiled steak or broiled fish — the literature is full of this. Our traditional methods of cooking and roasting i.e. heating, produce compounds in the food which do react positively in these new short-term systems. These are in fact carcinogens and mutagens which I have not so far detected in irradiated food. I hope I have made a point (which will come home to the Committee in 1980) in all the animal experimental evidence and the chemical evidence, plus our short-term work. If they want any more evidence and don't accept the work up to now, I'm afraid they won't accept it in the year 2000.



## SESSION I

## GENERAL BACKGROUND

CHAIRMAN: DR H J VAN DER LINDE
*Chemistry Division, Atomic Energy Board, Pretoria*



ZA8000314



# THE DEVELOPMENT OF SOUTH AFRICA'S FOOD IRRADIATION PROGRAM

P G MARAIS
*Fruit and Fruit Technology Research Institute, Stellenbosch*

## SAMEVATTING

In Suid-Afrika is die eerste voedselbestralingseksperimente deur die Navorsingsinstituut vir Vrugte en Vrugtetegnologie te Stellenbosch op aartappels, druiwe, perskes, vrugtesappe en appels uitgevoer. Die resultate was belowend genoeg om verdere navorsing te regverdig. In 1970 is 'n saamgestelde program deur die RAK en die Departement van Landbou-Tegniese Dienste begin. Sedert 1971 neem Suid-Afrika, saam met 23 lande, deel aan die Internasionale Voedselbestralingsprojek (IVBP).

'n Belangrike aspek van voedselbestraling is om die veiligheid daarvan vir menslike gebruik te bewys. Die IVBP-program dek die meeste van hierdie werk. Nogtans het Onderstepoort 'n korttermyn-voedingstudie van bestraalde mango's onderneem. Op Pelindaba word navorsing na 'n waterige model gedoen om die chemiese veranderinge te voorspel wat in die bestraalde vrugte plaasvind.

Die navorsingsprogram te Pelindaba het praktiese resultate ten opsigte van subtropiese vrugte soos mango's, papajas, avokado's en lietsjies gelewer. Daar is ook aandag aan hoendervleis, sampioene, aartappels, uie, knoffel en aarbeie geskenk. In 1977 is 'n aanvooraanleg in samewerking met die Letaba-koöperasie te Tzaneen opgerig.

Die Departement van Gesondheid is intiem betrokke by hierdie saak. In SA is bestraalde aartappels in Januarie 1977 onvoorwaardelik vir bemarking vrygestel. Sedertdien is bestraalde papajas, mango's, aarbeie, uie, knoffel, hoender, gedroogde piesangs en avokado's ook vrygestel. Die verbruikers het gunstig gereageer. Die verbeterde gehalte van die produkte het die hoër koste geregverdig.

## ABSTRACT

The first experiments on the irradiation of food in SA were conducted at the Fruit and Fruit Technology Research Institute in Stellenbosch on apples, grapes, peaches, fruit juices and potatoes. The results were sufficiently promising to warrant further research and in 1970 a joint program was initiated between the AEB and the Dept. of Agricultural Technical Services. Since 1971, South Africa has participated with 23 other countries in the International Food Irradiation Project (IFIP).

An important aspect of food irradiation is to prove the safety of the product for consumption. Most of this work is covered by the IFIP-program. However, a short-term feeding study was undertaken at Onderstepoort on irradiated mangoes, while at Pelindaba there has been an investigation using an aqueous model to predict the chemical changes which take place in irradiated fruits.

The research program at Pelindaba has yielded practical results with subtropical fruit such as mangoes, papayas, avocados and litchis. Other products also received attention, such as chicken, mushrooms, potatoes, onion, garlic and strawberries. A pilot plant was erected jointly with the Letaba Cooperative at Tzaneen in 1977.

The Department of Health has been closely involved. In January 1977 irradiated potatoes were unconditionally cleared for sale in South Africa. Since then irradiated papayas, mangoes, onions, garlic, chicken, strawberries, dried bananas and avocados have been cleared. Consumers reacted favourably. The improvement in the quality of the product more than warrants the additional cost involved.

## 1. INTRODUCTION

Food spoilage remains a worldwide problem despite many food preservation methods being used. These include cold storage, freezing, canning, fumigation and drying. Severe forms of foodstuff spoilage are mainly biological and are caused by micro-organisms such as bacteria, fungi and yeasts. These organisms can be destroyed by ionising rays, such as gamma rays from cobalt-60, and the use of such rays for preserving foodstuffs has created great interest throughout the world. In fact, the first patent on the use of food irradiation as a preservation technique was taken out in France in 1929.

It has been calculated that some 40 % of South Africa's agricultural produce, valued at R500 million annually, is being destroyed through decay and other factors[1]. It was therefore only natural for South African agricultural and other scientists to investigate the use of ionising radiation in combating these vast losses.

South Africa's involvement in food irradiation can be traced back to the Second United Nations International Conference on the Peaceful Uses of Atomic Energy, held at Geneva in September 1958. The then Head of the Section for Radioisotopes at the Fruit and Fruit Technology Research Institute (FFTRI) attended this conference where several papers from England, France, Norway and Russia described promising results obtained on the irradiation of various fruits, vegetables, grain and egg products. During the conference Russia announced that the sale of irradiated potatoes was allowed for human consumption in that country — the first clearance of irradiated food in the world.

The officer concerned also visited Norway, France and England after the conference to study food irradiation preservation techniques and the design of irradiation units. On his return he submitted a report to his Director recommending the installation of a cobalt-60 irradiation unit at the FFTRI and the launching of a food irradiation program. These recommendations were accepted and the funds for the unit were obtained from the Deciduous Fruit Board. The cobalt-60 unit (488 curies) obtained from the United Kingdom Atomic Energy Agency at Harwell in England was installed at the FFTRI in Stellenbosch on 19 July 1961[2], [3].

## 2. FIRST EXPERIMENTS

In the first experiments various fruits were first infected with organisms which cause rotting of the particular fruit. The infected fruits were then subjected to a wide range of radiation doses. After irradiation the fruits were stored at 21 °C to create an environment conducive to the development of any surviving organisms. Some of the results, obtained by *Matthee* and co-workers are now briefly discussed[4].

### 2.1 Golden Delicious Apples

The most important fungus causing rotting in apples is *Penicillium expansum*. Quantities of green and ripe apples were inoculated with this organism by making a small hole in the sides of the apples and placing the fungus inoculum in the hole. The apples were then divided into six different groups. One group was not irradiated and the others were exposed to increasing radiation doses. The depth of fungal penetration was determined after ten days at 21 °C. The results are summarised in Table 1.

**TABLE 1**
**THE INFLUENCE OF GAMMA IRRADIATION ON FUNGAL PENETRATION IN GOLDEN DELICIOUS APPLES**

| Radiation dose in kGy | Fungal penetration in mm | |
|---|---|---|
| | Green apples | Ripe apples |
| 0 | 22,7 | 21,0 |
| 0,98 | 23,7 | 23,0 |
| 1,96 | 24,0 | 23,9 |
| 2,93 | 17,9 | 14,1 |
| 3,91 | 16,4 | 6,9 |
| 4,89 | 6,7 | 3,7 |

From these results it is clear that gamma rays were extremely effective in reducing fungal penetration in the apples. In the control apples, the penetration was more than 20 mm, while at the maximum radiation dose (4,89 kGy) it was only 6,7 and 3,7 mm for the green and ripe apples, respectively. Reduction in penetration was therefore more than threefold in the case of green apples and sixfold in the case of ripe apples. Although there was practically no rotting at the maximum dose, a considerable amount of rotting occurred in the control apples and in the apples subjected to the smaller radiation doses. At the smallest radiation doses (0,98 and 1,96 kGy) rotting was even accelerated. Although it is therefore possible to control the fungus *P. expansum* in apples by means of gamma rays, the radiation dose must be carefully determined, otherwise the fungus may be stimulated and spreading thereof accelerated, or the rays may cause changes in the apples which may be conducive to development of the fungus.

The gamma rays had a distinct effect on the colour of the apples. Both the green and the ripe control apples retained their normal colour until the end of the experiment. The irradiated apples, on the other hand, not only developed a yellow colour which increased in intensity as the radiation dose was increased, but the tissues of these apples also became softer as radiation doses increased. Thorough investigation of these secondary effects of gamma rays will be necessary before general application of the radiation technique is resorted to.

### 2.2 Waltham Cross Grapes

*Botrytis cinerea* causes considerable damage in grapes. In some seasons as much as fifty percent of the crop could be lost in one season due to this disease. In this experiment Waltham Cross grapes were infected with *Botrytis cinerea* and at various periods after infection they were exposed to a range of radiation doses and stored at various temperatures. The results were extremely promising and it appeared that relatively low doses (ca. 1,0 kGy) could be used to control *Botrytis* decay. At high doses (ca. 5,0 kGy) the gamma rays had a definite effect on the colour of the grapes; they turned brown and developed an off-flavour.

### 2.3 Kakamas Peaches

The fungus *Rhizopus stolonifer* is the main cause of spoilage in stored peaches. Kakamas peaches were inoculated with this fungus and exposed to increasing radiation doses (0, 1,30, 2,25 and 4,90 kGy). The peaches were then stored at 21 °C. Gamma rays proved very effective in controlling this fungus, for while the control peaches were almost completely rotten within four days, there was a rapid decrease in rotting with increasing doses. With the highest dose (4,9 kGy) there was practically no rotting.

### 2.4 Fruit Juices

Preliminary experiments were conducted to determine to what extent gamma rays could be used for sterilising fruit juices in order to improve their quality. In one of the experiments three types of grape juice were subjected to a series of radiation doses, after which dilution plates were poured on yeast agar. After two days at 28 °C, the number of surviving yeast counts that had developed on the agar plates was determined.

**TABLE 2**
**SURVIVING YEAST COUNTS IN GRAPE JUICE AFTER GAMMA IRRADIATION**

| Exposure Dose in kGy | Number of Surviving Yeast Cells per $cm^3$ of Grape Juice | | |
|---|---|---|---|
| | Fresh juice with wild yeast | Clarified juice | Fresh juice with culture yeast |
| 0 | 4 815 000 | 1 342 000 | 4 170 000 |
| 1,29 | 48 700 | 3 000 | 315 000 |
| 2,24 | 28 200 | 480 | 192 000 |
| 4,89 | 0 | 0 | 22 000 |

The results in the first two columns of Table 2 show very clearly that gamma rays are extremely effective for controlling the development of yeast cells. In the case of fresh juice inoculated with a yeast culture some cells still survived at the maximum radiation dose (4,89 kGy) and a higher dose would therefore be necessary for complete destruction.

## 2.5 Potatoes

As early as 1954 Sparrow and Christensen[5] of the USA reported that "potatoes irradiated with 0,20 kGy were still firm and excellent in appearance after 18 months of storage". Mass losses were reduced considerably and no undesirable taste was found. These results have since then been confirmed by many research groups in several countries. However, since the best radiation dose to be used is determined by factors such as cultivar and storage conditions, the irradiation of potatoes was included in the FFTRI program[6].

In one of the experiments two cultivars (Up-to-Date and Arran Chief) were used. These were subjected to 0, 0,11 and 0,44 kGy and then stored at 7 °C and 18 °C. The main features of the results were that an exposure dose of 0,44 kGy was completely effective in preventing sprouting in both cultivars and at both temperatures, even after a storage period of five months, and that a lower storage temperature required a lower dose to inhibit sprouting.

These results obtained at the FFTRI were generally in agreement with those obtained in other countries and proved that micro-organisms which cause rotting in fresh fruit could be controlled effectively by means of gamma rays. By using relatively low doses, sprouting in potatoes was inhibited. The results were sufficiently promising to warrant semi-commercial trials, but although the cobalt-60 source at the FFTRI was later replaced by one with a tenfold higher activity, only small-scale food irradiation experiments could be conducted. The radiation unit was therefore used mainly in insect sterilisation studies and for the induction of mutation in plants.

# 3. NATIONAL PROGRAM ON RADIATION APPLICATION IN AGRICULTURE

In 1970 a joint or national program on radiation applications in agriculture was initiated by the Atomic Energy Board and the Department of Agricultural Technical Services. The necessary radiation facilities were available at Pelindaba and experiments were conducted in co-operation with several research institutes of the Department of Agricultural Technical Services, as well as fruit producer organisations. Progress in this field is closely scrutinised by a National Subcommittee, and more recently a Coordinating Committee has been formed which is responsible for the overall planning of the program. The Department of Health has been closely involved in all these developments and has kept well in touch with international progress in the field of food irradiation.

This program involved not only actual experiments with fruit (mainly subtropical) and other foodstuffs, but also wholesomeness studies, petitions for clearance, the establishment of a pilot plant and the marketing of irradiated foods. Several research projects are still receiving attention. Some of the results obtained up to date, and the other aspects referred to, will now be reviewed briefly.

## 3.1 Subtropical Fruits

Mangoes, papayas, litchis and avocados received attention and the effect of radiation on the control of insects, fungi and natural processes was studied. In the case of *mangoes* the results are particularly promising[7]. Losses in this fruit are due to three major causes:

(a) The mango weevil which develops inside the seed may emerge and chew its way through the flesh, producing unsightly damage and also enabling micro-organisms to enter and cause disease to develop.

(b) Fungal disease may set in and cause the fruit to decay.

(c) The fruit may ripen too quickly.

A relatively low radiation dose (0,75 kGy) and hot water (at 55 °C for 5 min) treatment controlled all three causes of wastage to such an extent that much wider markets, both locally and overseas, can be reached[8].

Promising results were also obtained by irradiating other subtropical fruits. For example, the saleable life of *papayas* and *avocados* under South African climatic conditions was increased by 6–10 days due to delayed ripening[7]. The *litchi* is a highly perishable product and marketing is limited by severe disease infections. From preliminary experiments it appears that a combination of hot water (46 °C for 20 min) plus 0,75 kGy ensures good fungal control[9].

## 3.2 Strawberries

It was confirmed that the major losses of strawberries under local market conditions are due to "leak" disease caused by *Rhizopus stolonifer*. It was also established that further losses in summer are due to anthracnose caused by the fungus *Colletotrichum acutatum* Simmonds. This is the first time that the latter pathogen has been isolated and identified and recognised as a problem regarding strawberries in South Africa[10].

Investigations with different cultivars clearly demonstrated the synergistic effect of disease control obtained when combining heat and irradiation treatments. A combination treatment (moist heat at 50–52 °C for 10 min plus 2 kGy) controlled both diseases effectively in strawberries, without affecting berry quality.

In simulated transport studies a minimal amount of berry softening occurred with the above treatment, but this was negligible compared with the beneficial effect obtained from disease control. In semi-commercial experiments this treatment effectively controlled "leak" disease for a period of several days since picking.

## 3.3 Deciduous Fruit

Early overseas work on disease control in deciduous fruit was disappointing due to adverse effects on the fruits. However, it is believed that much of this work deserves repetition with improved techniques, including combination treatments. As a start, attention has been paid to *table grapes.*

As already mentioned, one of the most serious post-harvest diseases affecting table grapes in South Africa is *Botrytis* rot caused by the fungus *Botrytis cinerea.* Preliminary experiments were conducted with batches of Barlinka grapes seriously affected by this disease[11]. Excellent control was obtained using a combination of hot water (46 °C for 20 min) plus irradiation at doses 0,75 to 2 kGy. The combination was better than either treatment used alone, again demonstrating the synergistic effect which can be obtained. In these experiments losses were reduced from between 50 and 60 % in the controls to less than 10 % with the combination treatment. This treatment had no adverse effect on the appearance (fruit bloom) or on the taste and odour of the grapes.

### 3.4 Fresh Fruit Juices

Irradiation doses of 2 to 3 kGy effectively reduced yeast counts to well within acceptable limits in orange and apple juice[12].

### 3.5 Sweet Melons

Serious post-harvest losses occur with this fruit as a result of severe fungal infections. A combination of hot dipping and irradiation (0,75 to 1,50 kGy) resulted in a reasonable control, without adversely affecting the taste, texture or colour of the fruit[13].

### 3.6 Dried Fruit

The down-grading and rejection of dried fruits (especially apricots and peaches) result from a browning in storage referred to as the Maillard reaction. Attempts were made to reduce the browning (possibly due to enzymatic action) with irradiation and heat treatments. The sulphur treatment (the method currently being used) was also used and gave the least browning. Various heat plus irradiation treatments were also effective, with the untreated batch being the least acceptable of all the treatments. The sulphur treatment resulted in a sharp, unpleasant taste which was not present in the irradiated samples[14].

### 3.7 Mushrooms

In Holland the authorities have given a full clearance for the sale of irradiated mushrooms in that country. Results from trials in South Africa using the popular white button mushroom showed that the untreated samples all showed signs of cap opening and brown discolouration within 24 to 48 h, whereas the irradiated samples (2 kGy) were all marketable 6 days after picking[15]. Similar results were obtained with the large brown mushrooms where a slimy covering over the cap (due to bacterial contamination) was the main problem causing rejection in the untreated sample.

### 3.8 Potatoes

The potato was the first commodity chosen as a model for the national food irradiation program because of the considerable amount of information already obtained in overseas investigations. The optimum dose for inhibiting sprouting under local storage conditions was determined, while the control of storage diseases of potatoes by means of hot water and heated fungicide dip treatments together with radiation is also receiving attention[16].

Greening of potatoes subjected to 24 h fluorescent lighting in supermarkets is a big problem in South Africa. Semi-commercial trials with Up-to-Date potatoes grown under different climatic conditions were undertaken. The marketable life of the tubers was more than doubled at irradiation doses of 0,15 to 0,20 kGy. Storage of up to 30 days after irradiation before exposure to fluorescent light in no way influenced this result[17].

Several tons of potatoes were irradiated in a trial-marketing study. The tubers sold well and the customers showed a marked preference for the irradiated potatoes.

### 3.9 Poultry

Doses of 3 to 5 kGy were effective in extending the shelf life of commercially slaughtered chickens from 2–4 days to 14–21 days at normal refrigeration temperatures[18]. These doses also eliminated *Salmonella* organisms present on approximately 50 % of the carcasses. Carcasses artificially inoculated with *Salmonella* strains of levels several orders of magnitude higher than normal were also rendered "pathogen free" by the recommended dose. No difference could be detected between irradiated and non-irradiated carcasses when judged organoleptically.

### 3.10 Meat and Fish

The shelf life of cuts of meat for retail marketing, even under good refrigeration conditions, is limited by bacterial growth to 2 or 3 days. Similarly, fresh fish, although rated far superior in taste to its frozen counterpart, deteriorates rapidly at "on-ice" temperatures. Application of a pasteurising irradiation treatment extends the acceptable life of these commodities in the refrigerator for 14 to 17 days, with obvious advantages to supplier and housewife alike. Such a treatment also served to "knock out" any pathogenic bacteria present and therefore eliminated the risk of food poisoning[7].

### 3.11 Disinfestation

Considerable losses of foodstuffs occur in storage due to insect attack, and controlling such insects by means of irradiation is an indirect food preservation technique. The export of certain commodities, such as citrus and deciduous fruit, is also hampered by restrictions imposed by importing countries on commodities which may contain contaminating insects. In the past, chemical insecticides have been widely used for disinfestation, but increasing opposition is developing throughout the world to the presence of chemical residues on foodstuffs and the use of alternative methods, such as ionising radiation, is being tested. The treatment of products with low doses of radiation prior to storage or export serves to kill or, in the case of more resistant insects, to sexually sterilise the pests, thereby preventing their multiplication and keeping damage to negligible proportions. Studies on the elimination of insect pests in deciduous fruits are at present being undertaken at the FFTRI in cooperation with the AEB[7].

### 3.12 Pilot Plant

A very significant development was the commissioning of a pilot plant for the treatment of subtropical fruits at Tzaneen (N. Transvaal) in January 1977. The purpose of this plant is to irradiate commercial quantities of produce for evaluation. This pilot plant has been used successfully to treat mangoes in a commercial sea-shipment trial, as well as several consignments of subtropical fruits such as avocados and papayas which were sent to local markets for evaluation[19].

### 3.13 Present Research Projects

Work on potatoes (control of sprouting and greening), garlic (control of sprouting), citrus (control of fruit fly) and fruit juice (increase of shelf life) have been completed successfully. More than a dozen research projects are at present receiving attention. These include studies on *inter alia* grapes (*Botrytis* control), dried fruit (preservation), guavas (increase of shelf life), litchis (additional work is required), mangoes (fruit fly), mushrooms (packing and shelf life), onions (additional information is required) and meat (preservation of offal, minced meat and cuts of meat). The food irradiation program is therefore still very much alive.

### 3.14 Wholesomeness Studies

An extremely important aspect of the food irradiation program is to prove that the irradiated product is safe for consumption. Although most of the work in this connection is covered by an International Food Irradiation Program, some work has been undertaken in the South African program.

In an animal feeding study, the effects of low-dose gamma irradiation on the wholesomeness of mangoes *(Mangifera indica)* was determined in short-term feeding studies on rats[20].

A control diet and diets containing 150 g non-irradiated or 150 g irradiated mango pulp/kg were given to rats. The study consisted, firstly, of reproduction trials and secondly, performance evaluations on young male rats followed by detailed haematological, blood chemistry and gross pathological examinations. The results were as follows:

(a) Dry matter digestibility and voluntary food consumption of all diets were similar.

(b) No significant differences were noted in the daily live-mass gains of young males, pups, nursing females or females during the immediate post-lactation period in any dietary group.

(c) No differences in haematological or blood values were observed which could be attributed to the feeding of irradiated mangoes. There was no evidence of any toxicity in the irradiated mango diet.

(d) Gross pathologic examinations revealed no aberrations which could be related to the ingestion of irradiated mangoes, nor could any deaths which occurred during the investigation be attributed to this cause.

From these experiments it may be concluded that the wholesomeness of mangoes was not affected by gamma irradiation at a dose of 0,75 kGy. However, further work was required for international acceptance and the AEB succeeded in persuading the IFIP to accept a project on feeding studies with mangoes. This study in which rats were to be fed on irradiated mangoes was allocated to the WARF Institute in Madison, Wisconsin, USA. The AEB had undertaken to supply the fruit on behalf of the IFIP, to irradiate the fruit and to send these to the laboratories concerned. It is hoped that these studies will lead to international trade in irradiated mangoes.

The AEB also studied the changes in ascorbic acid, carotene and sugar present in mangoes, papayas and litchis during gamma irradiation, canning and freezing, using doses which were at least 1,25 kGy higher than those recommended for commercial irradiation[21]. Chemical changes due to irradiation were generally small, amounting to losses of between 0 and 15 %. In comparison, changes due to freezing and heat processing were considerable; losses of the order of 50 to 70 % were recorded.

A concept of using a simple aqueous solution to predict the chemical changes which take place when fruits are irradiated was developed by the AEB[22]. Many studies indicated that the aqueous model provides a satisfactory basis for predicting chemical changes in a wide variety of fruits.

### 3.15 Petitions and Clearances

An important aspect of South Africa's food irradiation program was to submit petitions to the health authorities for the clearance of irradiated foodstuff. These authorities have fortunately agreed to consider the granting of clearances of irradiated products also on the basis of wholesomeness data obtained in other countries, thus eliminating the need for a repetion of expensive and time-consuming feeding studies.

A petition offor the unconditional clearance of irradiated potatoes was approved by the Department of Health in January 1977. Several other petitions followed and the present list of clearances in South Africa is summarised in Table 3, which includes information on the purpose of irradiation and the dose rates.

### 3.16 Marketing of Irradiated Foods

Following the above-mentioned and earlier provisional clearances, attention could be given to the marketing of irradiated foods. South Africa's food industry is of course not only geared to the local market but also to export markets. A commercial shipment of irradiated food was therefore undertaken and for this purpose 1 800 trays of Kent mangoes from the Letaba district were sent to Holland early in 1977. Approximately 80 % of the fruit was treated with a combined hot benlate dip at 55 °C for 5 min, plus radiation at 0,75 kGy. The remaining 20 % served as controls and received only the hot benlate treatment. The consignment was shipped at approximately 11 °C and the period since picking to arrival overseas was 26 days. Results taken one day after arrival in Holland showed that 75 % of the irradiated trays were acceptable compared with only 20 % in the non-irradiated batch[23].

**TABLE 3**
**LIST OF CLEARANCES IN SOUTH AFRICA FOR IRRADIATED PRODUCTS**

| Products | Purpose of irradiation | Radiation source | Dose kGy* | Date of approval | Type of clearance |
|---|---|---|---|---|---|
| Potatoes | Sprout inhibition<br>Delayed greening | Cobalt-60 | 0,12 – 0,24 kGy | 19.1.77 | Unconditional |
| Onion | Sprout inhibition | Cobalt-60 | 0,05 – 0,15 kGy | 25.8.78 | Unconditional |
| Garlic | Sprout inhibition | Cobalt-60 | 0,10 – 0,20 kGy | 25.8.78 | Unconditional |
| Chicken | Prolonged storage life and elimination of pathogenic micro-organisms | Cobalt-60 | 2 – 7 kGy | 25.8.78 | Unconditional |
| Papaya | Improved keeping quality | Cobalt-60 | 0,5 – 1,5 kGy | 25.8.78 | Unconditional |
| Mango | Improved keeping quality | Cobalt-60 | 0,5 – 1,5 kGy | 25.8.78 | Unconditional |
| Strawberries | Prolonged storage life | Cobalt-60 | 1 – 4 kGy | 25.8.78 | Unconditional |
| Dried bananas | Insect control | Cobalt-60 | max. 0,5 kGy | 28.7.77 | Provisional |
| Avocados | Delayed ripening | Cobalt-60 | max. 0,10 kGy | 28.7.77 | Provisional |

**1 kGy = 100 krad*

Irradiated mangoes and other products were also marketed in South Africa and because of the excellent consumer reaction it was decided that the time was ripe for a marketing and information campaign. This was launched in August 1978 by the Minister of Health with a statement on the safety and wholesomeness of irradiated foods. This statement was made during a function held at Pelindaba where various irradiated foods could be examined and tasted.

The trial marketing was started in four supermarkets, and later extended to seven in the Pretoria and Johannesburg areas. Irradiated strawberries, papayas, mangoes and potatoes were sold and the reaction on the part of the consumer, the prepackers and the retail outlets has been extremely positive and encouraging.

These marketing trials have been continued and up to date 110 t of potatoes, 20 t of papayas, 20 t of mangoes, 5,3 t of strawberries, 1 t of dried bananas and 36 t of garlic have been irradiated and sold. It appears therefore that irradiated food is accepted by South African consumers.

## 3.17 International Food Irradiation Project

To enable efficient international as well as national trade in irradiated produce, an International Food Irradiation Project was formed in 1970 under the auspices of the World Health Organisation, the Organisation of Economic Cooperation and Development, the International Atomic Energy Agency and the Food and Agricultural Organisation. South Africa has been a founder member of this project and a full member since 1974. The Host Centre is provided by the Institut für Strahlentechnologie at Karlsruhe in West Germany.

The aims of this project were to obtain and to present to the international scientific community evidence of the wholesomeness of irradiated foods. In September 1976 its findings on a number of food items were presented to a Joint Expert Committee on Food Irradiation. After reviewing the accumulated biological and chemical evidence this committee recognised irradiated potatoes, wheat, chicken, papayas and strawberries as unconditionally safe for human consumption, and gave provisional clearance to irradiated rice, fish and onions pending the results of ongoing studies.

The Expert Committee also agreed *in principle* to the clearing of irradiation as a process rather than as a food additive, and expressed the opinion that consideration should be given to the overall clearance of all foodstuffs (with certain possible exceptions) irradiated up to a dose of 5 kGy.

The virtual clearance of no less than eight food items by WHO was an extremely important milestone in the development of food irradiation programs. This achievement would not have been possible in the absence of the International Food Irradiation Program which has proved to be a fine example of what can be achieved by genuine international cooperation. It is to the credit of South Africa that it took the decision to finance full membership of the IFIP at a time when the prospects for food irradiation were rather bleak.

## 4. FUTURE PROSPECTS

The future development of South Africa's food irradiation program must take into account international developments in this field. Although nearly 30 different irradiated foodstuffs have now been cleared for sale in 20 countries, it remains a fact that only the Japanese potato irradiator (in operation since 1973) and a much smaller irradiator at Wageningen are producing irradiated foods commercially. The pilot plant at Tzaneen could also be included here.

This apparent lack of interest is often being used as "proof" that the food industry is not interested in radiation preservation. However, Diehl[24] of the Federal Research Centre for Nutrition at Karlsruhe reacted as follows to this argument in an article in the July 1977 issue of Food Engineering in which he discussed some proven applications of food irradiation: "I do not share this pessimistic evaluation. In order to be economically attractive, the new process must be applicable to more than a few food items. It is also essential that existing export barriers be removed. What good is a clearance for onion irradiation in the Netherlands or for potato irradiation in France if export to none of the neighbouring countries is possible? "

The marketing of irradiated foods in South Africa has been very successful, but for any noteworthy extension of the food irradiation program it is absolutely *"essential that existing export barriers be removed"*.

## 5. ACKNOWLEDGEMENTS

A paper of this nature is incomplete without paying tribute to the former President of the Atomic Energy Board, *Dr A J A Roux*, for his enthusiastic support of the Irradiation Program. The same support is being given by *Dr J W L de Villiers*, present President of the AEB, and by the Secretary for the Department of Agricultural Technical Services, *Dr D W Immelman* who delivered the opening address at this symposium.

Since the establishment of international trade in irradiated food is the next essential step in the food irradiation program, the very important role played by *Dr P S Elias*, Director of the International Food Irradiation Project, cannot be over-emphasised. His work at the IFIP is greatly appreciated.

## DISCUSSION

**Question:** What are your views on the treatment of deciduous fruit at lower doses for controlling fruit fly (especially in the light of Professor Maxie's negative attitude as a result of all his investigations)? Could this type of problem perhaps be controlled with combined treatments?

**Answer:** I believe that if insect sterilisation could be used as an internationally accepted sanitary measure for insects in deciduous fruits, (and I firmly believe that it is going to come in time), we are going to experience a tremendous increase in the application of ionising radiation. I have no doubt in this connection because everybody is getting sick and tired of all the poisons that we must swallow by eating fruit at the present time.

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# THE INFLUENCE OF RADIATION ON THE CHEMICAL CONSTITUENTS OF FOOD

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## SAMEVATTING

Ses hoofvoedselgroepe is nodig vir 'n gebalanseerde dieet, nl. vette, koolhidrate, proteïene, vitamiene, minerale en water.

Voedsaamheidsevaluasie word in twee kategorieë verdeel:

(a) Die vasstelling van verandering in voedsaamheidsinhoud.

(b) Ondersoek na die moontlike vorming van toksiese afbraakprodukte.

Navorsing neem die vorm van dierevoedingstudies of chemiese analise aan. Veranderinge wat deur bestraling ontstaan, is groter in modelkomponente, as in die heel voedsel. Veranderinge deur hitte en bestraling verskil in kwaliteit eerder as kwantiteit.

Nagenoeg geen voedsel bevat nie water as die belangrikste komponent nie. Die hoofradioliseprodukte van water is hidroksielradikale en gehidreerde elektrone.

Die afbraakprodukte van lipiede wat deur ioniserende strale, selfoksidasie en hitteprosessering gevorm word, toon groot ooreenstemming. Geen nadelige effekte is in proefdiere wat bestraalde, lipied-bevattende voedsel ontvang het, gevind nie.

Afbraak van polisakkariede deur ioniserende straling lewer eenvoudiger koolhidrate. Eenvoudiger koolhidrate word nie betekenisvol deur kommersieel-aanbevole dosisse gedegradeer nie. Die meeste radiolitiese produkte is karboniele. Die produkte wat tydens bestraling in vrugte en groente gevorm word, is nie toksies nie.

Geen betekenisvolle veranderinge kon in die voedsaamheid van verskeie proteïene bespeur word nie.

Vitamiene is stralingsensitief, maar 'n aantal is ook hittelabiel.

Vitamiengebreksiektes kon nie in proefdiere wat bestraalde groente ontvang het, opgespoor word nie.

Minerale se voedingswaarde word nie deur ioniserende straling beïnvloed nie.

## ABSTRACT

Six major components are necessary in an adequate diet, viz. fats, carbohydrates, proteins, vitamins, minerals and water.

Wholesomeness evaluation may be divided into two categories:

(a) The monitoring of any change in nutritional content.

(b) The examination of the possible formation of toxic degradation products.

Investigations take the form of animal feeding studies or chemical monitoring. Changes produced by irradiation are greater in model components than in the whole food. Changes brought about by heat and radiation differ in quantity rather than quality.

Very few foods do not have water as a significant component. The major radiolytic products of water are hydroxyl radicals and hydrated electrons.

The degradation products of lipids caused by ionising radiation, autoxidation and thermal processing are very similar. No untoward effects have been noted in laboratory animals fed irradiated lipid-containing foods.

Degradation of polysaccharides by ionising radiation yields simpler carbohydrates. Simpler carbohydrates are not significantly degraded by commercially recommended doses of radiation. Most of the radiolytic products are carbonylic in character. Products formed in irradiated fruits and vegetables have been shown to be non-toxic.

No significant changes could be detected in the nutritiousness of a variety of proteins.

Vitamins are radiation sensitive but a number of them are also heat-labile. No vitamin deficiency diseases could be detected in laboratory animals receiving irradiated fruits and vegetables.

Minerals are unaffected, nutritionally, by ionising radiation.

## 1. INTRODUCTION

Six major food components are required in an adequate diet. These are fats, carbohydrates, proteins, vitamins, minerals and water. These components are mutually interdependent for their correct functioning in the living organism.

Fats have a high fuel value and are therefore important in the diet. They improve the palatability of food and retard the process of digestion. Furthermore, fats act as carriers for the lipid-soluble vitamins during absorption in the intestine. Lipids also provide essential unsaturated fatty acids without which certain deficiency diseases develop.

Twice as much energy is stored in the form of lipids in the body as in proteins or carbohydrates.

Carbohydrates are the first and most efficient source of energy for vital processes. A minimum of 140 g carbohydrate/11 700 kJ must be ingested with fats to prevent abnormalities in lipid metabolism.

A minimal amount of protein is indispensible in the diet to provide for the replacement of protein in the body – the "wear and tear" quota. Proteins yield energy when fats and carbohydrates are in short supply but their main function is to serve as structural components, as biocatalysts, as hormones and as repositories for the genetic information characteristic of a species[1].

Vitamins, minerals and water do not yield energy but are essential components of the chemical mechanisms for the utilisation of energy and for the synthesis of various necessary metabolites such as hormones and enzymes. The minerals are also incorporated into the structure of the tissue and, in solution, play an important rôle in acid-base equilibrium.

The daily allowance of the six components for an average 70 kg, 22 year old American male subject to the usual environmental stresses are:

Total kJ count: 11 700
Fat: 20–30 % of the kJ intake, i.e. 66 g
Carbohydrate: 55–70 % of the kJ intake, i.e. 250–500 g
Protein: 10–15 % of the kJ intake, i.e. 65 g
Water-soluble vitamins: 84 mg
Lipid-soluble vitamins: 5 470 IU
Minerals: 1,96 g
Water: 1,8 – 2,5 l

Vitamins are present in very small quantities and it is important, therefore, that they do not undergo significant degradation during any food processing method.

## 2. GENERAL CONSIDERATIONS

Food systems are complex. Each component foodstuff whether it be lipid, protein, carbohydrate or vitamin can consist of a variety of constituents.

The different components can then occur together in differing ratios. The components have a marked influence on each other during preservative measures, e.g. the gelling of pectin which occurs only when the substance is heated in the presence of sufficient sugar.

All food processing methods are responsible for chemical and physical changes in the foodstuffs. The very effect of a method is wrought by these changes. Food preservation methods should cause minimum change. Such changes that do occur, should have no deleterious effects on the consumer.

Ionising radiation and other types of irradiation such as thermal and microwave processing, differ only in the type of energy employed. Most radiolytic products identified in irradiated foodstuffs can also be found in non-irradiated foods. Many of the identified chemical entities have been generated in foods by other processing techniques, e.g. heating. The cold process of ionising radiation is far less abusive than heating (unfortunately very little is known about the effects of microwaves). With the doses employed in food processing, the concentration of the most abundant radiolytic substances is confined to the ppm range[2].

Wholesomeness evaluation of irradiated food falls into two categories:

(a) Toxicology of the degradation products.

(b) Nutritional content of irradiated food. Evaluation is either by means of experimental animals or by *in vitro* testing in the laboratory

Various approaches to evaluation are followed. A great deal of research has been devoted to studying the effects of irradiation on aqueous solutions of the food components in model systems at irradiation doses far in excess of those applied commercially. The changes produced in these model systems are greater than those occurring in the whole food or combinations of foods. Furthermore, these model solutions are toxic in *in vitro* toxicological studies but thus far no sign of toxicity could be detected during *in vivo* studies[3,4].

Various multi-generation, multi-species animal feeding studies have been completed in independent commercial laboratories in different countries on a variety of irradiated foodstuffs. No significant impairment of the nutritional quality of the foods could be detected and no pathological abnormalities could be attributed to irradiation at commercially recommended doses. Those abnormalities detected could be ascribed to an unbalanced diet containing an excess of a basically toxic food such as mushrooms or onions[5].

## 3. THE INFLUENCE OF IRRADIATION ON THE BASIC COMPONENTS OF FOODSTUFFS

The present discussion is confined to the effects of irradiation on whole foods and, where possible, using doses recommended for commercial application. The components are examined separately but it must be emphasised that no food consists only of these constituents. The presence of other constituents could modify the effect of irradiation on the component under consideration.

### 3.1 Water

$^{60}Co$ or $^{137}Cs$ emits electromagnetic radiation with a wavelength below that of ultra-violet light. These gamma rays consist of photons with sufficient energy to cause ejection of electrons into the medium through which they pass – hence ionising radiation.

There are very few foods of which water is not a significant component. The high-energy photons are able to excite and ionise molecules along their path in an indiscriminate manner so that more water molecules will be affected during irradiation than other components as follows:

$$H_2O \rightsquigarrow OH^{\cdot} + e^-_{aq} + H^{\cdot} + H_2 + H_2O_2 + H_3O^+$$

| | |
|---|---|
| $OH^{\cdot}$ | Neutral free hydroxyl radical |
| $e_{aq}$ | Hydrated electron |
| $H^{\cdot}$ | Hydrogen atom |
| $H_2$ | Molecular hydrogen |
| $H_3O^+$ | Hydronium ion |
| $H_2O_2$ | Hydrogen peroxide |

The most important degradation products are $OH^{\cdot}$ and $e^-_{aq}$.

There is no significant loss of water during irradiation but the reaction products formed are highly reactive and attack the other food constituents. This is known as the indirect action of irradiation.

Hydroxyl radicals are rather unselective so that their targets are principally these components present in excess. For this reason the major components such as carbohydrates, proteins and lipids tend to protect the minor components such as vitamins. Hydrated electrons are more specific in their action and will attack compounds with low-lying vacant orbitals such as aromatics, carboxylic acids, aldehydes, ketones, thiols and disulphides. They do not react to any great extent with carbohydrates but only with certain amino acids in proteins. Hydrated electrons can therefore react with minor components such as vitamins[6].

## 3.2 Lipids

Fats are usually present in a substance with a limited water content. In this instance the gamma rays or photons will attack the fat directly – the so-called direct action.

98 % of natural fats consists of mixed triglycerides. The fatty acid composition of these triglycerides varies considerably from one fat to another. The fatty acids generally contain 16 to 18 carbon atoms per molecule. The remaining 2 % of the natural fats is made up of mono- and diglycerides, free fatty acids, phospholipids and fat-soluble vitamins.

The degradation products of ionising radiation, thermal processing and autoxidation are similar. Radiolysis products resemble heated fats more than oxidised fats. Heat yields a greater quantity of products than irradiation. Thermal degradation products start to appear after only five minutes at normal cooking temperatures while irradiation doses far in excess of those envisaged for commercial purposes are needed to produce the same effect.

The main mechanisms of degradation of fats in model lipids involve oxidation, polymerisation, decarboxylation and dehydration. Fortunately, the radiolysis products formed in natural fats are the same as in the model lipids so that extrapolation between the vast amount of research on model compounds and natural fats is possible. The major classes of compounds formed during irradiation, heating and autoxidation of a number of animal and vegetable fats are:

(a) Hydrocarbons
(b) Aldehydes
(c) Ketones
(d) Esters
(e) Free fatty acids[7].

## 3.3 Proteins

Proteins are complex compounds so that innumerable reactions are possible. For this reason the effect of irradiation on proteins can best be illustrated by way of a wholesomeness evaluation of a protein-rich food such as chicken. The results of the feeding studies are summarised in Table 1.

Nutritionally, irradiated-chicken protein is therefore no different from the untreated food. Chemically, the only significant finding in the irradiated poultry was an elevated peroxide value in the fat. This value was dose-dependent and increased during storage[8,9].

In general[10], ionising radiation will attack peptide bonds in proteins which will tend to increase the free amino acid concentrations slightly. The amino acids are unaffected when they are present in proteins. It is only in the free form that the radiation-sensitive amino acids such as tryptophan, cystine and methionine are degraded. The sulphur-containing amino acids decompose to yield volatile substances which could affect the flavour of irradiated meat but concentrations are in the ppb range.

**TABLE 1**
**ANIMAL FEEDING STUDIES OF AN IRRADIATED PROTEIN-RICH FOOD – CHICKEN**
Ratios: Standard diets
+ 35 % dry weight/50 % wet weight of chicken.

| Animal | Duration | Purpose | Findings |
|---|---|---|---|
| Mice | 80 weeks | Carcinogenicity testing | No indication of neoplastic growths. |
| Dogs | 52 weeks | Toxicological safety | No clinical or pathological changes. |
| Albino rats | 104 weeks | Wholesomeness | No significant or consistent difference between groups |
| Wistar | 3 generations | Multigeneration | Fertility unimpaired<br>Young unaffected |
| Bio-assay | | Net protein utilisation. Protein efficiency ratio | Unaffected |

p4p4

### 3.4 Carbohydrates

If the sugar content of irradiated foods is measured, no significant change is detected. For example, the sugar content of pineapples, canned peaches, strawberries, dried dates, grapes, apples and papayas remained unchanged after irradiation[11].

*In vitro* irradiation of the pure carbohydrates produces radiolysis products which are mainly carbonylic in character. To date these carbonyls have not been isolated from fruits If isolation is effected, it is hoped that the carbonyls will not be toxic.

### 3.5 Vitamins

The effect of irradiation on fruits at the commercially recommended doses is not significant.

Table 2 gives the concentration of certain vitamins present in some subtropical fruit, viz. mangoes, papayas and litchis and in strawberries. There is no significant difference between the vitamin content of the control and irradiated fruit[12].

### 3.6 Minerals

Minerals are unaffected nutritionally by irradiation. Iron is oxidised durig ionising radiation[10]. Although this is not detrimental to its absorption – an efficient reducing mechanism is present in the intestine – but it does cause darkening of red meat at high irradiation doses as a result of physical and chemical changes in the myoglobin present in the meat.

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**TABLE 2**
**THE CONCENTRATION OF CERTAIN VITAMINS IN SOME IRRADIATED SUBTROPICAL FRUITS**

| Fruit | Carotene IU/100 g | Ascorbic Acid mg/100 g | Riboflavin mg/100 g | Niacin mg/100 g | Thiamine mg/100 g |
|---|---|---|---|---|---|
| **Mangoes** | | | | | |
| Control | 6 727 | 12,23 | 0,07 | 0,72 | 0,070 |
| Irradiated | 7 017 | 11,70 | 0,06 | 0,74 | 0,060 |
| **Papayas** | | | | | |
| Control | 3 552 | 79,29 | 0,03 | 0,05 | 0,040 |
| Irradiated | 3 970 | 82,26 | 0,03 | 0,41 | 0,030 |
| **Strawberries** | | | | | |
| Control | 354 | 58,80 | 0,03 | 0,55 | 0,020 |
| Irradiated | 492 | 55,00 | 0,03 | 0,51 | 0,020 |
| **Litchis** | | | | | |
| Control | 0 | 39,15 | 0,08 | 0,31 | 0,006 |
| Irradiated | 0 | 39,38 | 0,08 | 0,29 | 0,004 |

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## DISCUSSION

**Question:** We learnt in your lecture that only minor chemical changes take place in foods when they are irradiated. Can we then conclude that only minor chemical changes take place in irradiated micro-organisms? If this is so, why are there lethal effects in the micro-organisms with these very minor chemical changes?

**Answer:** This is not my field but I think I can answer. It is a known fact that fruits or vegetables can withstand significantly higher irradiation doses than the growing plants or germinating seeds. Gamma rays may disrupt certain essential processes necessary for the continuation of life in living organisms. This may explain why a pathogen or insect can be rendered ineffective at irradiation doses which do not adversely affect the host tissue.

**Question:** Then how is meat affected by irradiation?

**Answer:** In the case of meat the micro-organisms are killed; the meat is dead already at the stage of irradiation.

**Question:** Could you give us an explanation of why there are changes in sugars *in vivo* and not *in vitro?*

**Answer:** Work on this topic is in process at Pelindaba at the moment. I suspect that the repair mechanism of the fruit could possibly be such that the fruit has recovered from the irradiation within a couple of hours. To give you an example, we are doing work on the vitamin niacin at the moment. The fruits are analysed within an hour of irradiation. The niacin content of the fruits is unaffected whereas niacin itself is extremely radiation sensitive. So it is possible that the repair mechanism is very rapid.

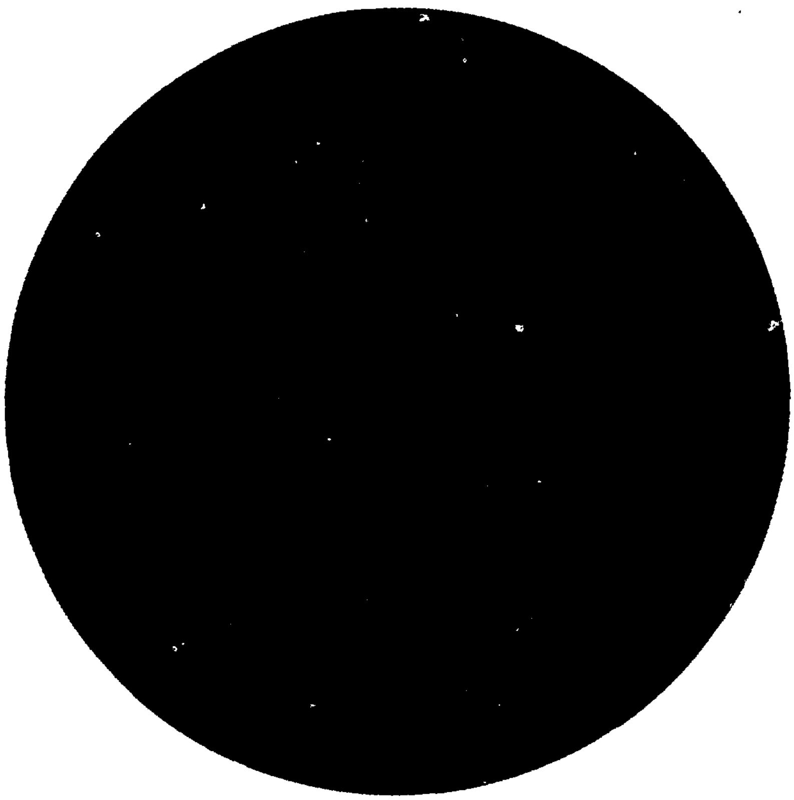
**Question:** What would happen in the case of fruit juices?

**Answer:** I think in the case of fruit juices it would depend on whether enzymes were inactivated or not. Juice with inactivated enzymes could possibly show signs of vitamin damage. In the enzymatically active fruit one would have a different effect.

**Question:** You indicated that toxic products were produced in the sugar solution whereas they were not produced in the actual fruit. It appears that some organisational interaction between the components of the fruit is protecting the sugar in the fruit. Have you done any studies on pectin plus sugar solutions and the degradation products when these sugar solutions are irradiated?

**Answer:** Actually this is one of our programs that is nearing conclusion. We have looked at what happens to a model sugar solution when it is irradiated in the presence of the different components of a mango. The next step would be to take the solution of the components of the mango without the organisation that exists in the fruit itself, and see if the solution is toxic.

**Comment by Dr van der Linde** (Atomic Energy Board, Pretoria): I would like to add something to the question because it is obviously of great interest. What has been found in the case of sugar solutions is that when one-component sugar solutions are irradiated it seems that there are anti-bacterial effects or even mutagenic effects when the solutions are tested *in vitro* on a single bacteriological system. However, as soon as one starts irradiating mixtures of sugars, we hope that the mutagenicity and antibacterial effects will decrease. This work has not been done yet. It is important to realise that many of these components which we would prefer to believe are carbonyls, are very short lived but they are very reactive and would react with some of the constituents of the fruit itself. When going even further to human cell cultures or animal feeding studies, we find no (and Dr Elias can expand on this) mutagenic effects with mangoes and papayas. It is therefore obvious that in the human system the products are broken down as well. Therefore, even though one finds antibacterial effects in single-component sugar solutions, it does not imply in any way that one would get the same effects in solutions of mixtures of sugars, or even in fruit juices, or more complicated, in the fruit itself.



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# THE INFLUENCE OF RADIATION ON MICRO-ORGANISMS WITH REFERENCE TO MEAT

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## SAMEVATTING

Die bakteriedodende uitwerking van ioniserende straling is alreeds in 1896 bestudeer. Voortgesette navorsing na die biologiese uitwerking van ioniserende straling het hierdie dodende effek asook die kragtige mutageniese werking op alle lewende organismes bevestig. Die DNA-molekule in die lewende sel is die primêre skyf vir stralingsenergie.

Daar bestaan 'n breë spektrum mikro-organismes ten opsigte van hulle stralingsgevoeligheid. Oor die algemeen is sporevormende bakterieë, soos *Clostridium botulinum*, besonder bestand teen bestraling. Daar is egter uitsonderings, soos *Micrococcus radiodurans* en *Moraxella-Acinotobacter*. Die oorlewingsmeganisme van hierdie nie-sporevormende bakterieë skyn 'n uiters doeltreffende DNA-herstelvermoë te wees.

Die beperkte bergleeftyd van verkoelde vis is hoofsaaklik aan die teenwoordigheid van 'n groot aantal verrottingsbakterieë, soos *Pseudomonas*, te wyte. Hierdie bakterieë is baie gevoelig vir bestraling sodat die rakleeftyd deur die aanwending van lae dosisse ioniserende straling aansienlik verleng kan word. Bakterieë, soos *Salmonella*, wat voedselvergiftiging veroorsaak, kan met betreklike lae stralingsdosisse in vleis vernietig word. Hoë dosisse ioniserende straling sal vleis steriliseer om sodoende 'n produk met 'n rakleeftyd van 'n hele aantal jare te lewer.

Vleis blyk dus 'n ideale voedsel te wees om die voordele van bestraling te benut.

## ABSTRACT

The bactericidal effects of ionising radiation was studied as early as 1896. Continued investigations into the biological effects of ionising radiation confirmed its lethal effects, as well as the potent mutagenic action on all living organisms. The DNA molecules inside the living cell are the prime target for radiation energy.

A broad spectrum of micro-organisms exists with regard to its radiation sensitivity. Spore forming bacteria are as a rule very radiation-resistant, e.g. *Clostridium botulinum*, although exceptions such as *Micrococcus radiodurans* and *Moraxella-Acinetobacter* exist. The survival mechanism for these non-sporeforming bacteria seems to be the possession of an ultra-effective DNA repair capacity.

The limited storage life of refrigerated meat is caused mainly by the presence of large numbers of spoilage bacteria, e.g. *Pseudomonas*. These bacteria are most sensitive to radiation so that a considerable extension of shelf life can be attained with low-dose applications of ionising radiation. Food-poisoning bacteria such as *Salmonella* can also be eliminated from meat at relatively low doses. Application of high doses results in sterilisation of meat and a product with a shelf life of several years.

Meat therefore seems to be an ideal food to benefit from irradiation.

## 1. INTRODUCTION

Soon after the discovery of X-rays and radioactivity, research on its biological effects was initiated. The very first paper on this subject was published in 1896 and dealt with the lethal effects on bacteria[1]. The title: *"On the Question of the effect of Roetgen Rays on Bacteria and the Possibility of their Eventual Application"* clearly forecasts the present situation.

In 1943 Proctor, Van de Graaff and Fram reported on their work on the preservation of hamburger meat with X-rays[2]. This was the first real and successful attempt at using ionising energy for food preservation although patents on food irradiation have been registered since the early years of this century[3].

## 2. WHAT IS IONISING ENERGY?

As the previous speaker has mentioned, ionising radiation has an energy high enough to cause ejection of an orbital electron from an atom or molecule. This includes beams of high velocity electrons and electromagnetic radiations of short wavelengths such as X-rays and $\gamma$-rays.

## 3. SOURCES OF IONISING RADIATION

The radioisotopes $^{60}Co$ and $^{137}Cs$ are the most commonly used sources of ionising radiation for food preservation. The unit of irradiation absorbed is expressed as Gray (Gy), where *00,01 Gy is equivalent to an energy absorption of 100 ergs per gram.* Ten kGy's are approximately equal to two calories[4].

## 4. EFFECTS OF IONISING RADIATION ON A BACTERIAL CELL

Little doubt exists that DNA is the critical radiation target in bacteria. The damage produced is initiated by *both direct and indirect effects,* the former by deposition of the radiation energy directly in the DNA molecule in the form of ionisation, and the latter by reaction of the DNA with another molecule that has been ionised or excited by radiation energy. Water, as the main component of the bacterial cell and its surroundings, yields the following radiolysis products when $\gamma$-irradiated: (The G-values, i.e. the number of molecules of radiolysis product formed per 100 eV radiation, appear in brackets.)

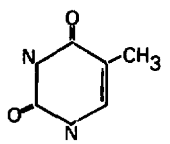
$$H_2O \xrightarrow{\gamma} \underset{(2,7)}{OH^\bullet} + \underset{(2,7)}{e^-_{aq}} + \underset{(0,55)}{H^\bullet} + \underset{(0,45)}{H_2} + \underset{(0,71)}{H_2O_2} + \underset{(2,7)}{H_3O^+}$$

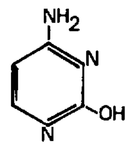
Some of these species are highly reactive,and it is suggested that OH' radical reactions with DNA are the significant events.

## 5. BRIEF REVIEW OF THE STRUCTURE OF DNA

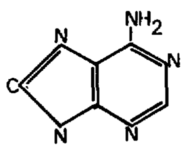
The DNA molecule consits of a "backbone" of deoxyribose and phosphate residues linked by diesterbonds in such a way that the 5' OH group is esterified by phosphoric acid which is attached to the 3' OH of the adjacent deoxyribose. Attached to the first carbon of deoxyribose by a N-glycoside bond are the bases viz:

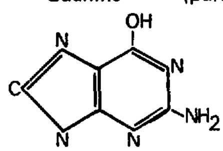
Thymine and Cytosine (pyrimidines)




Adenine and Guanine (purines)




These bases are matched in such a way that pairs are formed between a purine and a pyrimidine on opposite strands. The complementary strands are connected with each other through hydrogen bonds. In solution the DNA molecule is a double helix and contains all the genetic information necessary for reproduction and support of life in the cell. *What radiation damage is inflicted on DNA?* Recent work[5] showed that most of the radiation-induced DNA damage, which is up to 70 %, occurs on the base moieties even though they are protected inside the structure of the macro-molecule. Damage to deoxyribose accounts for the rest. Free and damaged bases are released from nucleic acids as a result of irradiation, and it has been suggested that a base is released at every strand break.

The most obvious damage to DNA as a result of ionising irradiation includes the following[6]:

(i) Single-strand (haplotomic) and double-strand (diplotomic) breaks;

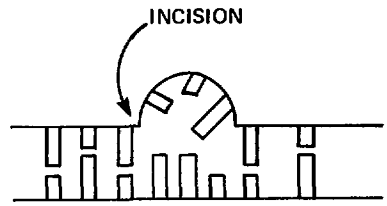
(ii) breaking of hydrogen bonds between the strands;

(iii) crosslinking with
  (a) in a strand between bases e.g. Thymine dimers
  (b) adjacent strands
  (c) another DNA molecule
  (d) or even a protein

## 6. DNA REPAIR

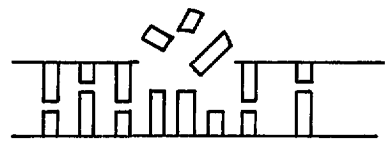
It is now evident that all living cells possess the ability to repair damaged DNA. Most of this knowledge has been obtained through studies with irradiated bacterial cultures. In bacteria three processes of DNA repair are known, viz. photo-reactivation, excision repair and post-replication repair. As an example, excision repair is discussed below.

Repair of a damaged DNA molecule is initiated by the ability of an enzyme(s) with endonuclease activity to recognise the 'damaged' area and to cause a 'nick' to the one side of it.



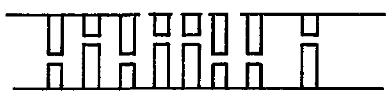

An 'exonuclease' then removes the damaged part,

EXCISION

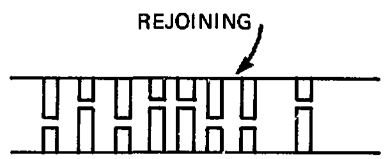


while a DNA polymerase synthesises a new strand using the complementary strand as template.

REPAIR SYNTHESIS



A polynucleotideligase links the newly built strand to render the DNA molecule intact[6].




When this repair process is not performed accurately, it leads to mutations. If repair is not performed at all, or if so much damage is inflicted on the DNA that the repair mechanism cannot cope, the cell will die.

## 7. RADIATION RESISTANCE OF BACTERIA

Micro-organisms are far more radiation-resistant than higher forms of life. A broad spectrum of micro-organisms exists with regard to its radiation sensitivity. Spore-forming bacteria are as a rule relatively resistant to ionising radiation, probably due to the low water activity in the bacterial spore[7], thus limiting the indirect radiation effects leading to death of the spore. Several non-sporeforming bacteria which are highly resistant to ionising radiation have been isolated, e.g. *Moraxella-Acinetobacter* (M-A)[8] and *Micrococcus radiodurans*[9]. Numerous mechanisms have been proposed to explain this unusual radiation resistance, e.g. pigments in bacteria acting as an energy absorber[10], possession of internal protective substances such as sulphydryls[11] and certain morphological features such as the presence of a peculiar wrinkled layer directly underneath the cell wall[12]. Most of these mechanisms have now been discounted and it has been proved that *M. radiodurans* possesses an ultra-effective DNA repair system capable of repairing single as well as double-strand breaks in a very short time[13]. The exact nature of the radioresistance of the M-A organisms is not clear.

## 8. THE EFFECT OF RADURISING DOSES OF GAMMA IRRADIATION ON THE BACTERIAL POPULATION IN MEAT

A variety of micro-organisms occurs in fresh meat, e.g. spoilage bacteria such as the pseudomonads and *Achromobacter (Alcaligenes)*, lactic acid bacteria, i.e. *Streptococcus* and *Lactobacillus*, pathogens such as *Staphylococcus* and *Salmonella* and other groups of uncertain significance, i.e. M-A. All these micro-organisms possess different degrees of resistance to ionising radiation. The pseudomonads are most sensitive whilst the enterobacteria such as *Salmonella* and *Proteus* have an intermediate resistance. Highly radiation-resistant bacteria in meat include the M-A group as well as *Micrococcus radiodurans*.

When the total aerobic bacterial population of vacuum-packed, low-dose irradiated meat is monitored during post-irradiation storage at refrigeration temperatures, the following pattern usually occurs (Fig. 1).

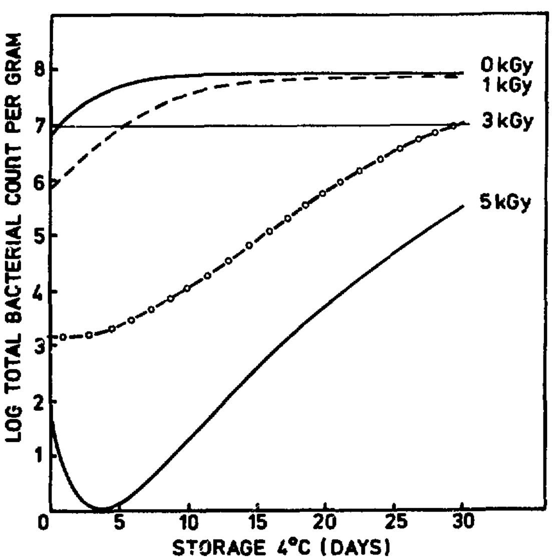



*Figure 1*
*Influence of gamma-irradiation on the total bacterial count in minced beef*

More of the bacteria present in the meat are destroyed with increasing doses. Those that survive the irradiation process and are able to grow at low storage temperatures (psychrophiles), start to grow, and eventually reach large numbers which result in spoilage[14]. The shelf-life extension attained is thus as a result of the delay in the multiplication of the bacterial population. The pseudomonads and enterobacteria are completely destroyed at doses higher than 1,5 kGy, whilst certain of the gram-positive bacteria such as *Microbacterium thermosphactum* and the lactic acid bacteria survive these radurising doses and eventually cause spoilage of the meat[14]. *Salmonella*, if present in the meat, is also completely eliminated at radurising doses. Spores surviving the radurising process do not pose a health hazard under these conditions as the meat is kept at refrigeration temperatures (below 5 °C). Of the radiation-resistant bacteria known to us, none are pathogenic and their participation in the eventual spoilage is questionable.

Investigations into the possibility of a health hazard as a result of a shift in the microbial population, survival and 'enrichment' of radiation survivors or possible pathogens and selection of mutants being more virulent, have proved to be highly unlikely, or impossible[15].

Radiation-sensitive bacteria which do survive irradiation, are 'crippled' as a result of their exposure and are often unable to grow normally. Even through repeated radiation cycles with several types of bacteria, no new characteristics associated with health hazard aspects have been acquired and pathogenicity was never found to increase but rather to decrease[15].

The unique effects of ionising irradiation can therefore be successfully applied to extend the shelf life of fresh meat by reducing the spoilage bacteria (radurisation), whilst elimination of pathogens (radicidation) will render a product of good hygienic quality. Complete sterilisation of micro-organisms (radappertisation) yields a product with indefinite keeping time.

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## DISCUSSION

**Question:** I would like to see Fig. 1 again, please. It would appear that there is an interaction effect, i.e. the higher the irradiation dose, the more rapid the growth of bacteria. Isn't the inclination of the 5 kGy line more than that of 3 kGy and of 1 kGy, and so on?

**Answer:** Yes, there is an increase in inclination with increasing dose and it could be the result of less competition due to lower numbers of bacteria, i.e. of more 'biological space' being available, leading to a diminishing of the generation time and therefore a faster increase in numbers. The initial decrease in numbers directly after irradiation was characteristic in all our experiments and could be the result of long-lived radicals formed in the meat during irradiation.

**Question:** Would you comment on *Clostridium* and the importance of avoiding a botulism hazard? Also, please indicate the radiation resistance of *Clostridium* spores in different meat products.

**Answer:** *Clostridium botulinum* is unfortunately very resistant to irradiation and has $D_{10}$ values as high as 3,5 kGy (that is the dose needed to kill 1 log of bacteria numbers). To ensure that no hazard is created by irradiation sterilisation, it was decided by the FDA and the US army that the 12–D principle applied to the canning industry for so many years, will also have to be met by the radappertisation process. This means that the 'safe' sterilising dose for meat and meat products would be the dose needed to destroy 12 log's of the most radiation-resistant *Clostridium* spores, for example for beef 45 kGy, ham 33 kGy and for bacon 25 kGy.

ZA8000317



# THE INFLUENCE OF RADIATION ON PLANT MICRO-ORGANISMS WITH REFERENCE TO FRUIT AND VEGETABLES

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## SAMEVATTING

Die sinergistiese uitwerking wat met bestraling en hittebehandeling, veral met betrekking tot patogene (swambesmetting) en hul gashere (vrugte en groente) verkry word, word bespreek.

Na gesamentlike hittebehandeling en bestraling is die groei en sporevorming in verskeie mangoswamisolate, nl. *Hendersonia creberrima* en *Colletotrichum gloeosporioides* doeltreffend vertraag. Hierdie resultate is bevestig toe mangosiektes met gesamentlike hittebehandeling (5 min. by 55 °C) en bestraling (0,75 kGy) suksesvol bestry is. Die doeltreffendheid daal namate die tyd tussen hittebehandeling en bestraling verleng word. Hierdie vertraging kan moontlik die sinergistiese uitwerking waardeloos maak deurdat die swam se DNA-herstelmeganisme kans kry om weer funksioneel te word.

Die sinergistiese uitwerking van gesamentlike hittebehandeling en bestraling op die bestryding van siektes is ook in ondersoeke met verskeie papaja- en aarbeicultivars bewys.

Die ondersoek na sinergisme in voedselbestraling is nog nie afgehandel nie. Navorsing moet voortgesit word om die optimale samestelling van behandeling vir bederwingsbestryding in verskeie biologiese sisteme te vind. Die doelstelling is om hierdie gesamentlike behandelings moontlik kommersieel toe te pas.

## ABSTRACT

The synergistic effects obtained by irradiation and heat treatments, especially in relation to the pathogens (fungal contaminants) and their hosts (fruits and vegetables) are discussed.

Effective inhibition of the growth and sporulation of several mango fungi isolates namely *Hendersonia creberrima* and *Colletotrichum gloeosporioides* was achieved in culture using combination treatments. This was confirmed with mango fruits where excellent disease control was obtained by the combination of heat (55 °C for 5 min) and irradiation (0,75 kGy). An extension of the interval between heat treatment and irradiation resulted in reduced effectiveness. Possibly this time lag enabled the fungal DNA repair mechanism to become functional, thereby nullifying the intended synergistic effect.

Investigations with different cultivars of papayas and strawberries also clearly demonstrated the synergistic effect on disease control which is obtained by combining the heat and irradiation treatments.

The study on synergism in food irradiation is far from complete. Investigations must be continued in order to find the optimal treatment combination for spoilage control in various biological systems, with a possible view to utilising these combinations in commercial applications.


## 1. INTRODUCTION

The irradiation of foods has been studied for nearly a quarter of a century, but it is only in the last ten years that the wider application and potential of this process are being recognised. Like any other process, irradiation must serve a useful purpose. Some years ago there was erroneous thinking among certain scientists who were convinced that irradiation, as a new process, would completely replace rather than supplement existing processes such as refrigeration, heating, controlled atmospheres, etc. At present there has been a change of attitude among many scientists who recognise the advantages and limitations of this new process and do not see this process as a panacea for all ills.

Approximately one third of the world's food supplies are lost each year due to various agents, the most important among these being various micro-organisms. One of the major aims of the irradiation research program in South Africa as well as in many other countries, has been the control of microbial spoilage in foodstuffs. Irradiation is used either to delay the onset of spoilage, i.e. by decreasing the number of contaminating micro-organisms (radurisation), or by completely eliminating the microbes, thereby rendering the irradiated product indefinitely stable (referred to as radappertisation).

A great deal of interest has been shown in recent years in the enhancement of radiation lethality on contaminating micro-organisms using combination treatments of irradiation together with various agents such as heating, cooling, controlled atmospheres, etc. This is especially important for microbial control in commodities which are very sensitive to irradiation and where moderate doses of gamma radiation could result in adverse taste, texture and flavour changes, e.g. in certain types of deciduous fruits. However, the studies reported in this paper are primarily concerned with subtropical fruits where irradiation has been used for disease control. Fortunately these fruits are able to tolerate moderate irradiation doses but even in these cases, combination treatments are important.

## 2. POST-HARVEST DISEASES

Some of the major post-harvest diseases encountered in subtropical fruits are given as follows:

### 2.1 Mangoes

Soft brown rot caused by the fungus *Hendersonia creberrima* is a serious problem, especially when fruits are kept for prolonged periods in cold storage, e.g. during shipment of fruits overseas. This has resulted in the decay and subsequent rejection of 50 – 100 % in overseas consignments of some of the most important fibreless mangoes currently in demand overseas.

Anthracnose (*Colletotrichum gloeosporioides* Penz) frequently causes serious losses especially in mangoes stored at ambient temperatures.

## 2.2 Papayas

Serious losses may occur from fungal rots caused by anthracnose *(C. gloeosporioides)*, stem rots *Phoma sp.)* and soft rot *(Rhizopus stolonifer)*.

## 2.3 Strawberries

Severe fungal infections which develop at a very rapid rate at ambient temperatures, are caused by *Rhizopus stolonifer*.

These are only some examples of the post-harvest diseases affecting fruits and are all caused by fungal pathogens.

# 3. STUDY OF FUNGAL PATHOGENS

Several experiments were conducted in these laboratories where some of the more important fungal pathogens were selected for these studies. The sensitivity of these isolates to heat and irradiation treatment was determined. Spores of *C. gloeosporioides* and *R. stolonifer* ($1,5 \times 10^5$ spores/ml) were aseptically transferred to sterile water in flasks and subjected to heat and/or irradiation treatment prior to being placed on potato dextrose agar plates and incubated at 20 – 25 °C.

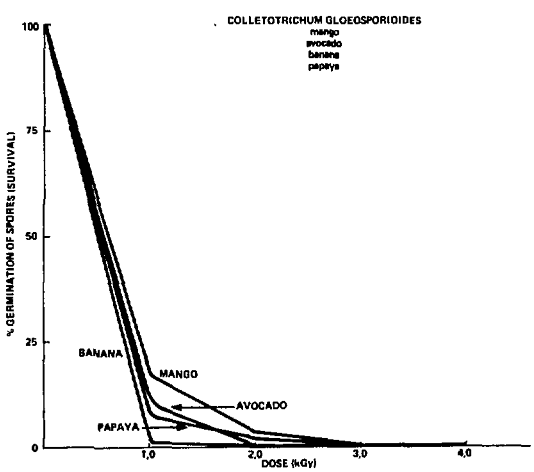


*Figure 1*
*Effect of irradiation treatment on the spore germination of several* **Colletotrichum gloeosporioides** *isolates from various subtropical fruits*

In Fig. 1 the results show that the radiation response of several isolates of *C. gloeosporioides* from mango, papaya, banana and avocado were very similar. The $D_{10}$ value (i.e. the dose required to kill 90 % of the micro-organisms) for these four isolates was approximately 1,25 kGy, thus showing them to be fairly sensitive to irradiation.

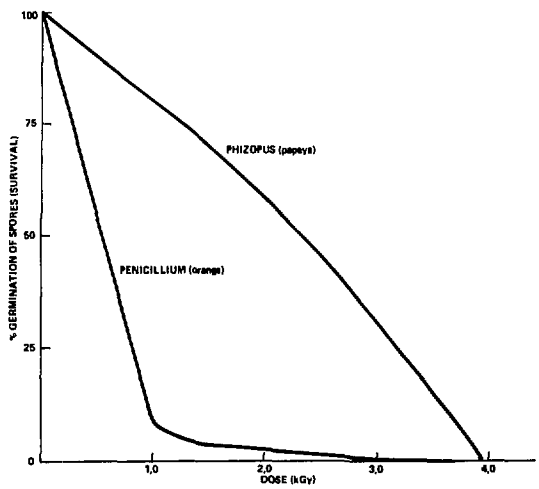


*Figure 2*
*Radiation response of* **Penicillium sp.** *and* **Rhizopus stolonifer** *in culture*

In Fig. 2, when comparing the radiation response of two other fungi, it is apparent that the $D_{10}$ value of *Penicillium sp.* is similar to *C. gloeosporioides* whilst the $D_{10}$ for *Rhizopus stolonifer* is nearly 4 kGy, thus indicating a far higher resistance to irradiation than the other fungi already mentioned.

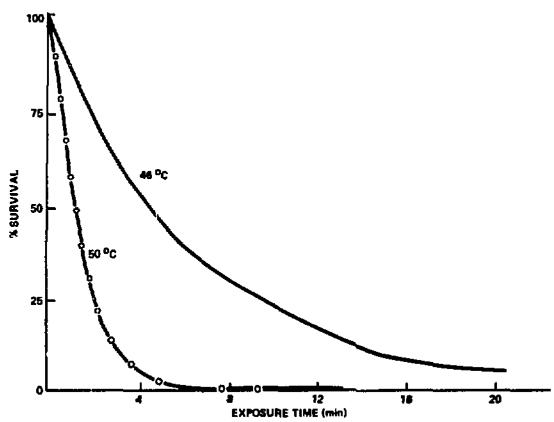


*Figure 3*
*Effect of heat treatments on* **Rhizopus stolonifer** *spores*

Figure 3 shows the effect of heat treatments at 46 °C and 50 °C for various durations on *Rhizopus* spores in culture. This temperature range is generally accepted for the post-harvest treatment of various fruit crops. It may be seen that spore survival decreases only slowly with increasing exposure time, and falls to 5 % after 20 min of treatment. This treatment, which hitherto was the accepted one for papayas, is evidently inefficient for *Rhizopus* control. At 50 °C, however, complete inhibition of spore germination resulted after a treatment time of only 6 min. The 50 °C treatment was subsequently selected for use in experiments in which irradiation was combined with heat treatment in order to achieve more effective control of this pathogen.

A further series of experiments was conducted in which the heat and irradiation treatments were combined. The results given in Fig. 4 clearly show that a heat treatment (50 °C for 2,5 min) applied prior to irradiation markedly improves the effectiveness of the irradiation treatment. The effect is especially noticeable with the more resistant *Rhizopus* isolate, where 1,5 kGy applied alone is only partly effective; in combination with heat, however, nearly a 100 % kill is achieved. This clearly demonstrates the synergistic effect obtained when combining heat and irradiation treatments.

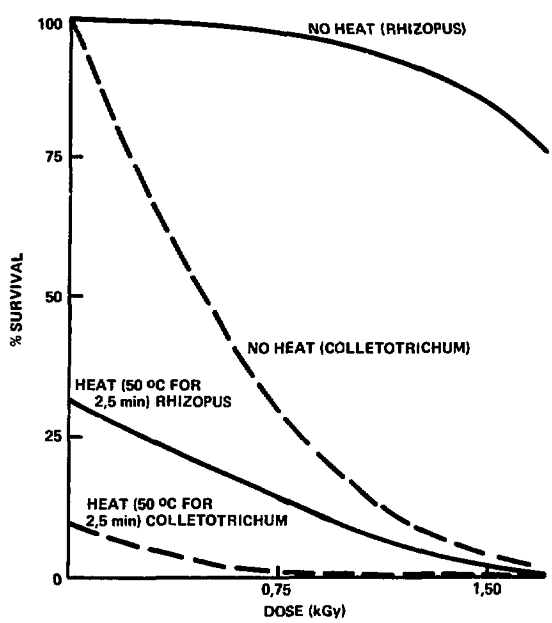


*Figure 4*
*Effect of heat and irradiation on two fungal isolates from papayas*

At this point, the mechanism of action with regard to both heat and irradiation treatment on these micro-organisms should be discussed. Radiation has a specific action on amino acids, proteins and nucleic acids. Nucleic acids are very important as these occur in every living cell (DNA and RNA) where they control the synthesis of protein and are responsible for the transfer of genetic material. Both DNA and RNA are long chains of alternating sugar and phosphate residues. Irradiation frequently results in breaks in these strands.

It is interesting to note that the recovery capability will depend on the effectiveness of the repair mechanism, e.g. radiation resistance of the bacterium *Micrococcus radiodurans* is probably its ability to repair DNA damage following irradiation. It is reported in certain micro-organisms that factors such as heat can disrupt the DNA repair mechanism so that micro-organisms become more sensitive to radiation.

## 4. RADIATION LETHALITY

Several types of treatment are known to enhance the radiation lethality in various micro-organisims. These are:

### 4.1 Heat

Heat is one of the most promising means of increasing the effectiveness of gamma irradiation when used in combination treatments. For example, the inactivation fungal spores of *Aspergillus* sp. resulted in maximum sensitisation when heating before irradiation[2].

Hot-water dipping 50 – 55 °C (5 – 10 min) followed by irradiation (0,75 kGy), coupled with low-temperature storage and shipment (10 – 12 °C), was found to be very effective in controlling fungal attack in mangoes and papayas[1]. In groundnuts the combination of heat and irradiation (65 °C and 0,5 kGy) inactivated toxigenic fungi such as *Aspergillus flavus*[2].

Thermoradiation occurs when the heat and irradiation treatments are applied simultaneously. This method has been effectively applied for the destruction of bacterial spores in spacecraft sterilisation[2].

### 4.2 Tyndallisation

This refers to the use of small doses of irradiation and applying repeated treatments. For example, in the case of grapes, which cannot tolerate high irradiation doses, this method has been used effectively for fungal control[3]. It is obvious that there are a number of practical problems associated with this method.

### 4.3 Chemicals

According to Farkas[2] micro-organisms become more sensitive to preservatives such as salt after being subjected to irradiation. It was reported by Roushdy[5] that the pre-irradiation treatment with phenolic compounds improved storability of potatoes with regard to sprouting and disease control.

### 4.4 UV radiation

UV radiation treatment followed by irradiation was recently investigated for decay control in papayas. The preliminary results did not show any significant effect[4].

When applying these basic principles in practice, it has been conclusively demonstrated in our laboratories that excellent disease control was obtained using a combination of hot water dip treatment (50 °C for 10 min for papayas and 55 °C for 5 min for mangoes) together with an irradiation dose of 0,75 kGy. However, in experiments with mangoes it was shown that the disease control decreases rapidly if there is some delay between heat treatment and irradiation. Results in Table I clearly show that effective control was obtained when irradiating within one day after heat treatment, but when this period was extended to 3, 6 and 8 d, the effect on disease control was noticeably reduced. This may well be related to the DNA repair mechanism. The commercial implications from these findings are, that from a practical point of view, it may be convenient to treat mangoes with hot water at the production area, and later to irradiate the consignment at a centralised irradiation facility (e.g. at the exit port). However, such an operation could involve a time lag of several days between the two treatments, which in the light of these findings is undesirable. Therefore the siting of such a facility may well have to be in the production area in these cases.

**TABLE I**
**EFFECT OF PRE-IRRADIATION DELAY ON DISEASE INCIDENCE**

| Hot Water – Irradiation Delay (days) | Percentage Non-Marketable Fruit (> 10 % infection) | | | |
|---|---|---|---|---|
| | No. days at 22 °C: 1 | 2 | 3 | 4 |
| 1 | 0 | 0 | 6 | 20 |
| 3 | 0 | 21 | 43 | 58 |
| 6 | 6 | 23 | 76 | 82 |
| 8 | 0 | 36 | 63 | 87 |
| Control (HW only) | 14 | 43 | 71 | 92 |

## 5. SUMMARY

5.1 There is usually only a very small difference between the radiation sensitivity of the food (host) and the micro-organism (pathogen), i.e. irradiation doses needed to kill the micro-organism may also damage the host tissue (fruit) and result in changes to the taste, texture, flavour and colour of the foodstuff.

5.2 When irradiation is combined with various factors such as heat, refrigeration, chemicals or UV radiation, it becomes possible to increase the effectiveness of irradiation and reduce the doses needed for disease control. The obvious advantages are:
(a) decreased costs; and
(b) adverse effects on the food are greatly reduced.

5.3 Many of these preservation methods which can be combined with irradiation are currently in use on a commercial scale; it may therefore be a relatively easy step to commercialisation, using these combination treatments.

5.4 The study on synergism in food irradiation is far from complete. Many parameters still have to be defined. Investigations must be continued to find the optimal combinations in the various biological systems in order to use these in commercial applications.

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## DISCUSSION

**Question:** Would you please explain the difference between kilorad and kilogray?

**Answer:** The new unit, 1 kGy, is equivalent to 100 krad.

**Question:** The treatments have always been heat followed by irradiation. What happens when you irradiate and follow this with heat treatment?

**Answer:** There is a specific reaction depending on the micro-organism. With certain of the micro-organisms, the synergistic effect is far greater when heat is applied together with irradiation, whereas with others it is more effective to apply the heat either before or after irradiation. Each biological system will have to be investigated separately to determine the best application procedure. Obviously, practical implications will have to be considered, for example the application of heat simultaneously with irradiation may be impractical. It will be necessary, therefore, to find the most practical combination which is the closest to the optimum for synergism in a particular situation.

In the case of subtropical fruits the most effective procedure was found to be heat followed by irradiation and fortunately this is the most practical, as a hot water dip at 55 °C for 5 min is normally given at the packhouse. The next logical steps are the waxing of the fruit, the packaging, and then irradiation prior to despatch.

**Question:** Is it possible to kill resistant fungi selectively when using a dose below that which will result in 100 % kill?

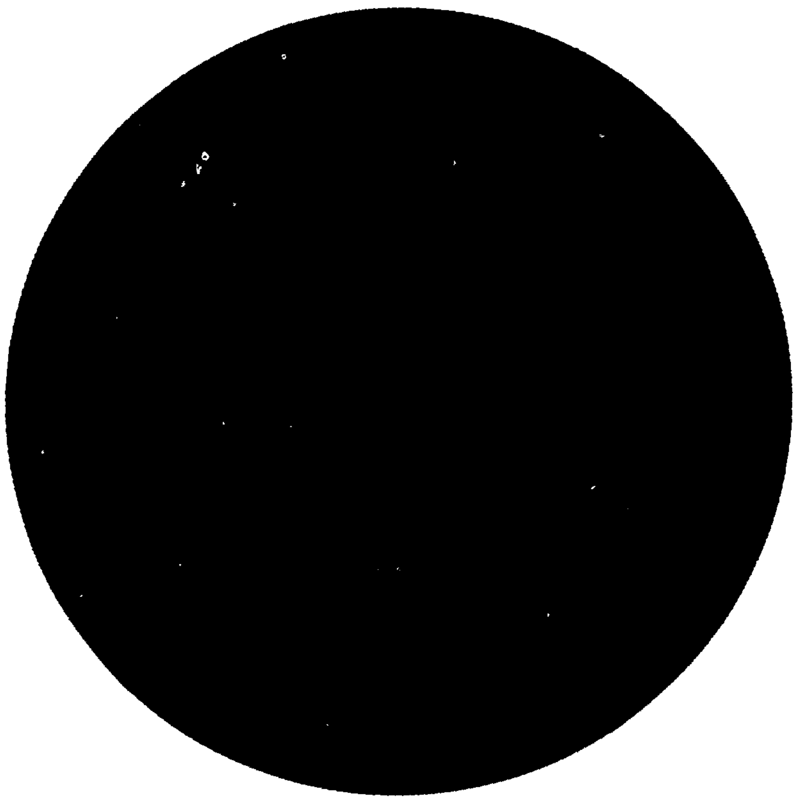
**Answer:** The answer to this question, which has been verified by researchers in the past, is that those micro-organisms which are not killed usually have some defective form in their repair and they will never be able to compete with the normal strains for their food supply. The question has probably been asked at every meeting concerned with the irradiation of micro-organisms.

Afternoon

## SESSION II

## MEAT

CHAIRMAN : Dr J H LOMBARD
*Meat Board, Pretoria*



# THE STATUS OF FISH AND POULTRY IRRADIATION IN THE WORLD

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*Karlsruhe, Federal Republic of Germany*

## SAMEVATTING

Die werk ten opsigte van voedselbestraling en nasionale vrystellings is tot dusver op die vernietiging van insekte in verskeie graansoorte en op die vertraging van die uitloop van aartappels en uie toegespits. Minder aandag is aan die vrystelling van vis en pluimvee geskenk. Tans is eksperimentele hoeveelhede pluimvee waarvan die ingewande verwyder is, in die USSR en Nederland goedgekeur. In Kanada, Nederland en Suid-Afrika is bestraalde pluimvee ook goedgekeur.

Tot dusver het nog net Kanada die proefbemarking van stokvis- en skelvismote goedgekeur, terwyl bestraalde garnale in Nederland vir proefneming in eksperimentele hoeveelhede vrygestel is.

'n Aansienlike aantal proefnemings word tans in die VSA uitgevoer ter stawing van die FDA se aansoek om vrystelling van bestraalde hoendervleis.

## ABSTRACT

Irradiation of food, and consequently, national clearances have concentrated hitherto on applications for disinfestation of various cereals and sprout inhibition in potatoes and onions. There has been less activity in relation to the clearance of irradiated poultry and fish. At present experimental batches of eviscerated poultry have been approved in the USSR and the Netherlands; irradiated chicken is approved in Canada, the Netherlands and South Africa.

With respect to fish only Canada has approved the trial marketing of cod and haddock fillets, while irradiated shrimps have been cleared in the Netherlands for trial in experimental batches.

A considerable amount of testing is underway in the US to support an application for clearance by the FDA of irradiated chicken.

## 1. INTRODUCTION

The irradiation of food and, consequently, national clearances, have concentrated hitherto on applications for disinfestation and sprout inhibition of various cereals, potatoes and onions. There has been less activity in relation to the clearance of irradiated poultry and fish.

## 2. FISH

### 2.1 General

Fish and fish products probably represent 10 – 20 % of the total protein consumption of the world and 50 – 70 % of the animal protein consumption in South and South-East Asia and the Far East (covering about 1 000 million people). Preservation of this highly perishable food is therefore especially important for people living inland. Irradiation has been shown to reduce spoilage by microbial contaminants and insects and to slow down deterioration. Doses of the order of 1,0 – 2,0 kGy can prolong storage twofold to threefold without changes in flavour, texture or appearance.

The irradiation process can be combined with boiling, drying or salting and can be applied to packaged products.

### 2.2 Provisional Clearance

The 1976 Joint Expert Committee gave a provisional clearance for fish, packaged or unpackaged, irradiated at a dose range of 1,0 to 2,0 kGy and kept at 4 °C [1]. Full acceptance was conditional uppon the provision of the results of the feeding tests, still in progress at that time, as well as of the results of the studies commissioned under the Asian Regional Project on Radiation Preservation of Fish and Fishery Products. The latter program is concerned with irradiated dried and salted fish.

### 2.3 Marketing

At present only *Canada* has approved the trial marketing of cod and haddock fillets, irradiated at a maximum dose of 1,50 kGy (2.10.1973). In the *Netherlands* experimental batches of shrimp, irradiated at doses from 0,50 to 1,0 kGy have been cleared for test marketing (13.11.1970)[2].

Commercial shipments were made of radiation-pasteurised codfish fillets from Rockaway, N J to the Netherlands in February 1977 (Radiation Technology, Inc.).

In 1976 some 5 t of shrimp and 10 t of cod and plaice fillets, both irradiated to 1,0 kGy, were released for marketing.

### 2.4 Technological Feasibility

Investigations into the technological feasibility were carried out in a number of countries.

**Spain:** De la Sierra [3] irradiated trout to 1,0 kGy and found that the shelf life could be extended twofold to threefold, if fish were kept at 2 °C. The microbial counts were reduced a hundredfold.

**Asian program:** Dried salted mackerel can be treated for extension of the shelf life with doses from 0,50 to 3,0 kGy, and fresh fish, packed in polythene bags, with doses of 1,50 to 2,0 kGy, if subsequently kept at 0 – 5 °C [4].

p7p2

**Germany:** Ehlermann and Reinacher[5] irradiated fresh redfish and haddock at sea to 1,0 kGy but found no advantages vis-a-vis keeping the fish in crushed ice, if the shelf life did not have to exceed 16 days.

## 3. CHICKEN

### 3.1 General

No comparative data on the proportion of the total world protein comsumption represented by broiler chicken are available.

### 3.2 Full Clearance

The 1976 Joint Expert Committee [1] gave a full clearance to eviscerated prepacked chicken, irradiated at doses from 5,0 to 7,0 kGy for the elimination of pathogenic micro-organisms. The real hazard from prepacked frozen chicken is due to contamination with *Salmonella*. There are no satisfactory alternative procedures available at the moment to eliminate this contaminant. Great care has to be exercised when handling broiler chicken. It has to be cooked adequately, otherwise disease due to *Salmonella* infection is likely to occur. In part this microbial contamination arises from the use of contaminated feedstuffs, which have not been treated specifically to eliminate microbial contaminants.

### 3.3 Marketing

At present the *USSR* has approved experimental batches of eviscerated poultry, packaged in polythene bags, irradiated at 6,0 kGy (4.7.1966), but we do not know what their marketing experience is [2].

*The Netherlands* fully approved for sale dry slaughtered broiler chicken[2] aged 10 weeks, parts of chicken, e.g. separately packaged heart, liver, stomach and neck, if irradiated to a maximum dose of 3,0 kGy ± 5 %; the conditions attaching to this clearance (10.5.1976) were

(a) the period between slaughter and irradiation not to exceed 24 h;

(b) the plastic packaging to be of the FDA approved type;

(c) the pack to be marked specially for sale by a specific sign and to be labelled with the keeping date;

(d) to store the packaged food at 2 – 5 °C;

(e) to review the situation in 5 years time.

This approval was based on the decision of the 1976 Joint Expert Committee and on microbiological evidence that less than 10 organisms survived irradiation treatment, that keeping and storage were improved, that the biological value of the protein remained unchanged, that little evidence of amino acid destruction was seen and that the vitamin content was not changed significantly.

**Canada** also approved the sale of irradiated chicken for test marketing; irradiation was to be carried out to a maximum dose of 7,0 kGy (20.6.1973) [2]. As far as we are aware, however, no testing has been carried out.

**South Africa** has recently approved the sale of irradiated chicken treated at doses from 2,0 to 7,0 kGy (August 1978) based on the acceptance by the 1976 Joint Expert Committee of the wholesomeness of chicken so processed[2].

In the USA, on the basis of a special FDA exemption, diet portions of radiation-sterilised chicken breast, pork link-sausage, pork chops, bacon, ham, beef steaks, and ground beef patties have been supplied to the Fred Hutchinson Cancer Centre in Seattle, WA for patients requiring sterile foods (Radiation Technology, Inc.) since 1968. These portions were packaged in retortable pouches. Here, the condition for treatment is sterilisation at doses from 24 to 43 kGy. This is a comparatively large dose, but the products are irradiated at –30 °C. Over the past five years of use these patients who are probably the most vulnerable subjects because of their lack of immune background, have been kept alive and well on irradiated sterilised food[6].

An application for clearance of radurised poultry has been submitted to the FDA by Radiation Technology, Inc. It is currently under review. The FDA is thus once again forced into the position of having to consider a submission on this subject. It will be interesting to see the outcome. However, it is likely that no decision will be forthcoming for the next two to three years because the American research group in the US Natick Laboratories is conducting extensive studies on irradiated chicken and chicken products involving several feeding studies on chicken irradiated with higher doses, for sterilisation for army use. Clearly no decisions will be taken until the results of all these tests are to hand. It is quite possible that in some other countries submissions will come forward, probably also in the UK, for the clearance of chicken treated by radiation specifically against *Salmonella*.

In the **Netherlands** limited market trials were carried out in 1976 with irradiated fresh broilers. With the assistance of a major national wholesale company this commodity was distributed to four hospitals and an old peoples' home for evaluation by purchasers, dieticians and kitchen personnel. The meat was broiled or cooked on the 4th, 8th and 10th day after slaughter. The prepared broilers scored highest on the 8th day and the lowest on the 4th day, on which 82,3 % of the participants evaluated this food as "excellent" to "good" and 17,7 % as "fairly good". No marks for unacceptability were recorded. None of the participants had any objections to the fact that the food had been irradiated and indeed the improved hygienic (microbial) quality was greatly appreciated[11].

Market trials of this nature will shortly be carried out on an expanded scale since full commercialisation of this product is planned; this appears possible because an unconditional Ministerial clearance is now available.

In 1976 Khan and co-workers reported from the US Natick Laboratories that fresh eviscerated broilers could be treated with 2,50 kGy and stored for 15 days at 1,6 °C without deterioration. The birds were found to be free from *Salmonella*[7].

At present the US Army Natick Research and Development Command are conducting an extensive animal testing program on chicken either gamma-irradiated in metal cans or electron-irradiated in flexible pouches[12]. The irradiation dosage is 45 to 68 kGy at –30 °C. The meat is being fed to rats, mice and dogs as deboned ground meat and skin. Three-year studies were carried out on rats and mice and a two-year study on dogs. A multigeneration study was done on dogs but difficulties arose with reproduction on this diet. In addition, mutagenicity studies in *Drosophila* and a heritable translocation test in mice are under way. The latter is probably one of the most expensive studies because something like 30 000 progeny of mice have to be followed over six generations. An Ames (*Salmonella* reverse mutation) test was also performed. The results were negative. This fits in well with the studies contracted through the Project. Recently a battery of *in vitro* and *in vivo* mutagenicity studies were done using the methodology developed by the Project[8, 9]. These studies included the investigation of water extracts and digests of irradiated cooked chicken by the Ames test, by forward mutation tests and *in vitro* chromosomal aberration tests in cultured cells, by *in vivo* tests in rats, mice and hamsters fed on irradiated chicken and by studies on the induction of DNA damage. The latter studies were carried out at an Institute in Vienna. Again there was no evidence that feeding irradiated chicken induces any mutations in the various test systems or causes damage to the DNA[10].

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## DISCUSSION

**Question:** I have a question about the experiments on board the German ship "Anton Dohrn". Didn't recontamination take place after irradiation? Could you perhaps expand on this?

**Answer:** It would be difficult for me to expand on this because I have only read the outline of the report. I gather that they had difficulty in preventing recontamination. Another complication was the fact that they had an X-ray irradiator on board. This machine can handle only small quantities at a time. The technical situation was therefore not of the best but the overall outcome, as far as they could determine, was that over a sixteen-day period, there is no great advantage in cooling the fish in crushed ice and irradiating it. The situation may be totally different when one lands the same fish in port within two or three days of going out and one then has ten days for transporting it all over the country. This may be a problem with us because one does not know from one day to the next when the railways are going on strike and one is stuck with a few loads of fish from Liverpool or from Newcastle on the rail. Here irradiation will be useful. Usually one would have to throw the whole lot away, whereas with irradiation the fish would keep, which would be an advantage. Irradiation gives a sixteen-day shelf life to fish which otherwise is a very perishable product.

**Question:** The recent Codex Alimentarius recommendation is that chicken must be irradiated at 4 °C. This has far-reaching implications because the Joint Expert Committee recommended the irradiation of poultry below 10 °C, which is attractive from a practical point of view. However, the 4 °C recommendation makes irradiation unattractive from a cost point of view. From what I understand from Dr Ladomery of the FAO at the recent meeting in Vienna, that is purely a technical aspect for the microbiologists. They do not want to change the existing procedures, that is, they don't want irradiation to be treated differently from existing processes but I feel that from a local standpoint irradiation at 4 °C is impractical. Do you think that this would interfere with treatment on a local basis? I can see that on an international basis it could be a limiting factor but I cannot see the necessity of irradiating chicken at 4 °C if the same thing can be done at 10 °C.

**Answer:** If I remember the proceedings of the meeting correctly the 4 °C figure arose from the Codex Standard on prepacked broiler chicken. This is the storage temperature for the prepacked chickens – these are untreated chickens. I don't think that one has to irradiate at 4 °C as long as the chickens are stored at that temperature subsequently. That is what they really wanted. They did not want to prescribe 10 °C storage for irradiated chicken. Once the chickens have been irradiated they should be treated like any other prepacked chicken and be stored at 4 °C. I think the interpretation that one has to irradiate at 4 °C is taking things a little too far. I think this is what is meant, but the hygiene provisions and handling should be exactly the same as in the present existing accepted International Standard for prepacked chicken.

**Comment** by Dr van der Linde (Atomic Energy Board, Pretoria): I think the Codex Alimentarius Commission is definitely specifying irradiation at 4 °C.

**Question:** Do you see *Clostridium* as a hazard in fish? How difficult, from a practical standpoint, will it be to keep fish at 10 °C and if the temperature goes beyond this level for a short time, do you see any practical difficulty as far as *Clostridium* is concerned?

**Answer:** As far as I can gather the *Clostridium* question in fish is being investigated. There is *Clostridium botulinum B* present in fish even if it is caught 500 miles off the coast. It is there, even in non-irradiated fish, so provided the period of temperature rise is not too long, one would have no problems. I think that if the temperature rose, spoilage would take over and the fish would be inedible anyway.

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# PROBLEMS, PRACTICES AND PROSPECTS OF THE RED MEAT INDUSTRY IN SOUTH AFRICA

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## SAMEVATTING

Verbruikertevredenheid is die uiteindelike doel van 'n suksesvolle vleisnywerheid. As gevolg van die verskeidenheid in die nywerheid, uiteenlopende belange en lojaliteit van ondernemers, moet daar in SA nog veel gedoen word om 'n optimale beeld vir rooivleis te skep. Die drie belangrikste aspekte van so 'n doelstelling is maksimale rakleeftyd, verwerkings- en eetgehalte. Aandag word aan die volgende aspekte van rakleeftyd geskenk:

1. Die belangrikheid van optimaal patogeenvrye vleis.
2. Die gebrek aan wetgewing wat die rakleeftyd van veral vars vleis beheer.
3. Die volgende probleme in verband met rakleeftyd is uitgeken en geniet aandag:
   (a) Die primêre bron van vark- en beeskarkasbesmetting deur organismes by slagpale.
   (b) Die spanning wat diere voor en tydens die slagproses ondervind, het 'n besliste uitwerking op die eetgehalte van die vleis.
   (c) Doeltreffende slagmetodes om optimale vleisgehalte te verseker.
   (d) Karkasverkoelmetodes kan òf 'n nadelige uitwerking op die verwerkings- en eetgehalte van die vleis hê òf dit kan mikrobiese bederf veroorsaak.
   (e) Verpakking van vleis in suurstofdeurlatende verpakkingsmateriaal bevorder die vermeerdering van bakterieë.
4. Heelwat kennis oor die behoud en verbetering van gehalte is beskikbaar. Bestraling speel in hierdie opsig 'n belangrike rol.

## ABSTRACT

Buyers' satisfaction is the ultimate objective of a successful meat industry. However, because of diversification in industry and diverging interests and loyalties of entrepreneurs, much has yet to be done in South Africa to establish the sought-after optimal image of red meat. Three of the most important aspects of such a goal are maximum shelf life, and processing and eating qualities of the product in all its forms. Attention is focussed on the following aspects related to the shelf life of red meat.

1. It is essential that meat be as free as possible of pathogenic organisms.
2. Virtually no legislation is available on shelf life, especially in the fresh meat industry.
3. The following problems related to shelf life have been identified and are receiving attention:
   (a) The main sources of pig and beef carcass contamination by spoilage organisms at abbatoirs.
   (b) Pre-slaughter and slaughter stress of livestock which has a very detrimental effect on meat quality.
   (c) Efficient slaughter procedures to establish optimal meat quality.
   (d) The methods of carcass chilling which are either detrimental to the processing and eating quality of the meat or cause "bone taint".
   (e) The packaging in oxygen-permeable film in supermarkets which allows the development of high bacterial counts.
4. Considerable expertise is available regarding quality preservation and improvement, irradiation playing an important role in this respect.


## 1. INTRODUCTION

Meat is the most important source of protein in the diet of the consumer in the Western World, Australasia and Southern Africa. It comprises some 40 % of the entire food budget of the housewife in South Africa. From an international point of view, however, red meat is still relatively inexpensive in this country as is clearly illustrated in Table 1. Only in the case of Australia was beef sold at a lower price than in the Republic. To illustrate the variation in prices of a beef carcass comparable figures published by the Meat and Livestock Commission in England and those obtained in a survey of 60 meat retail outlets in Pretoria and the Witwatersrand are listed in Table 2. This most essential and very expensive item on the menu is, however, a very perishable product and it is therefore all-important that optimal shelf life — the theme of the present

TABLE 1
INTERNATIONAL MEAT PRICES (c/kg : 1978)

| Country | *Beef sirloin | **Leg of mutton |
|---|---|---|
| South Africa | 221 | 242 |
| Australia | 175 | 213 |
| New Zealand | 312 | 194 |
| Western Germany | 1 168 | — |
| United Kingdom | 497 | — |
| United States | 367 | 592 |
| Japan | 1 862 | 347 |

*without bone
**with bone

TABLE 2
BEEF CUT PRICES (c/kg : June 1979)

| Cut | United Kingdom | South Africa |
|---|---|---|
| Topside | 668 | 276 |
| Sirloin | 785 | 303 |
| Rump | 920 | 371 |
| Fillet | 1 167 | 415 |
| Chuck | 465 | 181 |
| Brisket | 245 | 177 |

conference – should be the goal of the entire meat industry. One of the main reasons for the importance of maximum shelf life being the major determinant of an optimal image of meat, is the fact that 75 % of the red meat marketed in South Africa is sold as fresh meat which is more perishable than most processed meat products. The per capita consumption of carcass meat purchased by the South African consumer is listed in Table 3 comparing 1968 and 1978.

**TABLE 3**
**MEAT CONSUMPTION IN SOUTH AFRICA**
**(kg/capita)**

| Type | 1967/68 | 1977/78 |
|---|---|---|
| Beef and veal | 24,2 | 23,0 |
| Mutton and goat | 8,3 | 6,2 |
| Pork | 3,0 | 3,2 |
| Red meat – total | 35,5 | 32,4 |
| Poultry | 3,8 | 13,7 |
| All meat – total | 39,3 | 46,1 |

Red meat consumption has therefore decreased during the past 10 years, whereas white meat consumption has more than trebled during the same period, the latter being the only reason for an increase in the total meat consumption.

## 2. OPTIMAL IMAGE

Meat is an expensive food commodity, but very important to the consumer in South Africa. It is therefore most essential to establish and maintain the optimal image of this product in order to promote increased consumption and therefore growth in the industry. This optimal image is all important and in order to accomplish it, overall efficiency as well as effective liaison is essential between the producer of red meat, the middle man handling this product and finally, the consumer of the product. A relationship of this kind can lead to the creation of a stabilising life policy for the meat industry of this country.

## 3. MEAT-INDUSTRY CHAIN

The fusing links in the production chain joining the producer, middle man and consumer are the following in chronological order: Heredity and physiology of the meat animal which has to produce in a given environment. These three links are managed by the producer (Fig. 1).

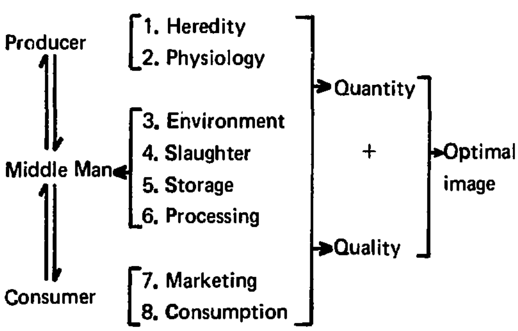



*Figure 1*
*Meat-industry chain*

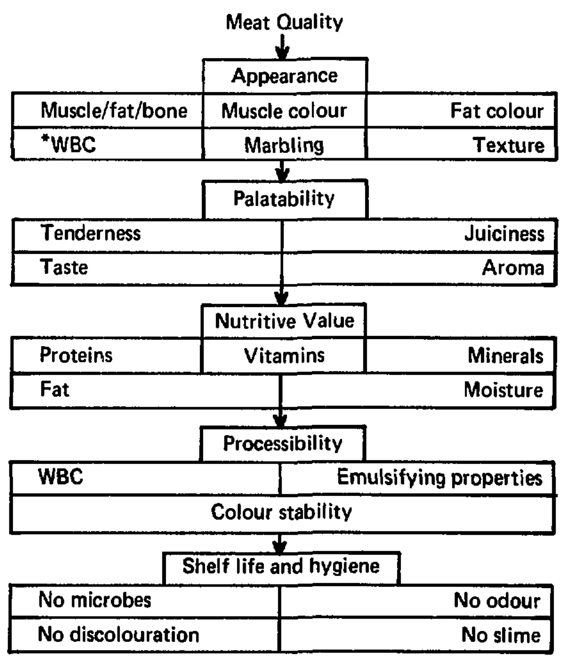
From the final finishing stage the animal is transferred within a given environment to the middle man who will slaughter the animal and store, as well as process the products within the next three links of the chain. Finally, the consumer will obtain the product (marketing) and consume it to feed his body and simultaneously experience optimal eating satisfaction. The common goal and need of the three persons regulating the eight links of the meat-production chain is to enhance the quantity and quality of the product and thereby establish an optimal image of red meat.

## 4. EFFICIENT SYNCHRONISATION

In order to accomplish the most efficient synchronisation in the entire marketing process, the producer should achieve the highest and most efficient possible production and also obtain the highest possible price for his product. At this stage the middle man accepts responsibility in the marketing chain with the object of promoting maximal consumption of a high-quality product and at the same time obtaining the highest possible price for his product. Eventually, the consumer's goal is to buy the best possible quality meat at the most reasonable price. A combination of the above conditions would yield the optimal image of the product. Therefore close liaison between the various links of the meat-production chain is of the utmost importance.

## 5. MEAT QUALITY

The keyword for success in the meat industry is quality – a very complicated concept. A schematic outline of meat quality is presented in Fig. 2.




*WBC = Waterbinding capacity

*Figure 2*
*Schematic outline of meat quality*

The consumer's first impression of the product could be of great importance in establishing an optimal image in her mind. Appearance of the product in terms of edible to non-edible product, texture and absence of drip in the pack has a marked influence on the decision process of the housewife.

Her meat purchases are then taken home and cooked for the family meal. The product should therefore be highly palatable — the ingredients of the second group of quality characteristics are tenderness, aroma, juiciness and taste. Although the palatability is to the consumer the most distinct and clear impression of quality, he would, from a long-term point of view, also need the assurance that the product is highly nutritious and contains most of the nutritional components of a balanced diet such as vitamins, minerals, essential fatty acids and amino acids. The quality characteristics of importance to the meat manufacturer are those of processibility, such as waterbinding capacity, emulsifying properties and colour stability. In the last instance the optimal shelf life and hygiene properties of the product are of major aesthetic, safety and financial importance to middle men and consumers. This implies that meat should be as free from contamination as possible, and no signs of decay or quality deterioration should be present in the form of objectionable odours, discolouration or slime formation.

From the discussion on meat quality it is evident that this extremely important concept in the meat industry is most complex, and should, because of the interwoven nature of these quality characteristics, always be considered in a wholistic manner in order to achieve the goal of an optimal image.

## 6. SHELF LIFE

The theme of the conference is shelf life of food products. In the South African meat industry the shelf life of fresh chilled meat is a key concept for a successful and sound trade in this commodity. The ratio of processed to unprocessed beef in the country is approximately 25:75; for mutton 2:98 and for pork 65:35. In the case of the 75 % fresh beef, 39 % is still sold in the conventional butcher shop and 25 % is being prepacked for supermarkets and 11 % sold per contract to institutions.

In the production chain, meat is being handled in many phases. At farm level some 75 000 producers are involved and at the next level the product is dealt with by 1 382 abattoirs, 225 wholesalers, 168 meat factories, 4 915 retail butchers and 624 supermarkets. Finally, the portion of meat is being handled in some way or another before consumption by 23 million consumers.

In South Africa 73 % of the meat consumed is classified as red meat and 27 % as white meat and of the red meat 68 % is beef, 21 % mutton and goat meat and 11 % pork.

In order to assist in maintaining an optimal level of safety and shelf life of the product, this aspect of meat quality is protected to a certain extent by legislation. For this purpose 13 Acts have been promulgated and are administered by 6 different State Departments. Synchronisation if therefore of the utmost importance. In order to achieve this, a number of liaison bodies have been established. These are amongst others the *ad hoc* committee for meat handling, liaison committee between the departments of Health and Agriculture, committees for carcass chilling, carcass grading, carcass and meat irradiation, a liaison committee for processed meat quality organised by the South African Bureau of Standards and a number of committees operating at the Meat Board. Close collaboration between these groups with the common objective of furthering and protecting meat quality, is therefore absolutely essential and will benefit producer, middle man as well as consumer, and therefore the entire meat industry.

## 7. ACTIVE INVOLVEMENT OF THE MIDDLE MAN

The task of the middle man is to transform slaughter stock to meat in whichever form the consumer may require it. In order to be efficient in this transformation operation, he should be a competent and skilled operator. This middle man is however not a single person. A multitude of disciplines are involved during this transitional period of the product. The following list comprises the most obvious primary middle man sectors:

7.1 Livestock transport
7.2 Livestock marketing
7.3 Abattoir industry
7.4 By-products industry ("fifth quarter")
7.5 Meat inspection
7.6 Carcass grading/classification
7.7 Carcass marketing
7.8 Carcass chilling
7.9 Carcass and meat transport
7.10 Wholesalers
7.11 Carcass and meat hygiene
7.12 Processing (manufacturing) and packaging
7.13 Retailers
7.14 Institutional buyers/consumers

Each and everyone of these middle men have a responsibility in terms of the establishment of optimal meat quality of which a most crucial component is the shelf life of the product.

## 8. PROBLEMS OF THE MIDDLE MAN INDUSTRY IN SOUTH AFRICA

The production goal of the livestock breeder and livestock producer is to produce a "finished" product for the market. This "finished" product should, however, first be converted into a consumable product before the marketing chain has been completed. This intermediate phase in the chain is extremely complicated and complex. Numerous problems confront the operators at each progressive step of the process. In order to illustrate this concept a number of problem areas will be discussed.

### 8.1 Transport

Livestock transport containers and methods of transport could result in carcass bruising causing poor shelf life of the affected tissues and decreased financial return. Long-distance transport could result in animals being stressed – causing muscle fatigue and rapid depletion of muscle glycogen. When animals in this condition are slaughtered without a pre-slaughter rest period, only a low level of lactic acid, hence a high pH, will be present when muscles are in *rigor mortis*. The appearance of meat with a high (> 6,0) ultimate pH is exceptionally dark, firm and dry (DFD), and the meat itself is very prone to spoilage and will therefore have a very poor shelf life. If this kind of meat is slowly chilled due to either the physical characteristics of the carcass or the low efficiency of refrigeration, then the "deep leg" temperature of 15 °C within a short period after slaughter will not be achieved and "bone taint" as a result of the growth of anaerobic micro-organisms, will develop. Meat of this nature would have poor processing characteristics and would have a very typical green appearance inside a vacuum pack.

Glycogen can be rapidly replenished in pig muscle by feeding sugar to the animals prior to slaughter, which would then result in normal levels of lactic acid in muscles fully in *rigor mortis*. This method of correcting stress only applies to the monogastric pig and not to the ruminant.

## 8.2 Pre-slaughter Stress

A further example of stress especially in the case of the pig, is found when animals are handled roughly immediately prior to slaughter, for instance, by improper transport, mixing groups of pigs, shouting, beating and using an electric prodder at the abattoir. This kind of stress even in the case of stress resistant pigs, but especially with stress susceptible pigs, will cause a very rapid post-mortem glycolysis in the muscles resulting in a low muscle pH (< 6,0) while the muscle temperature is still close to body temperature (> 32 °C). This combination invariably results in muscle protein coagulation causing the condition known as pale, soft, exudative pork (PSE). Meat of this nature has poor processing qualities and has a relatively limited shelf life. When stress susceptible pigs are subjected to pre-slaughter treatment as previously described, it could even result in early deaths of pigs in transit or in lairage.

## 8.3 Stress During Slaughter

A third problem area of the middle man industry is that of the slaughter of livestock. In South Africa 1 380 abattoirs are in operation, slaughtering 1,9 million cattle, 6 million sheep and 1,5 million pigs per annum.

### 8.3.1 STUNNING

The stunning procedure applied has a marked effect on the meat quality of slaughter stock. Captive bolt stunning of pigs causes the development of PSE pork in the case of 80 % of the animals slaughtered. Indirectly, electrical stunning also has a detrimental effect on pork quality. Pigs are slaughtered at some 450 abattoirs and bacon factories in South Africa. Poor slaughter management could therefore be extremely detrimental to optimal shelf life and hence to overall quality of fresh meat purchased by the consumer.

### 8.3.2 "BLOOD SPLASH"

Undue delay between stunning and bleeding an animal is a further cause contributing to poor meat quality. It is believed that this delay gives rise to an increase in blood pressure, resulting in numerous intramuscular and visceral haemorrhages causing the so-called condition of "blood splash". Meat affected in this manner is aesthetically unacceptable to the consumer of fresh meat and has a limited shelf life due to the presence of blood on the cut surfaces of meat. In a survey at two of the largest abattoirs in South Africa it was ascertained that the mean duration between stunning and bleeding of cattle was 49,5 and 66,3 seconds with a period of more than 60 seconds for only 14,2 % of the cattle slaughtered at the former abattoir and as high as 52,4 % in the case of the latter, where, incidentally, "blood splash" was reported sporadically serious in cattle, which is rare for this species. Incorrect electrical stunning of pigs and sheep can also cause "blood splash". Improving slaughter procedures can therefore greatly improve meat quality, especially with respect to shelf life.

## 8.4 Abattoir Hygiene

In a pig slaughter plant the bacterial load on carcass surfaces immediately after dehairing is extremely high (Fig. 3).

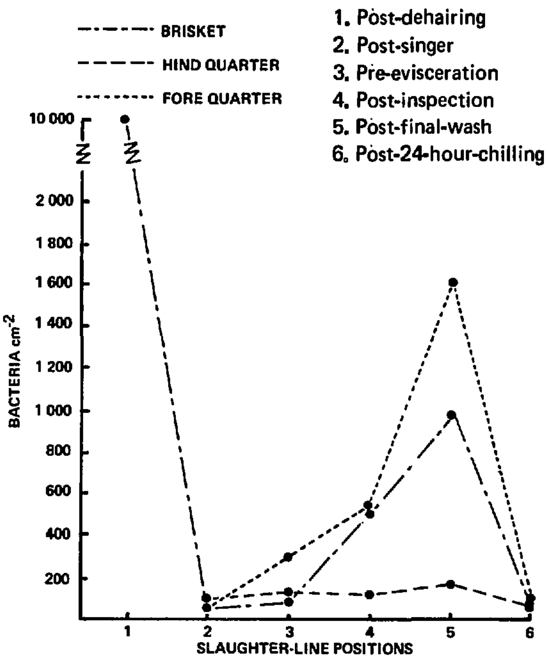



*Figure 3*
*Aerobic mesophilic bacterial counts on pig carcasses along the production line*

After having passed through the singer in which the flame temperature is as high as 2 000 °C carcass surfaces are almost sterile. Carcasses are however handled and processed at a number of positions on the slaughter-line, causing contamination and a fairly high bacterial count is found on carcasses after the final wash and prior to chilling. The chilling process was found to be fairly effective in inhibiting bacterial growth. Poor hygiene during slaughter or chilling operations could therefore have a detrimental effect on the shelf life of meat.

## 8.5 Processing Hygiene

In the bacon factory discussed in 8.4 bacterial contamination during the bacon manufacturing process was studied (Fig. 4).

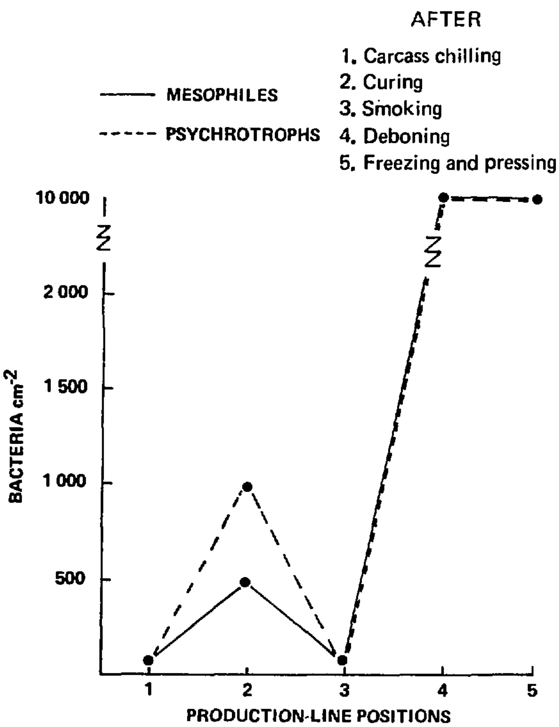



*Figure 4*
*Aerobic bacterial counts on bacon along the production line*

The counts after carcass chilling is the same as those of position 6 in Fig. 3. An increase in bacterial load was measured after curing, a marked decrease after smoking due to increase in temperature and possibly a bactericidal effect of the smoke, followed by an alarming increase in bacterial numbers measured after deboning, which remained high when measured after freezing and pressing of deboned meat. This state of affairs has a markedly negative effect on the shelf life of bacon.

## 8.6 Vacuum-packed Beef

The vacuum packaging industry is rapidly increasing throughout the developed world. A forecast published in England recently stated that by 1982 of the fresh beef sold in various countries the following proportions would be sold as vacuum-packed beef: France 47 %; Germany 60 %; Italy 18 %; United Kingdom 67 %; Scandanavia 47 % and the United States 63 %. Therefore abattoir, deboning and packaging hygiene will become increasingly important for ensuring optimal shelf life of fresh meat packed in oxygen films for sale at the chilled meat counter of supermarkets.

## 8.7 Carcass Pre-chilling

In order to prevent "bone taint" carcasses have to be chilled to a "deep bone" temperature of 15 °C as quickly as possible and in order to comply with EEC chilling requirements for countries importing meat into the EEC, a "deep bone" temperature of 7 °C has to be attained before carcasses may be transferred from the chillers to any next step of the marketing chain. *Salmonella* growth is inhibited at temperatures below 7 °C. In an attempt to achieve a "deep bone" temperature of 7 °C within a one-day-cycle, rapid chilling is practised causing the temperature in several superficial muscles, such as the *M. longissimus lumborum et thoracis*, to be lowered to below 10 °C within 10 hours after slaughter – that is while the muscle pH is still higher than 6,0 and muscles still react to cold stimulation. Severe muscle contraction results in these muscles due to cold shock, causing a condition known as "cold shortening" with a dramatic toughening effect on muscles. This condition is only rectified by applying extended ageing periods to the meat. The paradox of rapid chilling evident from this discussion, therefore, is that in this case a good hygiene practice could lead to poor eating quality of meat – which will have a negative effect on the image of red meat throughout the world. "Cold shortening" of certain leg and back muscles can be prevented to a large extent by suspending carcasses from the pelvic bone with the carcass hook through the *obturator foramen* which will prevent contraction of these muscles, instead of suspending the carcass in the conventional way with the hook through the achilles tendon which allows muscles to contract more readily when cold shock is applied. In these two methods muscles will then pass into *rigor mortis* either in a relaxed or contracted condition, resulting in tender or tough meat respectively.

Muscle toughening due to rapid chilling of carcasses can also be prevented by passing an electric current of 500 to 800 V through the carcass for 60 s within 40 min after stunning. This will deplete the energy in the muscles so rapidly that by the time the muscle temperature has been lowered to a level of lower than 10 °C, which is the "shiver level" of *pre-rigor* muscles in a carcass, insufficient energy will be available to allow severe contraction, shortening and toughening of the muscles. Differences of more than 100 % in the tenderness of muscles have been observed between stimulated and non-stimulated carcasses which had all been chilled rapidly after slaughter.

## 8.8 Extended Chilling of Carcasses

The most commonly known way of tenderising meat, is by hanging chilled carcasses for one to three weeks allowing intrinsic proteolytic enzymes to ripen or age or tenderise the muscles. Results have shown that electrically stimulated carcasses chilled for two days attains comparable tenderness to muscles of non-stimulated carcasses which had been chilled for 12 days after slaughter. Extended periods of chilling, however, are costly in terms of energy expenditure, occupying costly refrigeration space and loss of moisture and therefore mass loss of carcass meat. Dessication, of certain muscles, causes formation of metmyoglobin and hence a darkening of meat colour. In an attempt to prevent excessive surface dessication of carcasses, and therefore mass loss, carcasses were wrapped in plastic film. Bacterial growth proved to be a problem with these carcasses with a moist surface.

Leaner as well as smaller carcasses are all prone to a higher loss in mass than larger and fatter carcasses. "Dark cutting" meat with a high ultimate pH has a very limited shelf life in terms of colour stability as well as keeping quality under chilled conditions. Optimal muscle and hygiene conditions are therefore of the utmost importance to achieve maximum shelf life of the carcass cut or prepacked portion.

## 8.9 Freezing of Carcasses and Cuts

### 8.9.1 PRE-RIGOR FREEZING (LAMB CARCASSES)

If a carcass is frozen before *rigor mortis* has set in, extreme shortening, toughening and exudation of muscles will occur when the meat is thawed and the condition is known as "thaw rigor". This was first observed in New Zealand lamb carcasses exported to the USA and the UK and was due to the installation of more efficient freezing equipment in New Zealand abattoirs during the mid-sixties of this century. Most unacceptable eating quality, as well as shelf life, found in this kind of meat forced the New Zealand lamb industry to hang carcasses for a few hours before the commencement of blast freezing, which allowed the muscles to sufficiently advance into the *rigor* condition, preventing the typical symptoms of *pre-rigor* freezing when thawed.

### 8.9.2 POST-RIGOR FREEZING (MEAT)

In a freezing investigation of beef all the deboned primal cuts of beef carcasses were vacuum-packed and frozen at two rates, simulating househould (−15 ºC) and industrial freezing (−28 ºC).

When thawed for further processing marked differences in thawing losses between the various cuts and within the same cuts frozen at different rates were measured (Table 4).

TABLE 4
VACUUM-PACKED DEBONED PRIMAL CUTS OF BEEF

| Primal cut | % Thawing loss when frozen at | |
|---|---|---|
| | −15 ºC | −28 ºC |
| Rump | 8,1 | 6,0 |
| Topside | 4,9 | 3,9 |
| Brisket | 2,2 | 1,4 |
| Shin | 1,9 | 1,0 |

The most expensive cuts proved to be the most vulnerable in relation to the less valuable cuts, and slow freezing, because of the increased drip loss, will cause a much reduced shelf life of these cuts after freezing, as well as reduced processing characteristics due to the poorer water binding capacity of the meat proteins. The latter is due to the protein damage caused by thawing of the larger ice crystals which are formed during slow freezing in contrast to small ice crystal formation of more rapidly frozen cuts.

## 9. OPTIMAL IMAGE

In order therefore to establish an optimal image of red meat in industry, every phase of the production chain, from the producer, to the middle man, to the consumer, has to be very well synchronised with the next phase through the closest possible collaboration of all entrepreneurs. The golden rule of the weakest link determining the strength of the chain is most applicable. Two of the major characteristics of this optimal image is optimal quality and optimal shelf life. To sum up, a poor shelf life can be prevented by ensuring that stress is absent, and that slaughter and process hygiene are maintained, followed by correct chilling and freezing, correct packaging and retail marketing – with the very attractive possibility of appreciably extending shelf life by the process of irradiation.

## 10. CONCLUSION

The prime objective of the meat industry should therefore be to produce a product with optimal processing and eating quality (the responsibility of the producer and the middle man), in which maximal shelf life is guaranteed (the responsibility of the middle man) establishing an optimal image of the product (resulting in consumers' satisfaction). The end result of this ideal situation will be progress and stability in the meat industry.

ZA8000320



# IRRADIATION OF EDIBLE FOOD ANIMAL OFFAL

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## SAMEVATTING

Eetbare afval is uit 'n ekonomiese en voedsaamheidsoogpunt vir tradisionale verbruikers van belang. Die meeste afval word as afgespoelde afval verkoop wat baie maklik sleg word. Verbruikers en handelaars van afval besit selde yskaste, daarom is die rakleeftyd baie beperk

Hierdie voedsel huisves potensiële patogeniese of toksigeniese mikro-organismes. Metodes wat die mikrobiese toestand kan verander sonder om die koste te verhoog of om die natuurlike voorkoms aansienlik te verander, word dus vereis. Die totale aërobiese en anaërobiese mesofiele bakterieëtellings het, na gammabestraling van 1 tot 2 kGy, met meer as 90 % gedaal. Verskeie spesies van sekere klasse naamlik *Bacillus, Micrococcus, Streptococcus, Staphylococcus* en *Clostridium* het selfs 6 kGy oorleef. *S. aureus, S. dublin* en *C. perfringens* kon nie na bestraling met 6 kGy in geïnokuleerde gemaalde afgespoelde afval opgespoor word nie. Dit blyk dat die houvermoë van afgespoelde afval deur middel van radurisering met 'n faktor 2–3 verleng kan word. Die voordele van bestraling was oor die algemeen meer opvallend in voedsel wat by kamertemperatuur geberg is as by 4 °C.

Verhitting van die afval tot 80 °C voor bestraling met 4 kGy het beter resultate gelewer as slegs bestraling met 6 kGy. 'n Beperkte organoleptiese evaluasie het nie beslissende resultate gelewer nie.

Alhoewel bestraling wel voordele inhou, is verdere werk nodig. Die ekonomie van hierdie proses is nog nie ondersoek nie.

## ABSTRACT

Edible offal is economically and nutritionally of considerable significance to traditional consumers. Most offal is sold as rough washed offal (RWO) and is highly perishable and since consumers and retailers of offal rarely possess refrigerators, shelf life is limited.

This food harbours potentially pathogenic or toxigenic micro-organisms. Methods are therefore required to improve its microbiological state without adding to the cost or significantly altering the natural appearance of the product. Counts of total aerobic and anaerobic mesophilic bacteria decreased by more than 90 % after gamma-irradiation treatment at 1 to 2 kGy but species of certain genera notably *Bacillus, Micrococcus, Streptococcus, Staphylococcus* and *Clostridium* survived up to 6 kGy. *S. aureus, S. dublin* and *C. perfringens* could not be recovered from inoculated minced RWO after 6 kGy irradiation. It appears that the keeping quality of RWO could be extended by a factor of 2 to 3 by radurisation. The advantage of irradiation was generally more marked in material stored at room temperature than at 4 °C.

Heating of RWO to 80 °C prior to irradiation at 4 kGy gave better results than irradiation at 6 kGy. A limited organoleptic evaluation failed to yield conclusive results.

Although irradiation of offal holds certain promise, further work is required. The economics of the process have not yet been investigated.


## 1. INTRODUCTION

More particularly in developing countries, but wherever the cost of animal protein food is a consideration, edible offal is an economically and nutritionally important food. In addition there are population groups who traditionally consume offal out of preference. This condition prevails in many parts of the world and also in Southern Africa.

The rumen or tripe is perhaps the most sought-after part of the gastro-intestinal tract used as offal. The ten largest abattoirs in South Africa handle some 350 t of rough washed rumen per day. The more sophisticated consumer requires tripe to be scalded, scraped and bleached. Such processing reduces the average mass of a bovine paunch from 8,46 to 5,28 kg and increases the price at the Offal Pools from 30 to 77c/kg. Scalding and scraping or any process which alters its 'natural' character, is not favoured by most of the traditional consumers who prefer it in the rough washed state. In this latter process the rumen is simply opened and emptied of its contents prior to the ingesta being washed out in clean running water before it is hung to drip dry. The ruminal wall consists of light to dark brown epithelium supported by various layers of involuntary (white) muscular tissue which varies greatly in thickness according to the part of the ruminal wall concerned. The nature of the ingesta and the epithelium lining the rumen frequently results in visible feed particles adhering to the epithelial papillae. These projections vary in size and shape in different parts of the rumen according to the age and feeding regimen of the animal concerned.

## 2. PERISHABILITY

Rough offal (tripe) is highly perishable by virtue of the presence of catheptic enzymes in the tissues and of astronomically large numbers of a variety of organisms in and on the epithelium. The total bacterial content varies from 9 – 11 logs/g. Depending on the nature of the feed, counts may vary. The nature of the feed also determines the types of bacteria which predominate. They may be classified as cellulolytic, hemicellulolytic, pectinolytic, proteolytic or capable of splitting mono- and disaccharides, starches and organic acids[7].

Ruminal wall has been found to be a substantial source of physochrotrophic, mesophilic and thermophilic organisms with counts of 10 000, 4 000 000 and 430/g respectively being recorded in England[8]. In South Africa total aerobic counts of $8 \times 10^5$ to $4 \times 10^6$ have been recorded for rough washed offal while staphylococcal and clostridial counts have varied from $9 \times 10^2$ to $4 \times 10^4$/g and from $2 \times 10^3$/g to $5 \times 10^3$/g, respectively[9].

From this it becomes clear that the very nature of ruminal epithelium and the contents of the rumen renders it most difficult, if not impossible, for the rumen to be adequately cleaned and so converted into a marketable foodstuff which is of a hygienic status close to that required of other foods of animal origin. In addition, a particular situation which prevails in slaughter cattle requires consideration: Cattle sent for slaughter inevitably experience some degree of stress, thirst and starvation during transit to and holding at the abattoir. On arrival and prior to slaughter they are given access to water and feed, the latter frequently being strange to them. These factors may lead to slow or abnormal ruminal fermentation as evidenced by elevation of pH, decrease of the volatile fatty acid content and an increase in the concentration of lactate in the ruminal fluid[7]. In the rumen of the normal and regularly fed bovine, *Salmonella* organisms do not survive[2] but ruminal dysfunction facilitates survival and proliferation of those *Salmonella* which gain access to the gastrointestinal tract[1]

This again leads to excretion and consequent elevation of levels of *Salmonella* contamination of the environment in which cattle are transported and held before slaughter. These circumstances make the presence of *Salmonella* in rough washed tripe a distinct possibility. A survey in Johannesburg revealed such a high incidence of *Salmonella* species, *Escherichia coli* and *Clostridium perfringens* in the tripe and intestine offered for human consumption that the authors concluded that the offal was inadequately cleaned[6].

In terms of the usual microbiological standards applicable to meat and other foods, rough-washed offal (tripe) can only be classified as unsatisfactory, unhygienic and potentially harmful due to the presence of pathogenic and toxinogenic bacteria. For the traditional consumer of such offal it is essential that the product be kept "au naturae" and that processing and storage costs be kept to the minimum. Some form of processing to render the product more hygienic and therefore safer and of improved keeping quality is, however, clearly required.

## 3. OTHER FORMS OF PRESERVATION

Various attempts have been made at developing an inexpensive method of improving the hygienic status and keeping quality of offal[2]. Regulations require that offal be chilled to −2 °C or lower if not removed from the abattoir within two hours of slaughter of the animal concerned. Scraping and alkaline treatment reduces the bacterial load but adequate subsequent chilling is essential to maintain this situation.

Scraping alone does not materially reduce the high bacterial counts of rough washed tripe[9]. While storage at 4 °C kept total aerobic bacterial counts under control, staphylococcal counts tended to increase[9]. In England it was found that during storage at 0 °C the numbers of mesophiles in minced ruminal wall increased gradually over the first three days, to be followed by a rapid increase over the following four days, until unpleasant odours became detectable and bacterial counts had risen to $2,4 \times 10^7$/g. Parboiling and chilling has been reported to be of some benefit[2], as is rinsing in weak organic acids before chilling[9]. At the country's largest offal pool, tripe is currently frozen and sold in plastic bags. To my knowledge the effects of chilling and freezing have not been evaluated in controlled experimentation. Amongst the traders in and consumers of rough washed offal, the possession of refrigeration facilities is uncommon and the effect of thawing prior to retail sale in smaller portions can be imagined.

Whereas the wisdom of permitting the sale, as food, of rough washed ruminal wall (tripe) may be questioned from the hygienic point of view, there can be no doubt about the nutritional value of this type of offal[3, 4] Calculated against whole egg as reference standard (1), one finds the Essential Amino Acid Index of fresh beef to be 0,8 and that of tripe to be 0,6[7].

## 4. RADURISATION

Radurisation appears to offer obvious possibilities and it could possibly be done at the ten larger abattoirs in the controlled marketing areas of the Republic where about 68 % of the total of some 1,5 million cattle are slaughtered annually. This would require processing of some 86 700 tons (1 ton = 1 000 kg) of tripe/a or 333 tons/d.

*Experimental work:* With irradiation being done at Pelindaba, our initial work showed that doses of 1 to 2 kGy reduced counts of total aerobic and anaerobic mesophilic bacteria by >90 % but certain genera survived, e.g. *Moraxella, Acinetobacter, Bacillus, Micrococcus, Streptococcus, Staphylococcus* and *Clostridium*[10]. On the other hand, minced tripe experimentally contaminated with 24 h old cultures of *Staphylococcus aureus, Salmonella dublin* and *Clostridium perfringens* were freed of these organisms by 6 kGy of $\gamma$-irradiation. The apparent effect of radurisation on the keeping quality of minced tripe stored at 4 °C was to extend the shelf life by a factor of 2 to 3[10].

Subsequent studies attempted to establish useful and objective methods of assessing spoilage of tripe. Fresh tripe has a characteristic odour which many persons find unpleasant and objectionable and even amongst traditional consumers there exists variation in acceptance levels of the organoleptic changes which develop on storage of tripe.

We considered the pH, $H_2S$ content and Total Volatile Nitrogen (TVN) levels of fresh, whole and minced rough washed tripe after storage at 4 °C and ambient (room) temperatures (RT), and recorded organoleptic changes as well as the total bacterial counts.

The assessment of the value of irradiation by pH, $H_2S$ and TVN levels was, however, complicated by the considerable variation in the initial bacterial counts of untreated tripe and the fact that eventual counts were self-limiting at 10 to 11 logs/g irrespective of treatment or storage temperature. The latter did, however, exert a very marked influence on the increase of both aerobic and anaerobic counts of untreated tripe, counts of 10,9 logs/g being reached after 48 h at room temperature and only after 25 d at 4 °C. Generally, the experimental material was retained until organoleptic changes had reached such an advanced stage that it could no longer be examined.

The results of assessment of the parameters detailed above in respect of whole rough-washed (RW) tripe stored at room temperature (RT) and 4 °C are summarised in Figs. 1–8. Although none of the parameters proved to be an outstanding measure of the condition of the tripe in terms of the bacterial load or our own organoleptic evaluation of its consumer acceptability, these graphs serve to show that in almost all instances material irradiated with 2 to 6 kGy fared better than the untreated controls. Generally the benefit of radurisation was greater in tripe stored at RT than at 4 °C. The greatest benefit was obtained by heating tripe to 80 °C prior to 4 kGy irradiation.

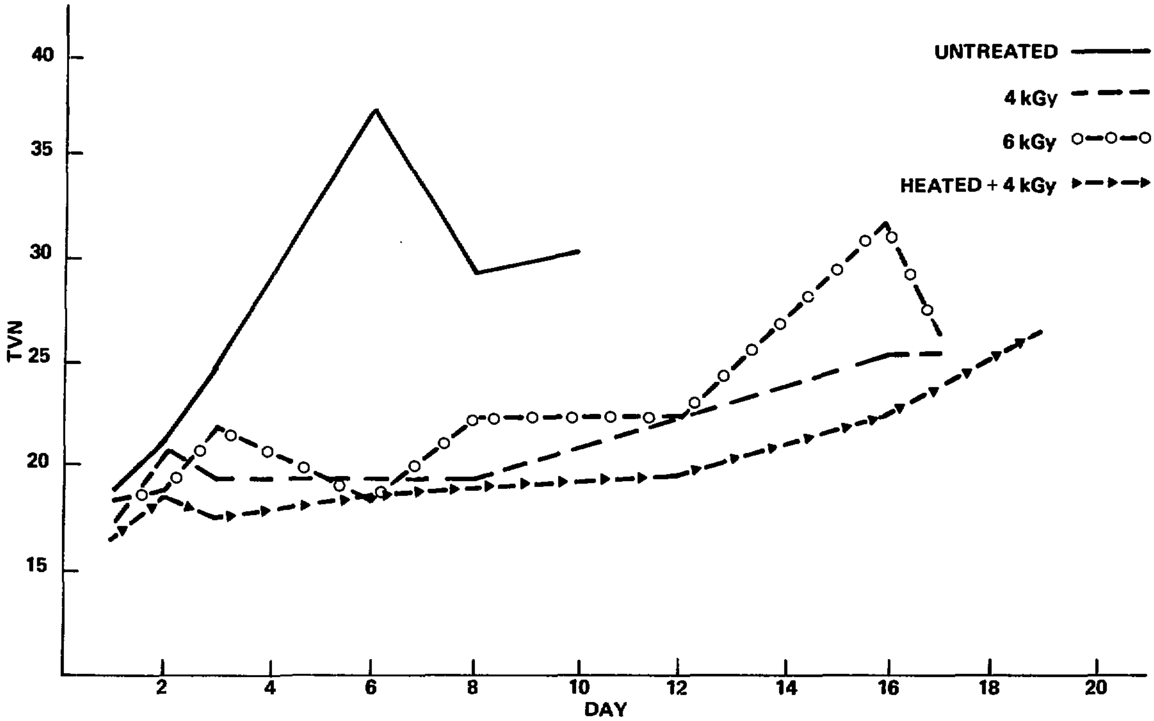


*Figure 1*
*Mean TVN-values of whole RWT stored at RT*

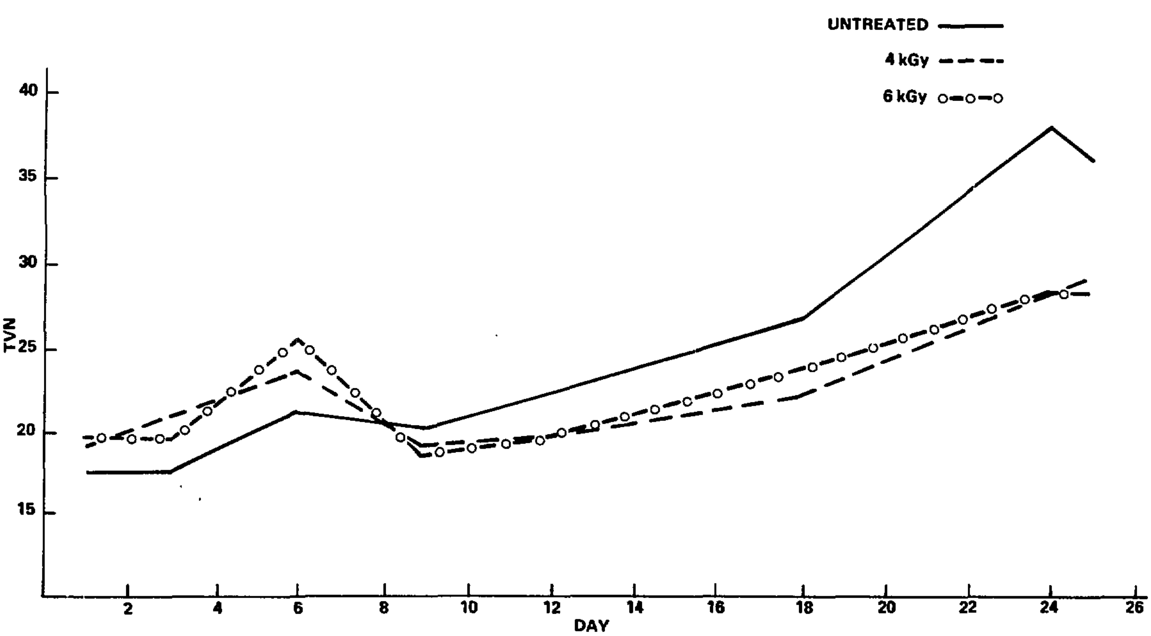


*Figure 2*
*Mean TVN-values of whole RWT stored at 4 °C*

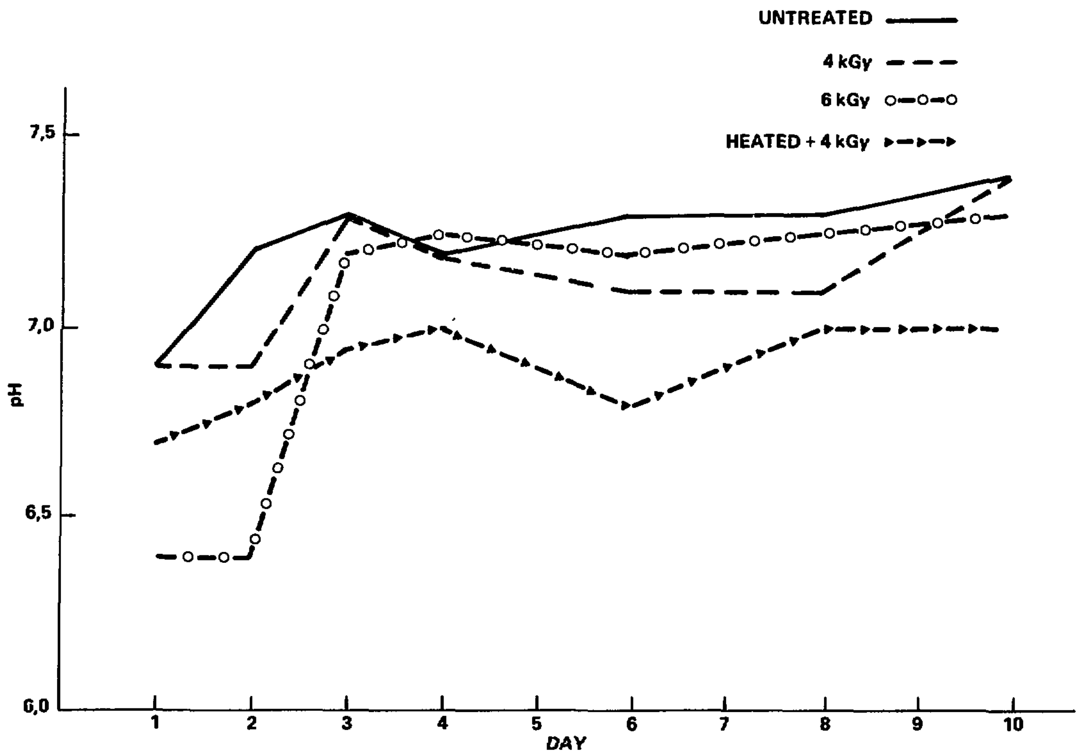


*Figure 3*
*Mean pH-values of whole RWT stored at RT*

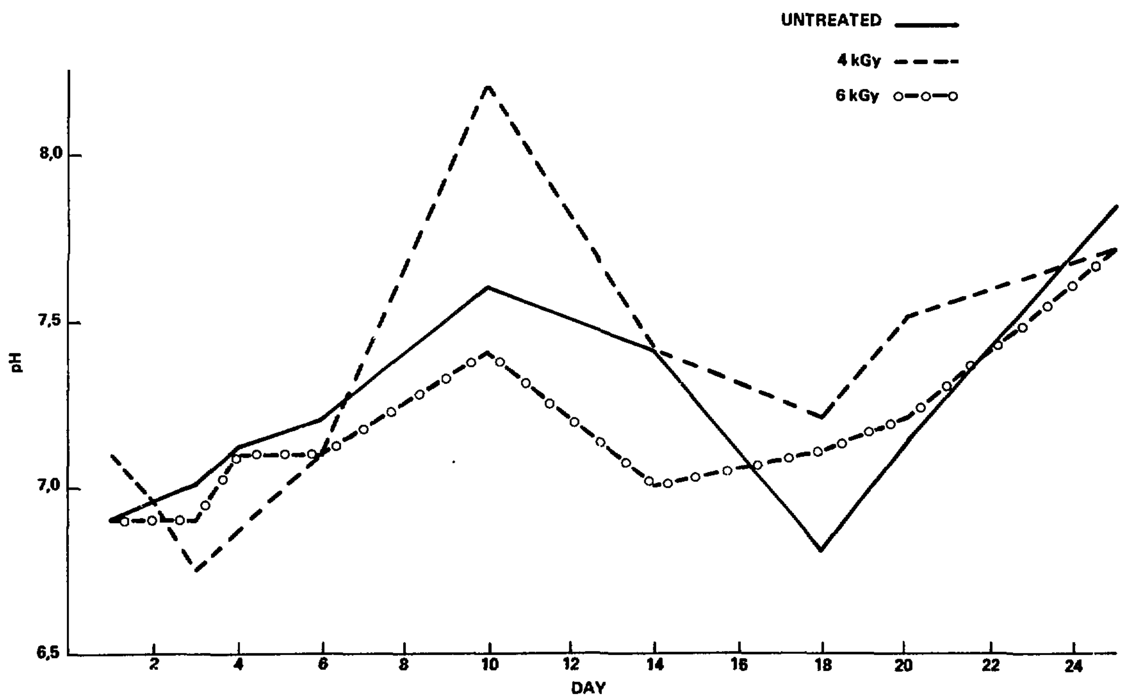


*Figure 4*
*Mean pH-values of whole RWT stored at 4 °C*

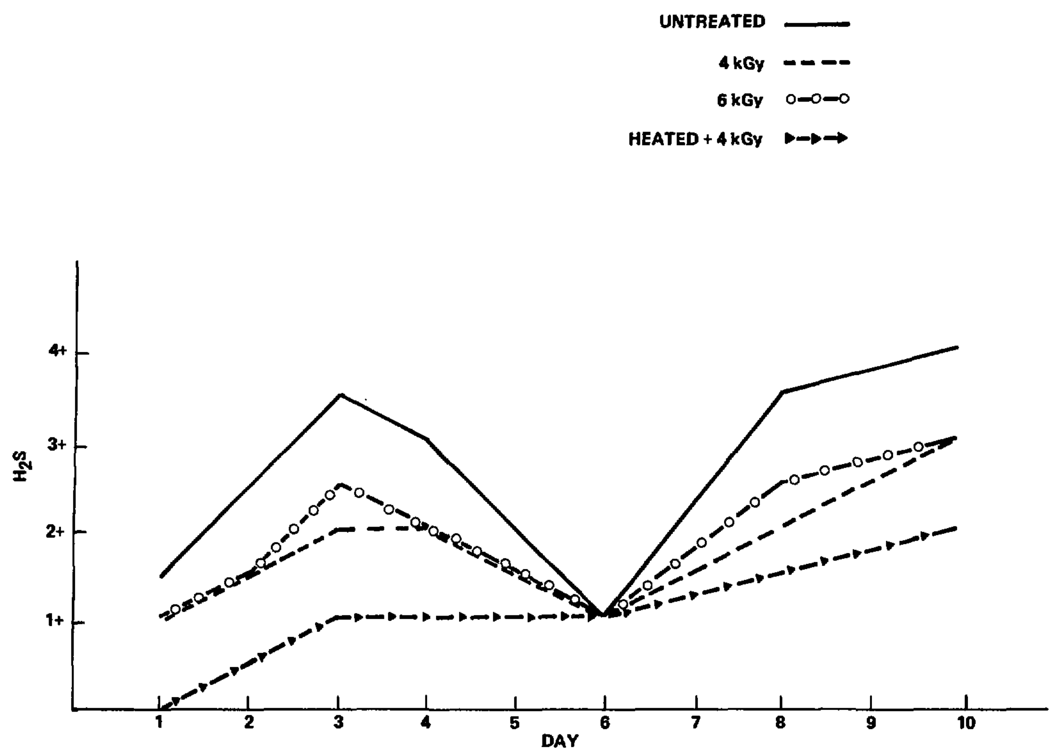


*Figure 5*
*Mean $H_2S$-values of whole RWT stored at RT*

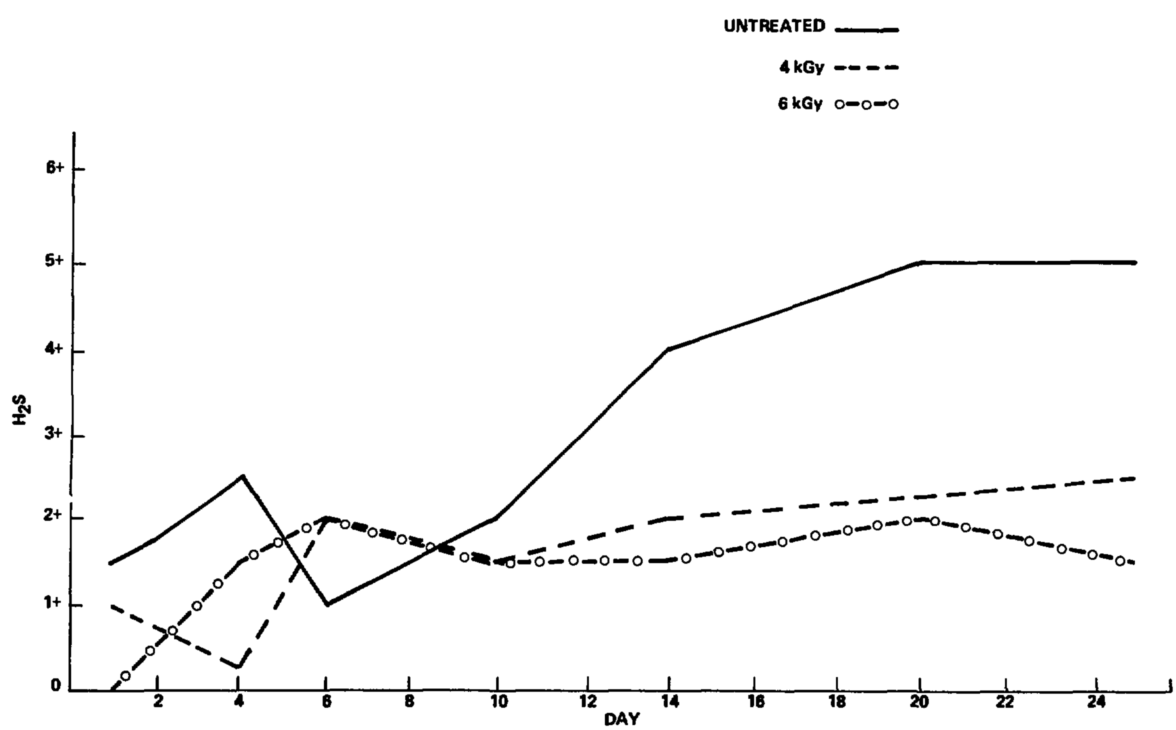


*Figure 6*
*Mean $H_2S$-values of whole RWT stored at 4 °C*

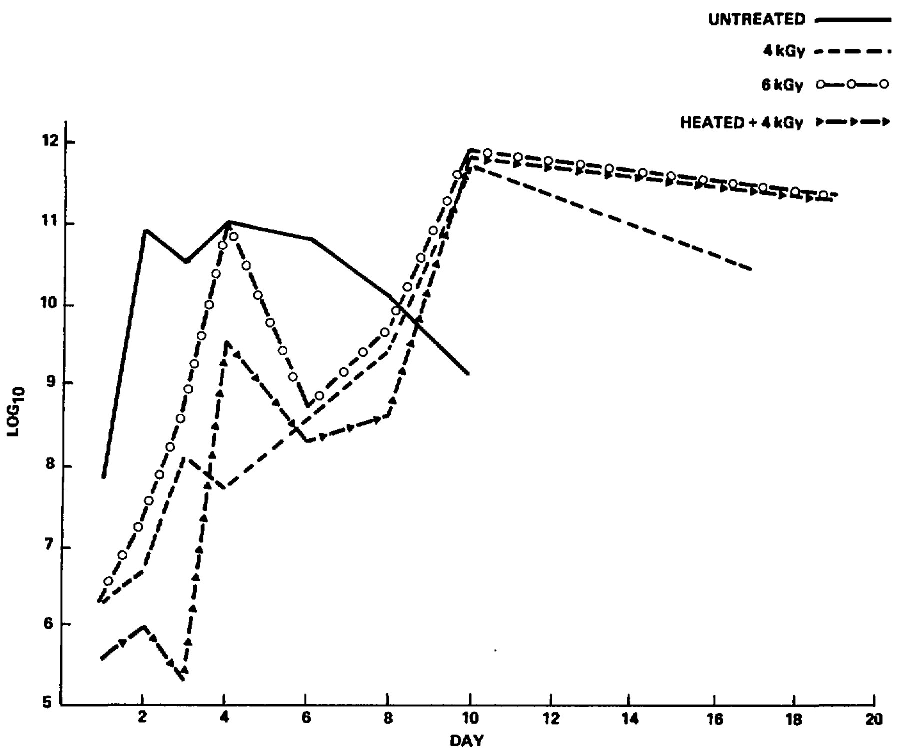


*Figure 7*
*Aerobic bact. count(Log10) of RWT stored at 4 °C*

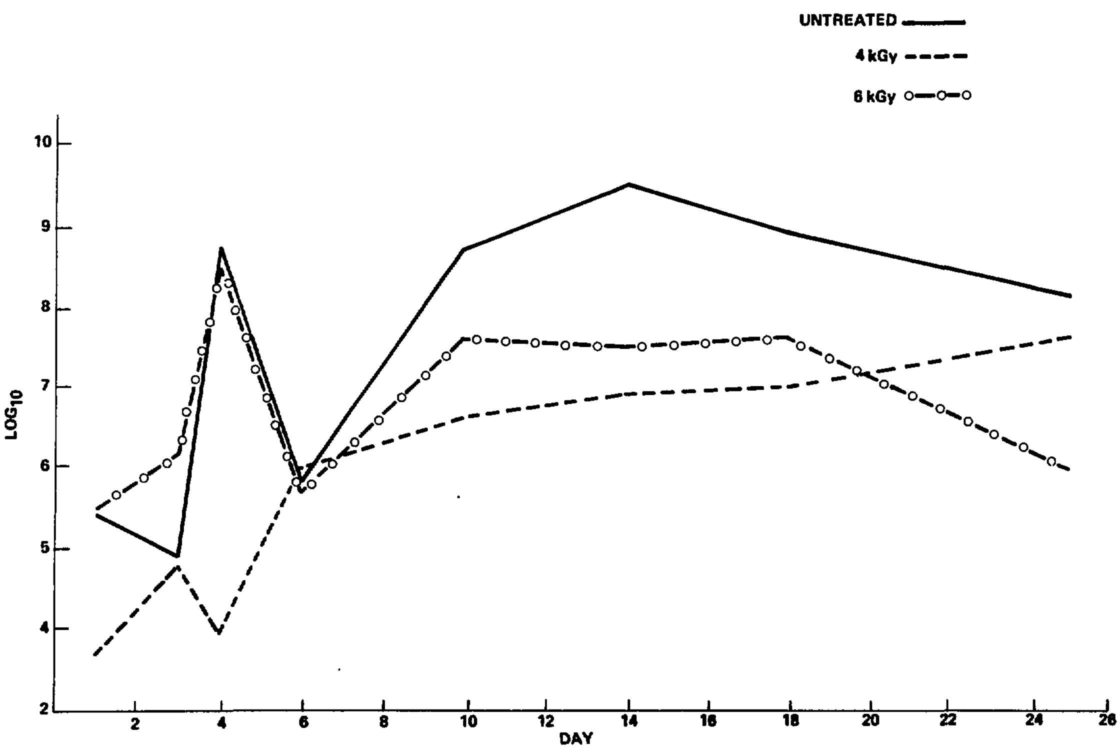


*Figure 8*
*Mean Anaerobic bact. count(Log10) of RWT stored at 4 °C*

The assessment of consumer acceptability and hygienic status of RW tripe by means of pH and TVN levels poses certain problems when using standards for red meat or fish as reference. The ultimate pH for red meat is well below 6,0 (down to 5,4 at times). RW tripe consists of both epithelium and involuntary muscle, the proportions varying according to the length of the epithelial projections and the thickness of the muscular layer. It is, therefore, not surprising that recorded pH values of fresh minced tripe varied from 6,4 to 7,7 and that the inhibitory effect of low pH values in red meat is absent in tripe.

Regarding TVN levels, white fish with > 50 mg TVN/100 g and beef with > 17, are regarded as unacceptable to the consumer[5]. After storage for 24 h at 4 °C, RW tripe already possessed mean TVN levels of 17,5 to 19, whilst after 24 h storage the values ranged from 22,5 to 40 mg TVN/100 tripe.

Regarding bacterial counts, irradiation with 2 to 6 kGy led to a significant decimal reduction of both aerobic and anaerobic counts. Heating to 80 °C for 5 min prior to 4 kGy irradiation gave the best overall results. This was not surprising in view of the fact that the catheptic enzymes in ruminal wall obviously require thermal inactivation in addition to reduction of bacterial numbers by means of irradiation.

A limited acceptability trial by a small group of traditional consumers of RW tripe failed to indicate any increase of "shelf life" as a result of irradiation. They did however, notice the reddish appearance of the muscular layers of the irradiated tripe and this caused rejection of the tripe regardless of odour or other evidence of deterioration.

A final point of interest is the fact that fly larvae developed during storage of some sealed containers of RW offal at room temperature. It was concluded that fly eggs had been deposited on the material at the offal pool. No such larvae developed in the aliquots that had been irradiated.

It is clear that further work is necessary to evaluate the benefit of radurisation of offal, particularly after heat processing. Whatever the case, it must be borne in mind that the final product must have a reasonable shelf life which is not dependent upon any form of refrigeration.

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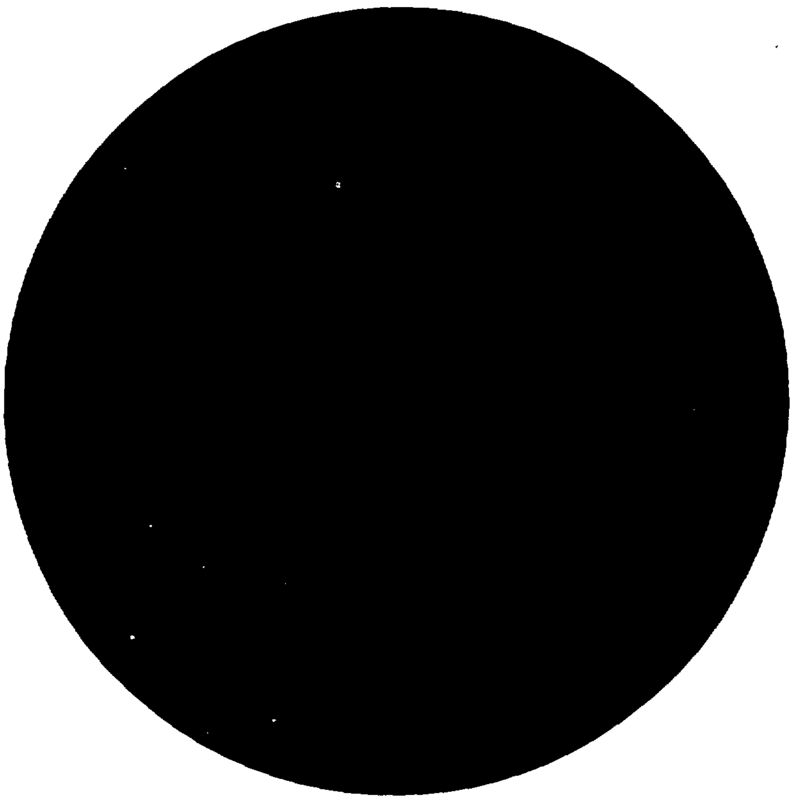
## DISCUSSION

**Question:** In one of the last slides there was a decrease in bacterial spoilage, that is, a decrease in the bacterial count. Is there any reason for it reaching a maximum and then going down as a function of time?

**Answer:** I am afraid I cannot answer that question. I can only assume that we found a rather consistent situation in both the control and irradiated material in that the counts very rarely went over the level of about 10 – 11 logs/g. I can only assume that the degradation products or a local situation within the material became inimical to the development of whatever bacteria were available at that stage. I regret that I have no further information on this aspect.



ZA8000321



# STERILISATION OF CYSTICERCI WITH GAMMA RADIATION

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## SAMEVATTING

Blaaswurms van *Taenia solium* en *Taenia saginata* is aan gammastralingsdosisse van 0,2 tot 1,4 kGy blootgestel. Bestraling het 'n nadelige invloed op die vermoë van die blaaswurms om *in vitro* uit te stulp. *Taenia solium* het 'n vertraging van nege dae getoon terwyl *Taenia saginata* na ses dae uitgestulp het. Party blaaswurms van *Taenia solium* wat met lae dosisse (0,2 tot 0,8 kGy) behandel is, het 24 dae na behandeling uitgestulp terwyl geen *Taenia saginata* na 15 dae uitgestulp het nie.

Blaaswurms was na stralingsdosisse van 0,2 tot 1,2 kGy nog net so aansteeklik vir goue hamsters as die onbehandelde blaaswurms. Lintwurms wat van bestraalde blaaswurms ontwikkel, kan hulself nie onbeperk handhaaf nie en word vanaf dag +12 uitgeskei of verteer. Hierdie lintwurms groei nie, maar word geresorbeer en bestaan uiteindelik net uit 'n skoleks. Dit blyk dat bestraling sel-deling inhibeer en dat die selle nie na die behandeling herstel nie.

Karkasse wat ligtelik met sistiserkose besmet is, kan deur middel van lae gammastralingsdosisse (0,2 tot 0,6 kGy) vir menslike gebruik beveilig word.

## ABSTRACT

Cysticerci of *Taenia solium* and of *Taenia saginata* were exposed to gamma radiation in doses varying from 0,2 – 1,4 kGy. Radiation had an adverse effect on the ability of the cysticerci to evaginate *in vitro* after a time lag of nine days in *T. solium* and after six days in *T. saginata.* Some cysticerci of *T. solium* treated with low doses (0,2 – 0,8 kGy) evaginated 24 days after treatment but no *T. saginata* cysticerci evaginated after 15 days.

Cysticerci exposed to radiation doses of 0,2 – 1,2 kGy are as infective to golden hamsters as untreated cysticerci. Cestodes resulting from irradiated cysticerci, however, cannot maintain themselves indefinitely and are excreted or digested from Day +12 onwards. Such tapeworms do not grow but are resorbed and finally consist of only a scolex. It appears that radiation inhibits the ability of the cells to divide and the cells do not recover from this treatment.

Carcasses lightly infested with cysticercosis could be rendered fit for human consumption by exposure to low doses (0,2 – 0,6 kGy) of gamma radiation.

## 1. INTRODUCTION

Man is the definitive host of two tapeworms which utilise domestic animals as their intermediate hosts, viz. *Taenia solium,* the so-called "pork tapeworm", and *Taenia saginata,* the "beef tapeworm".

The life cycle of *T. solium* is briefly as follows: When a human being ingests a living bladderworm or cysticercus the immature tapeworm is liberated and it attaches itself to the wall of the small intestine. During its growth many proglottids (segments) are produced and the oldest ones are eventually filled with eggs. These proglottids become detached from the rest of the worm and are voided with the faeces. When such an expelled proglottid moves or disintegrates, the eggs are liberated. If a pig swallows these eggs, they hatch in the intestine and are carried by the circulatory system to the muscles where they develop into a cysticercus. The life cycle of *T. saginata* is similar but cattle act as the intermediate host.

Both these tapeworms have a cosmopolitan distribution but their prevalence varies in different parts of the world. According to Merle[5] *T. solium* no longer occurs in some European countries (e.g. Denmark) and is rare in others (e.g. France and Germany). In Africa *T. solium* has been recorded from 13 countries, viz. the Cameroons, Benin, Djibouti, Republic of Malagasy, Morocco, Mocambique, Niger, Senegal, Sudan, Upper Volta and Zaire[5], also Uganda[6] and the Republic of South Africa[10,12]. In the last four decades the incidence of *T. saginata* has increased in many countries such as Germany and Poland[8]. In Africa prevalences above 10 % have been recorded in 16 countries: Ethiopia and Zaire[5]; the Cameroons, Nigeria and Sierra Leone[3]; Central African Republic, Djibouti, Libya, Mali and Ruanda[2]; Chad[4]; Kenya, Sudan, Tanzania and Uganda[6]; and Swaziland[2]. The actual prevalence is undoubtedly higher as 27,7 % of the infested carcasses are not detected during routine meat inspection[1].

Carcasses lightly infested with cysticercosis are usually frozen for a prescribed period to inactivate the cysticerci before the meat is released for public consumption. Van Kooy & Robijns[11] and Taylor and Parfitt[9] investigated the possibility of sterilising infested carcasses with radiation. Because *T. saginata* develops to sexual maturity in the human being only, they used evagination *in vitro* to indicate the effect of radiation on the cysticerci, but this merely indicates that the parasite is alive and it does not necessarily mean that it is infective or that it can maintain itself in a host.

Subsequently Verster[13] found that golden hamsters treated with immuno-suppressants are susceptible to infestation with *T. solium* and *T. saginata.* Because at least 50 % of these hamsters survive this treatment for 30 d, they may be used to determine the infectivity of irradiated cysticerci and the longevity of the tapeworms that develop from them. However, hamsters are less susceptible to infestation with *T. saginata* (40 % of adults and 60 % juveniles become infested) than with *T. solium*, with which 70 – 100 % of adults become infested, and the majority of these experiments were therefore carried out on *T. solium* and the results confirmed in more limited experiments with *T. saginata.*

## 2. MATERIALS AND METHODS

On separate occasions cysticerci from ten heavily infested pigs and from four heavily infested bovine carcasses, were exposed to gamma radiation in a 50 kCi Gammabeam-650 (AECL) irradiator. All irradiations were carried out at a constant dose rate of 10 kGy/h.

Irradiated cysticerci were examined to determine the effect of various radiation doses on –

2.1 Evagination *in vitro* to determine whether they survive the irradiation.

2.2 The infectivity of such cysticerci when they are fed to hamsters.

2.3 The ability of worms resulting from such cysticerci to establish themselves and survive in hamsters.

2.4 Whether the deleterious effects of radiation on the resulting tapeworms are reversible or permanent.

## 3. RESULTS

### 3.1 Evagination *in vitro* of Irradiated Cysticerci

Cysticerci, exposed to radiation doses varying from 0,2 to 1,4 kGy, were tested every third day to determine their ability to evaginate *in vitro* (Table 1 and 2).

TABLE 1
EVAGINATION (%) OF CYSTICERCI OF *T. solium*

| Day | Control | Irradiation Dose (kGy) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0,2 | 0,4 | 0,6 | 0,8 | 1,0 | 1,2 | 1,4 |
| 0 | 90 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 3 | 95 | 100 | 100 | 80 | 75 | 90 | 90 | 15 |
| 6 | 100 | 100 | 95 | 90 | 80 | 75 | 80 | 60 |
| 9 | 76 | 100 | 60 | 65 | 20 | 30 | 5 | 15 |
| 12 | 85 | 100 | 100 | 65 | 80 | 70 | 25 | 15 |
| 15 | 81 | 95 | 100 | 63 | 45 | 37 | 5 | 0 |
| 18 | – | 80 | 90 | 100 | 85 | 15 | 20 | 0 |
| 21 | 40 | 85 | 45 | 40 | 40 | 15 | 0 | 0 |
| 24 | 60 | 55 | 50 | 30 | 40 | 0 | 0 | 0 |

TABLE 2
EVAGINATION (%) OF CYSTICERCI OF *T. saginata*

| Day | Control | Irradiation Dose (kGy) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0,2 | 0,4 | 0,6 | 0,8 | 1,0 | 1,2 | 1,4 |
| 0 | 95 | 98 | 93 | 83 | 98 | 93 | 95 | 98 |
| 3 | 87 | 83 | 63 | 98 | 90 | 83 | 70 | 70 |
| 6 | 93 | 40 | 50 | 72 | 67 | 40 | 53 | 37 |
| 9 | 50 | 23 | 7 | 12 | 7 | 7 | 3 | 3 |
| 12 | 23 | 10 | 23 | 4 | 0 | 0 | 0 | 0 |
| 15 | 23 | 17 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

These results agree with those of Taylor and Parfitt[9] who showed that radiation doses up to 1,4 kGy did not affect the ability of the cysticerci to evaginate. Movsesijan, Sokolic and Mladenovic[7] found a reduction in the percentage evagination of the larval stage of *Echinococcus granulosus* after three days at a radiation dose of 0,6 kGy, after six days of 0,4 kGy and later at lower doses.

In the present experiments appreciably fewer cysticerci of both *T. solium* and *T. saginata* evaginated from Day 6 onwards. The time lag for this to occur is dependent on the radiation dose, particularly at 1 kGy and more.

### 3.2 Infectivity of Cysticerci

When cysticerci of *T. solium* exposed to radiation doses varying from 0,2 – 0,6 kGy, were fed to hamsters, they proved to be infective. Subsequently hamsters were infested with cysticerci exposed to radiation doses varying from 0,6 – 1,40 kGy. These animals were examined when they died or 20 days after infestation. It was found that cysticerci exposed to 0,2 – 1,2 kGy retained their infectivity.

TABLE 3
INFECTIVITY OF IRRADIATED CYSTICERCI OF *T. solium* (FIVE ANIMALS PER GROUP)

| Irradiation Dose (kGy) | Age of Infestation (Day) | No. of Hamsters Positive |
|---|---|---|
| Unirradiated | 10 | 5 |
| 0,20 | | 4 |
| 0,30 | | 5 |
| 0,40 | | 5 |
| 0,50 | | 3 |
| 0,60 | | 5 |
| Unirradiated | 20 | 4 |
| 0,60 | | 1** |
| 0,80 | | 1* |
| 1,00 | | 1** |
| 1,10 | | 1*** |
| 1,20 | | 1*** |
| 1,40 | | 0 |

**Recovered on Day 10;* ** *Recovered on Day 11;*
*** *Recovered on Day 12.*

Taylor and Parfitt[9] conducted similar experiments with *T. pisiformis.* Cysticerci irradiated at 0,10 and 0,20 kGy developed but the worms were stunted; at 0,3 and 1,0 kGy no worms were found 42 days after infestation and at 0,5 kGy immature worms were found when the animal died 11 days after infestation.

### 3.3 Longevity and Growth of Tapeworms Resulting from Irradiated Cysticerci

In the previous experiments no worms were recovered from animals infested with irradiated material after Day 12. Several groups of hamsters were infested with cysticerci of *T. solium* exposed to doses of 0,2; 0,4 and 0,6 kGy while a control group was infested with unirradiated cysticerci. These animals were examined at various times from Day 10 to Day 30 (Table 4). In addition, on four occasions hamsters were infested with cysticerci of *T. saginata* which were exposed to 0,6 kGy radiation. These animals, as well as control groups infested with untreated cysticerci, were examined as or when they died or 30 days after infestation (Table 5).

As the worms resulting from the irradiated cysticerci aged they became progressively smaller until only scolices remained. Such scolices could not maintain themselves and were subsequently digested or excreted. However, the rate of resorption of these worms was not constant in the different batches of cysticerci used in these experiments. Thus in one experiment all the worms resulting from irradiated cysticerci consisted of scolices only on Day 18, but on two other occasions this size was present on Day 25 and Day 30. This variation is probably due to differences in the age of the cysticerci, as young organisms are more susceptible to the effects of radiation[11].

TABLE 4
LONGEVITY OF TAPEWORM RESULTING FROM IRRADIATED CYSTICERCI OF *T. solium*

| Age of Infestation (Days) | Treatment of Cysticerci | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Unirradiated | | 0,2 kGy | | 0,4 kGy | | 0,6 kGy | |
| | Hamsters in group | | Hamsters in group | | Hamsters in group | | Hamsters in group | |
| | No. | Positive (%) | No. | Positive (%) | No. | Positive (%) | No. | Positive (%) |
| 10 | 10 | 70 | 10 | 90 | 10 | 70 | 10 | 70 |
| 12 | 8 | 87 | 18 | 72 | 20 | 55 | 10 | 100 |
| 15 | 19 | 63 | 29 | 48 | 30 | 43 | 30 | 70 |
| 18 | 8 | 75 | 19 | 21 | 20 | 55 | 20 | 50 |
| 20 | 10 | 80 | 10 | 100 | 10 | 60 | 10 | 80 |
| 21 | 10 | 70 | 9 | 33 | 9 | 33 | 10 | 10 |
| 25 | 10 | 100 | 10 | 40 | 10 | 50 | 10 | 40 |
| 30 | 10 | 80 | 10 | 20 | 10 | 40 | 10 | 0 |

TABLE 5
LONGEVITY OF TAPEWORMS RESULTING FROM IRRADIATED *T. Saginata*

| Number of Hamsters | Treatment of Cysticerci | |
|---|---|---|
| | Unirradiated | 0,6 kGy |
| Infested | 92 | 104 |
| Positive (%) | 37 | 2* |

* *Recovered on Day 25; consisted of scolices only*

In the initial experiments (Table 3) worms were not recovered after Day 12 but in subsequent experiments worms were recovered up to 30 days after infestation (Table 4). It was noted, however, that these worms did not grow at the same rate as those resulting from unirradiated cysticerci (Table 6).

TABLE 6
MEAN LENGTH (mm) OF *T. solium* RESULTING FROM IRRADIATED AND UNTREATED CONTROL CYSTICERCI

| Age of Infestation (Days) | Mean Length (mm) | | | |
|---|---|---|---|---|
| | Unirradiated controls | Radiation dose | | |
| | | 0,2 kGy | 0,4 kGy | 0,6 kGy |
| 10 | 9,3 | 5,9 | 4,6 | 4,8 |
| 15 | 25,8 | 3,1 | 2,5 | 2,4 |
| 20 | 61,6 | (10–12)[1] | (7–8)[1] | (4)[1] |
| 25 | 193,9 | (4–15)[1] | Scolices | Scolices |
| 30 | 173,8 | Scolices | Scolices | – |

[1]*Size of the largest worms recovered; remainder consisted of scolices only.*

## 3.4 Survival of Tapeworms

In another experiment cysticerci of *T. solium* were exposed to 0,2; 0,4 and 0,6 kGy before they were fed to 45 hamsters. The animals were examined for tapeworms on Day 49. A single scolex was present in one hamster infested with cysticerci exposed to 0,2 kGy but the remaining 44 hamsters had no tapeworms. Nine of the 15 control hamsters fed normal cysticerci were infested with tapeworms which varied from 5,0 to 39,5 cm in length. It therefore appears that tapeworms which develop from irradiated cysticerci loose the ability to grow and do not recover from the effects of radiation.

## 4. CONCLUSION

These investigations have shown that cestodes which develop from irradiated cysticerci do not increase in size when compared with the tapeworms of the control groups, which grow considerably. Moreover, the tapeworms which develop from irradiated cysticerci are resorbed, until only scolices remain. Irradiation probably suppresses cell division and multiplication in the neck region of the worm where growth occurs. Carcasses infested with cysticerci could therefore be rendered fit for human consumption by exposing them to low doses of gamma radiation which will not denature the proteins and therefore affect the taste of the meat.

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## DISCUSSION

**Question:** How serious is the *Trichenella spiralis* problem in this country?

**Answer:** *Trichenella spiralis* does occur in South Africa but so far only in the Kruger National Park. It has never been found outside the Kruger National Park.

# PROBLEMS IN THE BROILER POULTRY INDUSTRY

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## SAMEVATTING

Verandering in koopgewoontes veroorsaak dat vars pluimvee, met 'n beperkte rakleeftyd, geleidelik bo bevrore pluimvee, met 'n onbeperkte rakleeftyd, verkies word. Die vraag na vars pluimvee wissel afhangende van die dag van die week, die week van die maand, en die maand en seisoen van die jaar. Dit bring die probleem mee dat die vraag korrek voorspel en die pluimvee altyd gereed vir verspreiding moet wees, terwyl 'n gelykmatige en doeltreffende produksiestelsel steeds gehandhaaf moet word. Produksiestelsels vereis 'n ononderbroke lewering en 'n gelykmatige wegruiming om doeltreffend te wees. Wanneer die vraag daal, word die oortollige produksie geberg in afwagting op toekomstige aanvraag.

Aangesien vars pluimvee bederfbaar is, kan dit nie vir die toekoms oorgehou word nie en produksie moet by die vraag aanpas. Prosesseringsmetodes, wat rakleeftyd verleng deur die verlaging van mikrobiologiese besmetting, kan die produsent help om meer doeltreffend te wees deur die produksie in die middel van die maand en dié in die begin van die week wat tans nutteloos is, te benut. Afleweringsroosters kan doeltreffend opgestel word om aansienlike besparings in brandstofverbruik en arbeid te verkry.

Hedendaagse besorgdheid oor meer higiëniese voedsel en moontlike skadelike bymiddels, lê nadruk op metodes wat patogeenvrye voedsel sonder chemiese preserveermiddels kan verseker.

## ABSTRACT

Changing buying habits are causing a swing away from frozen poultry, with an indefinite shelf life, towards fresh poultry with a limited shelf life. The demand for fresh poultry varies with the day of the week, week of the month and month and season of the year. This creates the problem of anticipating demand and having the poultry available for distribution while still maintaining a steady and efficient production system. Production systems require a steady supply of raw materials and a steady offtake to be efficient. When demand varies, storage after production is used to take up surplus production in anticipation of future demand.

Fresh poultry, being perishable, cannot be held over for the future and production is thus varied to meet demand. Processing methods which extend shelf life by reducing microbiological contamination could assist the manufacturer to become more efficient by utilising mid-month and early-week idle capacity. Delivery scheduling could be rationalised and considerable fuel and labour savings achieved.

Modern concern over more hygienic food and potentially harmful food additives gives weight to methods which will ensure pathogen-free foods with no added chemical preservatives.

## 1. INTRODUCTION

The intensive production of broiler poultry is a comparatively new industry and it is only since the early 1960's that poultry ceased to be a Sunday treat and became an everyday substitute for other traditional meats. This change was largely brought about by the improvements in breeding stock and animal nutrition which enabled the farmer to produce large quantities of chicken at relatively low cost, particularly when compared with other meats. South Africa, with its then plentiful supply of cheap feed grains and animal and vegetable proteins, followed this trend and up to 1975 the industry grew at the phenomenal rate of 19 % per annum.

## 2. INCREASING PRODUCTION COSTS

Since 1975, costs have increased substantially as the prices of feed grains, proteins, fuel and all the other factors influencing production have risen dramatically. Before 1975 there were also steady increases in these production costs, but the poultry farmer was able to increase his end selling price and still sell his total production at a profit. This was possible because the price of other meats was rising at an even greater rate than that of poultry.

## 3. CONSUMPTION AND DEMAND

From 1975 until very recently, the price of red meat has remained relatively static which resulted in a slowing down of the poultry industry's growth and depressed prices. Table 1 gives the broiler production statistics for the period from 1968 to 1978 and also an estimate of expected production growth. From this Table the growth of the industry and the *per capita* consumption are evident. It is interesting to note the more than doubling in *per capita* consumption from 1968 to 1975 and the levelling off of consumption since then.

**TABLE 1**
**BROILER PRODUCTION STATISTICS**

| Year End June | Total Broilers Processed (Millions) | % Annual Increase | Per Capita Consumption in kg |
|---|---|---|---|
| 1968 | 47,8 | – | 3,50 |
| 1969 | 55,9 | 17,0 | 3,98 |
| 1970 | 59,4 | 6,3 | 3,88 |
| 1971 | 61,3 | 3,1 | 3,86 |
| 1972 | 71,3 | 16,4 | 4,35 |
| 1973 | 87,3 | 22,4 | 5,34 |
| 1974 | 108,0 | 23,9 | 6,30 |
| 1975 | 127,7 | 18,1 | 7,20 |
| 1976 | 137,8 | 7,8 | 7,59 |
| 1977 | 155,3 | 12,7 | 7,48 |
| 1978 | 159,3 | 2,6 | 7,18 |
| Estimate | | | |
| 1979 | 169,0 | 6,1 | 7,49 |
| 1980 | 174,0 | 3,0 | 7,49 |
| 1981 | 179,0 | 2,9 | 7,51 |

The levelling off of consumption *per capita* and the growth of the industry continuing at a greater rate than the increase in population, has led to a surplus of production over the local demand. Luckily, strong export demand has enabled the industry to avoid the building up of stocks which would have caused prices to fall and would have had disastrous consequences for an already economically depressed industry.

Recently there has been an increase in the demand for poultry products and prices have improved although cost increases have been horrifying. It is thus evident that the industry needs only to curtail growth and to wait for the inevitable rise in red meat prices for the demand of its products to increase and to become reasonably profitable again.

This scenario and the consumption and figures given in Table 1 do not tell the whole story. There has been a steady swing in demand from whole frozen birds towards whole fresh poultry, and more recently, towards fresh portions. Table 2 indicates my estimate of these trends in local broiler sales.

**TABLE 2**
**RATIO OF BROILERS SOLD AS FROZEN COMPARED TO FRESH WHOLE BIRDS AND FRESH PORTIONS**

| Year | Broiler Production (Millions) | Total % Fresh | % Fresh Whole | % Fresh Portions |
|---|---|---|---|---|
| 1969 | 56 | 15 | 12 | 3 |
| 1974 | 108 | 25 | 17 | 8 |
| 1979 | 169 | 40 | 24 | 16 |

These figures are only estimates as no official production figures are available. They do, however, serve to illustrate that over the past 10 years, and more particularly over the last 5 years, dramatic changes in the demand pattern occurred. This change in demand pattern is not unique to South Africa. Recently it was reported that by the end of this year, 40 % of British housewives' poultry purchases will be fresh birds[2], which amounts to an increase of 25 %, as compared with 1978. Total chicken sales, however, only increased by 5 % while the offtake of frozen whole birds dropped. The increase in fresh chicken sales is thus even more dramatic than it would appear at first glance, and it is estimated that the market for chicken portions is growing at twice the rate of the fresh whole-bird market. At present chicken portions account for 18 % of chicken sales in the United Kingdom. As real incomes improve, housewives tend to buy what they consider to be a better quality product rather than a larger quantity of an inferior product. The perceived quality advantages of fresh against frozen chickens must be considerable to justify a UK price differential of 10p per lb or approximately 20c per kg.

I have just returned from an extensive study tour of the United Kingdom and Europe and everywhere producers and retailers are aware of the trend away from frozen poultry products, which has forced them to reconsider their manufacturing, distribution and retailing facilities. The problems caused by the swing towards fresh poultry were also highlighted during recent discussions in the United States of America during the National Broiler Council's Marketing Seminar[3]. One producer reported: "We cannot go to the stores less than three times a week and have a fresh product". A retailer reported the following: "I am not in the inventory business, I am in the selling business. We cannot build different coolers for storage. Forget the expense and remember the purpose. We want *that* product to be so fresh that even if the shopper abuses it at home, it will still be fresh." Another delegate to the NBC Seminar remarked: "Product gets overstocked and goes into the freezer or the deli for cooking, or is being pulled out of the freezer to thaw. There are quite a few things that can happen at retail. Weather changes things, so does competition. We have last minute adjustments and orders, deletions and additions that make it impossible for a distributor to control inventory if he has less than, or anything more than a 40 hour lead time in starting product moving to him." The swing from frozen to fresh poultry products and the slowdown in overall demand have thus resulted in many problems for the broiler chicken producer.

## 4. PRODUCTION

These problems all basically stem from the differences between the production, distribution and retailing methods and the frequency of purchase of the two products. How the housewife handles the product after purchase is also a factor which has to be considered. Frozen products, generally speaking, are mass produced in anticipation of future orders. Excess stock is stored in a –20 °C cold store. Heavy demand is met by drawing ex stock or curtailed by raising prices.

Production methods are relatively simple. After killing and evisceration, the bacterial load is considerably reduced by washing and chilling in spin chillers, prior to packing, and rapidly freezing in a blast freezer. Distribution of frozen poultry calls for refrigerated vehicles and a holding cold store at retailer level. Relatively few deliveries per week or month are necessary to maintain adequate stocks. In-store merchandising usually consists of filling a refrigerated bin with frozen chicken or "rocks" or "footballs", as someone once called them. Being frozen, no damage can be done to the product by rough handling (although one's fingers could suffer occasionally! ). The housewife then purchases a deep frozen product which can tolerate and suffer considerable abuse, such as being left to thaw out for many hours in a hot motor car, before causing any permanent damage, due to the growth of a large number of micro-organisms.

It is thus not difficult to see why, when demand was high, the industry satisfied this by increasing the production of frozen products, as the price premium obtained from fresh poultry products did not seem to warrant the additional effort. Fresh poultry products are highly perishable and require different techniques to ensure a shelf life of sufficient length to allow for distribution, retail display, the housewife's shopping journey and storage in her refrigerator prior to cooking.

The main difference between fresh and frozen production methods is in the cooling process. Frozen birds are spin chilled and washed in cold water before being packed and rapidly blast frozen. After evisceration, fresh birds are washed by briefly spraying with cold water. Spin chilling would result in an excess of water absorption which would weep from the product after bagging and result in an unappealing end product. After the birds have been washed, they are dried and chilled in a blast of cold air before being packed and stored at 0 °C until distribution. Unlike frozen products, the deterioration process has not been stopped indefinitely with fresh birds, but has only been arrested by ensuring an as low as possible initial microbial load and keeping the temperatures of the product as close to 0 °C as possible. Fresh products are usually marked with a "sell-by" date to protect the end consumer from a product which has exceeded its safe shelf life.

Fresh poultry is supplied to order, as little stock can be kept due to the possibility of deterioration. A low demand is met by decreasing production (and keeping the live birds on the farms), while a high demand is met by increasing production up to the limit of the particular processing plant. Abnormally high demands are just not met, which result in lost sales.

Distribution methods call for refrigerated vehicles making frequent calls, in many cases as often as once a day, as the retailer must keep his stock as low as possible to avoid exceeding the "sell-by" date.

In-store display of fresh chickens calls for far greater merchandising skills as excess handling tends to make the product less appealing to the housewife and in the case of fresh portions, can also result in broken trays. Stock rotation is very important as a "first-in-first-out" sales policy is the only way to ensure that stock does not become outdated because of poor merchandising.

Once purchased the product, not being frozen, has little residual "coolth" to ensure that, unless delicately handled, its temperature does not increase to such a level as to encourage microbial growth. It is thus essential that the housewife places the chicken in her refrigerator as soon as possible after purchase and uses it within a couple of days, unless she decides to place it in her deep freeze immediately after arriving home.

The swing from frozen to fresh products has thus resulted in the need for a product which retains its freshness in spite of what the housewife and the retailer and distributor does to it. It has also resulted in frequent deliveries to the retailer to ensure freshness and a greater need for team work between the supplier and store to match supply and demand. This problem is one of the biggest which faces the fresh chicken producer. To maximise sales it is important to have the chickens available on display at all times. To minimise losses through products which have expired or exceeded their "sell-by" date, stock levels and purchases must be carefully monitored.

If the housewife's purchases were reasonably steady throughout the month, the problem would be relatively simple and anticipated increases or decreases in the amount purchased could be matched with increases and reductions in price in an endeavour to maintain a steady flow through the processing plant. The housewife's purchases are, however, very erratic, to say the least. Fresh chicken sales can vary with the season of the year, the month of the year, the week of the month and the day of the week. Seasonal and monthly variations can be reasonably controlled by increasing or reducing prices. It is the weekly and daily variations which cause the biggest headaches. Typically, the demand during the mid-weeks of the month can be as low as 50 % of month-end demand. Likewise, demand on the heavy selling days at month-end, namely Thursdays and Fridays, can be as much as 3 times that of the slack days in the same week.

Let us consider the typical integrated broiler producer as shown in the following diagram (see Fig. 1). It is evident that the production cycle from breeder day-old chick to processed broiler is very long. At various points decisions can be taken to alter the production quantities. However, the closer one comes to the processing plant the more difficult the decision becomes. Once eggs are in the hatchery, space must be made on the broiler farms for the chicken which will hatch in three weeks time. On the broiler farm the gap or period between grown broilers out, to day-old-chickens in, is usually 10 days. If the processing plant is unable to process because of breakdowns or marketing problems, the gap narrows and one runs the risk of catching one's tail. Ideally one thus strives for a steady daily and weekly production to keep the pressure off the farming side of the business.

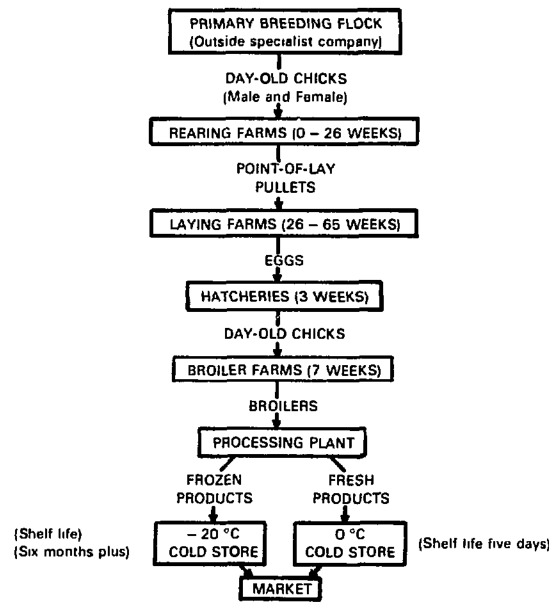


*Fig. 1*
*Flow diagram – integrated broiler production*

The smooth production flow through the processing plants would be a small problem if there were a steady off-take or if the possibility existed of storing excess production in anticipation of future demand. In a typical production system the raw-material store and the finished-goods stores serve to isolate or buffer the production unit from the changing market place and/or raw-material supply position. In the case of the typical broiler producer, however, the farms offer very little opportunity for buffering and there is thus a need for very detailed planning to ensure a smoother flow of grown broilers through the processing plants.

When the broiler producer was producing only frozen products, his cold store provided the buffering element between himself and the markets. Whenever stocks built up too rapidly, cut-prices and deals with supermarkets helped to relieve the pressure on his limited cold storage space.

This is one of the main reasons behind the often violent changes in frozen broiler prices which so often confuse the housewife, bring joy to supermarkets and sadness to the broiler producers.

With fresh products, however, the production methods used today do not allow the product and in-store shelf life of much more than four days after processing. If any of these days are utilised to buffer the supply/demand position at the factory, "shelf life" in the retail outlets is reduced. This results in a greater probability of the goods being unsold when the "sell-by" date expires. The goods are then unsaleable and are withdrawn from the market at a loss to the farmer and producer.

The following Table (Table 3) illustrates a typical demand/supply pattern for fresh products during a busy week towards the end of the month. The figures represent demand as a percentage of available production. Typically, goods ordered on Monday are delivered the next day.

**TABLE 3**
**MODEL PRODUCTION/DELIVERY SYSTEM WITH NORMAL SHELF LIFE**

| Day | Mon | Tues | Wed | Thurs | Fri | Sat | Sun | Mon | Total |
|---|---|---|---|---|---|---|---|---|---|
| Demand | | 70 | 60 | 140 | 160 | 50 | – | 20 | 500 |
| Production | 70 | 60 | 100 | 100 | 70 | | | | 400 |
| Deliveries | | 70 | 60 | 100 | 100 | 50 | | 20 | 400 |
| Shortfall | | | | (40) | (50) | | | | (100) |
| Excess prod. | | 30 | 40 | – | – | 30 | | | 100 |

This simple illustration indicates the problem with a fresh-poultry processing plant which, in this example, is working at 80 % capacity utilisation although potential demand could be 20 % higher. The position is very much worse if one considers the slack mid-month demand periods.

The provision of only two extra days "shelf life" would make the production system much more effective as is illustrated in Table 4. This oversimplified model illustrates that, given a relatively small additional shelf life and some in-plant storage, the fresh poultry producer would be in a position to meet widely fluctuating demands and utilise his plant to greater efficiency. If shelf life could be extended even further, the fresh poultry producer would be able to conduct his business in a similar fashion to his frozen-chicken competitor and use his 0 °C cold store as a buffer between him and his market.

**TABLE 4**
**MODEL PRODUCTION/DELIVERY SYSTEM WITH INCREASED SHELF LIFE**

| Day | Mon | Tues | Wed | Thurs | Fri | Sat | Sun | Mon | Tues |
|---|---|---|---|---|---|---|---|---|---|
| Demand | | 70 | 60 | 140 | 160 | 35 | – | 35 | |
| Production | 100 | 100 | 100 | 100 | 100 | | – | 100 | |
| | | 40 | | 40 | 100 | 35 | | | 40 |
| Deliveries | | 70 | 60 | 140 | 160 | 35 | – | 35 | 70 |
| Carry Over | 30 | 60 | 100 | 60 | | 65 | 65 | 30 | 60 |

Highly variable demand, furthermore, also entails variable delivery ability. Few manufacturers wish to keep a fleet of trucks just for a few heavy-demand days. Not only is the capital involved important, but with fuel shortages and rising wages no one wishes to have partially utilised trucks. With today's escalating fuel costs and the costs of maintaining motor vehicles the only way to reduce the cost of distribution is to do less of it. To achieve this, it is essential that part of the need for storage to meet the high demand is provided by the retailer. He must be prepared to buy in advance in anticipation of heavy demand. With limited shelf life, the risk of wrongly gauging demand (with the risk of either losing sales or having goods expired) is considerable and up to now few retailers have been prepared to take this risk.

The shelf life of a product such as poultry is dependent on the initial microbial population and on storage conditions which may inhibit, retard or promote their growth. This fact is recognised in modern processing techniques and throughout the aim is to minimise contamination of the product by external sources and to reduce the naturally occurring micro-organisms to as low a level as possible. Management seeks to keep the plant and workers clean and to achieve this aim rigid cleaning and washing disciplines are enforced.

Once the poultry has been processed and packed, rapid cooling and storage at low temperatures are essential. Once cooled, the cold chain must not be broken through poor distribution methods or through in-store handling methods. Unfortunately, as mentioned earlier, even in highly consumer-orientated countries like the USA the product is liable to be abused on the way home.

Various methods have been tried to extend the shelf life of fresh chicken products. As mentioned, they all hinge on efforts to ensure as hygienic a product as possible, to prevent subsequent contamination by suitable packaging, to keep it as cool as possible, to retard the growth of undesirable micro-organisms and emphasise cooking before the numbers of micro-organisms build up sufficiently to spoil the product. Methods with which some success have been obtained, are listed below in increasing order of their ability to extend shelf life –

* vacuum packaging
* inert gas flushing
* chemical preservative dips
* microwave heating for short periods
* irradiation

Irradiation holds much promise as a method of freeing the poultry producer from the necessity of having to acquire expensive freezing facilities to make a product which is rapidly losing favour with the consumers. He will thus be able to sell the higher priced fresh product and still have an efficient production system. Given the full cooperation of the retailers he could also possibly reduce distribution costs by making less frequent deliveries and utilising his transport closer to its optimum carrying capacity at all times. He could extend his market to include outlying country areas which are currently denied the full range of fresh products.

In a recent article, Dr Ari Brynjolfsson of the USA Army Food Engineering Laboratory, summarised the advantages of pasteurisation by irradiation by stating that the consumer will have a greater variety, the industry greater flexibility to meet market fluctuations and the producer will have more stable production|4|.

In conclusion, I would like to state that irradiation as a proven method of extending shelf life holds great promise for the fresh poultry producer. He will, however, be very hesitant to allocate the considerable capital required for an irradiation plant if, (i) there is not general acceptance by the consumer that irradiated products are a sign of quality, (ii) if the methods used are not under close government supervision and (iii) if the economic advantages do not outweigh the additional cost of irradiation.

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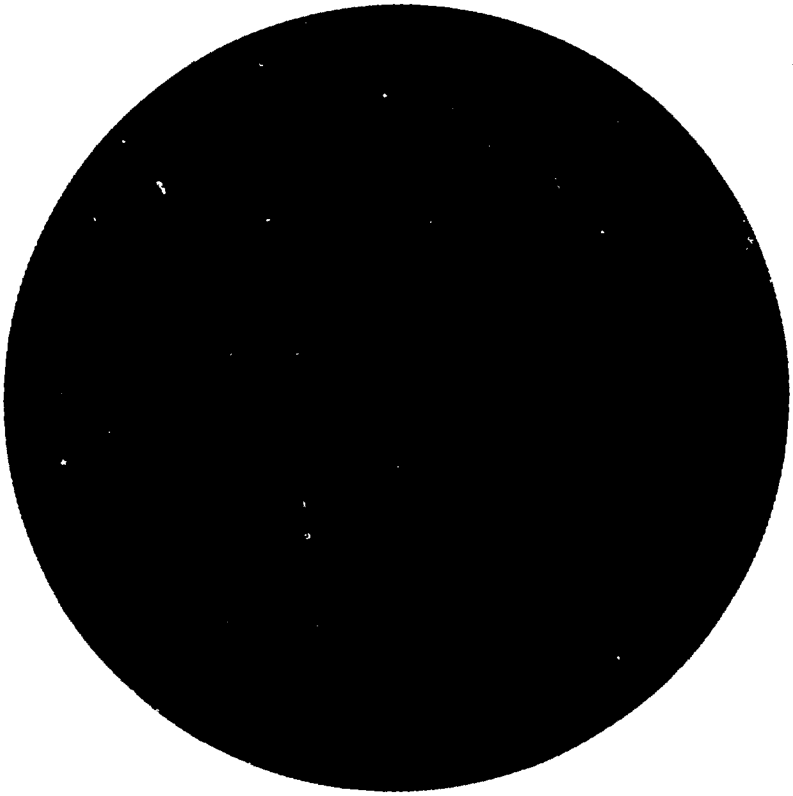
## DISCUSSION

**Question:** What is the attitude of the poultry industry towards the *Salmonella* problem? Do you see any real problems from the side of the poultry industry towards *Salmonella*?

**Answer:** We recognise *Salmonella* as a very real problem and as I mentioned earlier *Salmonella's* incidence is more or less related to its incidence in the original feedstuffs. So, first of all we must go back to the feed manufacturer. We in South Africa are using only pelleted feeds which have gone through a heat process at the feedmill mainly because we like the physical characteristics of pelleted food. But pelleting also has a beneficial effect on the digestion of the carbohydrates in particular in the feed and helps to eliminate some of the micro-organisms present. We monitor for *Salmonella* in our process plants and we do find *Salmonella.* We try to type these, and if one types long enough one will find every *Salmonella* in the book. The whole idea with poultry processing and *Salmonella* and any other pathogens is to try to reduce the numbers to such an extent so that in one subsequent handling the bacteria do not increase to such an extent that they will cause any problems in normal preparation methods in the kitchen. Now, if one has a Supermarket Manager who insists on putting fresh poultry right in the middle of his delicatessen or processed meats, he is asking for trouble, and if a housewife is so silly as to prepare the meat on a slab and use it uncleaned for her salads and other foodstuffs, I'm afraid no infected product, and I include red meats, could be guaranteed not to contaminate the others. Normal handling of poultry in this country has not been one of the major causes of *Salmonella* poisoning

**Question:** Are there any reasons for the changing preference from frozen poultry to fresh chickens apart from the Farmer Brown advertisements? Secondly, this new process that we are discussing now – do you have any idea if it would be economically feasible?

**Answer:** With regard to your second question, the economic feasibility of a process such as irradiation will depend very much on whether or not we can recover the costs in either cost savings such as earlier distribution and rationalising the production flow, or, secondly, recovering it from the consumer who receives this as another plus-factor Here, I like your first comment – Farmer Brown has a plus-factor and that is the reason why he commands a premium position on the market. Your first question as to why the swing from frozen to fresh poultry: I think, talking as a frozen-poultry producer as well, and we certainly freeze a substantial quantity of our product, the frozen-poultry producer did not do himself any favour when he seemed to be putting water into his products. Now this is part of the whole process, the water is incidental to the process, but it is one of the negative aspects of frozen poultry as far as housewives are concerned. The second one is that, in the early sixties, it was unfortunately found by animal nutritionists that if one fed chickens on maize with a bit of fishmeal added and nothing else, they grew, and grew. The amount of fishmeal that was added improved the growth but the end result was that the chickens tasted very fishy. Certainly, organoleptic tests on chickens from other parts of the world revealed that our chickens had a flavour which wasn't so attractive Subsequently, nutritionists determined the reason for the fishy taste and this has been eliminated. Unfortunately, frozen chicken and fish still seem to be associated. At the moment preference is definitely for fresh poultry and in organoleptic tests it was found that the fresh product has improved. Part of this could be because the meat has had the opportunity of first going through rigor (as mentioned earlier by Dr Naudé) whereas the frozen poultry hasn't prior to thawing. The natural flora which are on the product, and which remain and increase over the period of distribution prior to cooking, could also contribute to the flavour. Work is being done on this in America



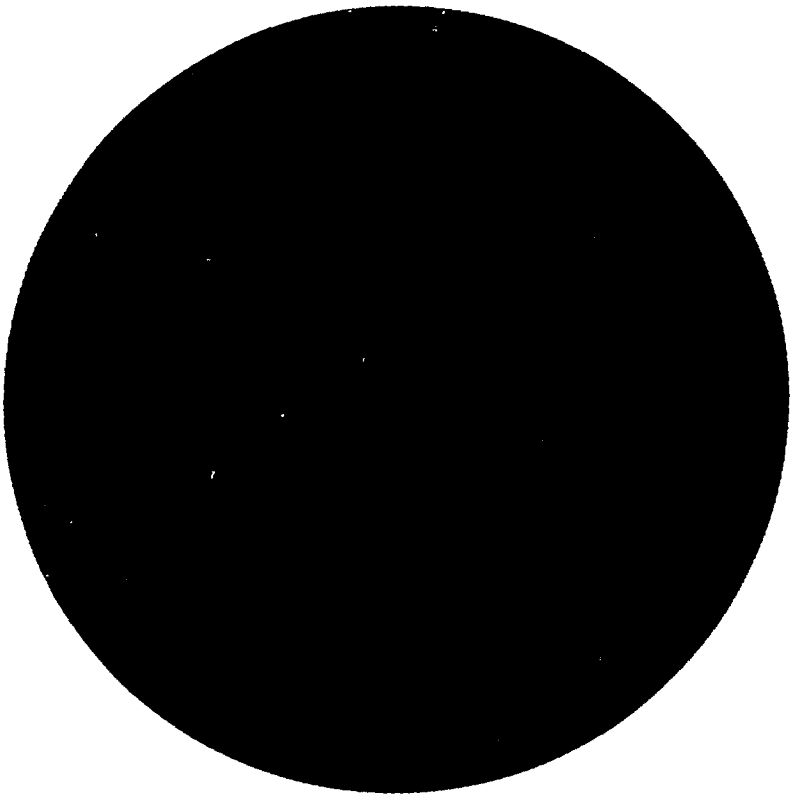
## FRIDAY 5 OCTOBER

**Morning**

## SESSION III

## AGRICULTURAL PRODUCTS

**CHAIRMAN: DR J G BOYAZOGLU**
*South African Embassy, Paris.*



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# FRUIT PRODUCTION IN SOUTH AFRICA

J H GROBLER

*Citrus and Subtropical Fruit Research Institute, Nelspruit*

## SAMEVATTING

Die vrugteproduserende gebiede van Suid-Afrika word met betrekking tot klimaatstreke bespreek. Suid-Afrika is bevoorreg dat die meeste klimaatstipes, behalwe egte tropiese toestande, wat vir vrugteproduksie gunstig is, hier voorkom. As gevolg hiervan word 'n groot verskeidenheid vrugte met welslae geproduseer.

Die produksie van die belangrikste vrugtesoorte, nl. sagtevrugte, druiwe, sitrus en subtropiese vrugte, asook statistiek oor produksie, bemarking en groei van die nywerheid word bespreek.

## ABSTRACT

The areas in South Africa where fruit is produced are discussed with reference to the climatic zones that occur in the country. South Africa is very fortunate in that most climatic types which favour fruit production, except real tropical conditions, occur. This fact makes it possible to successfully produce a great variety of fruits.

The production of the most important fruit types, such as deciduous fruits, grapes, citrus and subtropical fruits is discussed and statistics of production, marketing and growth of the industry are also given.

## 1. INTRODUCTION

The fruit industry was among the first of the farming industries established in South Africa. Our first industry came into being with the establishment of a halfway station between Europe and the East in 1652. Citrus and deciduous fruits were planted to provide sailors with, among other things, the very necessary fresh fruit and thus enabling them to reap the accompanying health benefits on the long sea journeys. From this small beginning the industry expanded and today it plays a very important role in the economy of our country. We have not only become producers of fruit, but also have become large exporters of fruit. Our export trade commenced early this century in all seriousness – initially especially to the United Kingdom and later to virtually all other parts of the world.

When cognisance is taken of the large industry established at the southern tip of Africa it strikes one that all fruit originated in other parts of the world and that by sustained research suitable cultivars have been developed and suitably adapted to our special conditions.

South Africa is in the very fortunate position that virtually every type of climate where fruit can be grown successfully is found here. In many parts of the country, however, the rainfall is too low for the successful cultivation of fruit, but due to the ingenuity of our engineers it was possible to construct dams and huge canal systems whereby the problem was solved.

**TABLE 1**
**The value of fruit sold on overseas and local markets 1978/79**

| Fruit Type | Export Value SA Rand x 1 000 | Local Value SA Rand x 1 000 |
|---|---|---|
| Deciduous Fruits | | |
| Apple | 131 043 | 61 000 |
| Pear | 27 915 | 16 117 |
| Grape | 41 134 | 23 266 |
| Plum | 3 630 | 2 311 |
| Peach | 834 | 402 |
| Apricot | 188 | 101 |
| Total | 204 744 | 103 997 |
| Subtropical Fruits | | |
| Citrus | 181 000 | 26 115 |
| Pineapple | 25 442 | 9 346 |
| Banana | – | 13 742 |
| Mango | 1 506 | 3 997 |
| Avocado | 13 770 | 2 637 |
| Papaya | 2 371 | 2 365 |
| Guava | 911 | 618 |
| Grenadilla | – | 220 |
| Litchi | 613 | 44 |
| Total | 225 613 | 59 083 |
| Grand Total | 430 357 | 163 080 |

Table 1 gives an indication of the importance of this sector of the farming industry as portrayed in 1978.

Highly productive arable land with optimum physical and chemical characteristics is relatively limited; of the 122 million hectares of which the country consists, only 15 % is suitable for tillage and the cultivation of crops. The area under permanent fruit trees is less than 0,4 % of the total area of South Africa, and if we realise that fruit worth more than R600 million is produced in this relatively small area, we cannot but be impressed with the efficiency of the fruit farmer.

As South Africa is earning most of its income from fruit on the export market, and since those markets are very competitive, it is imperative to offer only the very best. Export fruit should also reach the consumer in a healthy and sound condition. In order to comply with these prerequisites, it is necessary and most essential that rapid precooling must take place as soon as possible after harvesting, if possible, on the farm. The main reason for this is the fact that especially the handling of tropical fruits, and transporting them from producer to consumer pose problems. Because of the rate at which these fruits ripen, they require special handling techniques and this fact is no doubt one of the main reasons why the world market trade in tropical fruits is still relatively small.

The inherently high perishability of especially tropical fruits, and their susceptibility to cold damage during low temperature transport, complicates the problem still further. Most tropical fruits cannot tolerate 0 °C but must be transported at about 7 °C, with the result that they ripen and perish faster.

As the markets for our fruit are a considerable distance away and the transport, especially by air, is extremely expensive, the pre-harvest and post-harvest technology should be afforded top priority in research on these fruits.

A great problem which both the citrus and deciduous fruit industries of the world experience these days, is that the traditional overseas markets have virtually reached a saturation point and that growth is very slow. On the other hand, in the case of tropical fruits the markets in many cases are totally unexploited. It has been estimated that on the European markets citrus and bananas together comprise up to 99 % of the tropical fruits sold, with all the other tropical fruits representing only 1 %.

It is quite obvious that citrus, apples, grapes and pineapples are the most important fruits grown for the export market, and with the exception of pineapples, also for the internal market, where pineapples are replaced by bananas.

## 2. CITRUS

Citrus is generally grown under subtropical conditions in medium to light well-drained soils. The main areas of production in South Africa, however, differ widely in altitude, rainfall and soil types. Large plantings and excellent production is found in the Mediterranean climate of the South-Western Cape, the areas of summer rainfall in the Transvaal and Natal and the semi-arid regions of the Eastern Cape Province. The altitude of these regions ranges from sea level to more than 1 000 m. It is very noticeable that the various climatic regions have a definite influence on fruit quality and on the choice of cultivars for cultivation.

The citrus industry is mostly export-orientated. Exports which commenced in 1907 with the export of 3 000 cases of oranges to Europe have grown to the extent that in 1978 a total of 28 109 575 cases of citrus with a mass of 15 kg each were exported (see Table 2) to various markets around the world.

**TABLE 2**
**Number of 15 kg cases exported from South Africa**

| Year | 15 kg cases exported |
|---|---|
| 1907 | 3 000 |
| 1920 | 130 000 |
| 1930 | 184 000 |
| 1940 | 3 863 000 |
| 1950 | 4 630 000 |
| 1960 | 9 381 000 |
| 1970 | 19 552 000 |
| 1978 | 28 109 000 |

In South Africa we have a well organised central marketing organisation handling all citrus on the local as well as on the overseas market, viz the Citrus Board. The sole marketing agent for the Board is the South African Co-operative Citrus Exchange which does all the marketing and also stipulates standards for marketing in collaboration with the Department of Agricultural Technical Services.

## 3. APPLES

Apples are grown mainly in the winter rainfall area, in the Elgin-Vyeboom, Langkloof and Ceres-Koue Bokkeveld regions of the Western and South-Western Cape. Small quantities are also produced in the colder summer rainfall areas of the Free State and the Transvaal.

The three cultivars Granny Smith (41,7 %), Golden Delicious (19,5 %), and Starking (30,1 %) represent just over 91 % of all apple trees in the major area of cultivation.

Today approximately 50 % of the crop is exported. The export trade commenced early this century and today more than 175 000 t are exported annually (see Table 3).

**TABLE 3**
**Export of apples from 1941 to 1979**

| Year | Tons |
|---|---|
| 1941 | 199 |
| 1948 | 2 699 |
| 1958 | 36 374 |
| 1968 | 122 461 |
| 1979 | 175 962 |

In an effort to coordinate the marketing of deciduous fruits, the fruit farmers established the Deciduous Fruit Exchange in the twenties. To be able to control single-channel marketing, the Deciduous Fruit Board was established in 1939. Under the supervision of the Board, South African deciduous fruit is now sold very successfully on the overseas markets.

As it is of vital importance that the South African apples should reach the European markets in good condition, a great deal of research is concentrated on the cooling and transporting of apples. New packing methods are being investigated to determine their influence on fruit quality.

## 4. GRAPES

Table grapes are grown mainly in the Western Province, especially the Hex River Valley where the area under cultivation in 1972 reached 3 073 ha. Other areas in the same vicinity are Paarl (1 226 ha), Groot Drakenstein (283 ha) and Worcester (196 ha).

The most important cultivar is Barlinka, a late-ripening black variety which is very popular on account of its high yield, taste and long shelf life. Second in importance is Waltham Cross, a white cultivar which ripens in mid-season. Other important cultivars are Alphonse Lavallée, New Cross, Queen of the Vineyard, Almeria and Selba.

The export of grapes has grown over the last few decades and a total of 36 610 t was exported in the 1978/79 season (see Table 4).

**TABLE 4**
**Export of table grapes from 1948 to 1979 in tons**

| Year | Tons |
|---|---|
| 1948 | 12 097 |
| 1958 | 18 854 |
| 1968 | 30 521 |
| 1979 | 36 610 |

Research on the evaluation of imported cultivars and original breeding of new cultivars has high priority. New cultivars have now also been released for the summer rainfall area, which are resistant to cracking and ripen early in the season.

The research programs of the Department of Agricultural Technical Services will no doubt have far-reaching effects on the table grape industry in years to come.

## 5. PINEAPPLES

The main areas where pineapples are produced in South Africa are:

(a) Coastal belt of the Eastern Cape.
(b) Umkomaas area, south of Durban in Natal.
(c) Empangeni and Hluhluwe areas in Northern Natal.
(d) Levubu area in the Northern Transvaal.

The first pineapple plants were introduced into South Africa in 1660, but would unfortunately not grow in the Cape peninsula area. A second trial in 1865 in the Eastern Province proved to be a success and provided the start of the present-day industry with a turnover of R33 million per annum.

Smooth Cayenne and Queen or Rough Ananas are commercially grown. The Cayenne is grown mainly for the canning industry and for export by sea and air to Europe. The Queen, again, is grown mainly for the local fresh pineapple market.

At present 26 100 ha are under pineapple cultivation.

The total mass and the value to the grower rose sharply from 1970 to 1976 (see Table 5).

**TABLE 5**
**Export of fresh pineapples in tons and value in Rands from 1970 to 1976**

| Year | Mass in tons | Value in Rand |
|---|---|---|
| 1970 | 170 537 | 5 589 513 |
| 1971 | 175 508 | 5 956 555 |
| 1972 | 164 744 | 5 374 275 |
| 1973 | 183 824 | 6 265 171 |
| 1974 | 203 311 | 9 626 817 |
| 1975 | 176 894 | 8 400 060 |
| 1976 | 183 630 | 9 626 817 |

Sales of fresh pineapples rose from R1 411 000 in 1970/71 to R3 826 000 in 1977/78. The remainder of the pineapples are sent to canning factories for processing.

## 6. BANANAS

No bananas are exported from South Africa. As we have no real tropical climatic areas, bananas are produced in relatively marginal areas. Due to intensive research and excellent management, we are, however, in the position to produce enough for our local use.

The increase in production over the last decades is mainly due to the application of research results and better management (see Table 6).

**TABLE 6**
**Bananas produced in South Africa from 1969 to 1979 in tons**

| Year | Mass produced in tons |
|---|---|
| 1969 | 75 223 |
| 1970 | 63 513 |
| 1971 | 81 355 |
| 1972 | 74 908 |
| 1973 | 99 260 |
| 1974 | 101 653 |
| 1975 | 97 998 |
| 1976 | 87 474 |
| 1978 | 89 564 |
| 1979 | 102 756 |

The sale of bananas as fresh fruit in South Africa is only surpassed by citrus, apples and grapes.

The ripening and marketing of bananas in South Africa is controlled very successfully by the Banana Board which plays an important role in the stabilisation of the income to the farmer.

Practically all varieties of fruit are produced in South Africa. In Table 7 and Fig. 1 the volume produced and the production seasons are shown. Table 8 portrays the export of South African fruit.

It is evident from Table 7 that the value of other types of fruit which are exported from South Africa is becoming more and more important. Rapid increases are especially experienced with some of the subtropical fruits, e.g. avocado exports rose from 1,73 million cases in 1978 to 2,27 million cases in 1979, an increase of over 30 %.

Apart from selling fruit as fresh produce, the fruit industry has also developed parallel industries in producing dried fruit, canned fruit and a flourishing wine industry. For the purpose of this paper these aspects will not be dealt with. I would like to mention a development which is new in the manufacturing industry, i.e. the manufacturing of "atjar" or spicey preserved mango, not to be confused with chutney. This product is made from the very young mango and a conservative estimate is that during the 1978/79 season more than 8 000 t of young green mangoes were used for the production of "atjar".

The world's supply of fruit is far less than could be consumed by the world population. The two main reasons for this are that not enough is produced and a substantial part of what is produced is destroyed during storage and distribution. It is therefore obvious that the preservation of fruit must be regarded as of a very high priority. With the ever-increasing criticism of pesticides and fungicides, a very gullible public, and the injudicious use of these substances, it is unfortunately today becoming more important to ban fairly safe chemicals than to feed a hungry world. I would not like to be regarded as a Malthusian pessimistic disciple, but with a projected increase of 3 billion more mouths to be fed in the next 25 years, peace itself will be in jeopardy unless hunger and starvation can be prevented.

One of the most efficient and also one of the most harmless tools in preserving our fruit and food supplies is irradiation. It has already been shown that this method can be most successfully applied with a large number of foods and fruits. The only disadvantage is that many health authorities are more than over-cautious in recognising this method of preserving fruit and food, possibly due to ignorance or due to the influence of the masses.

Forecasts are regularly prone to oversimplification, but an eminent philosopher once stated: "I might be wrong, and if I am wrong, I want to assure you it is only for a short period." My forecast is that in years to come a hungry world population will fully accept the very useful and successful method of irradiation in preserving food for the masses.

**TABLE 7**
**PRODUCTION OF FRUITS IN SOUTH AFRICA FROM 1969/70 to 78/79 IN TONS**

| | 69/70 | 70/71 | 71/72 | 72/73 | 73/74 | 74/75 | 75/76 | 76/77 | 77/78 | 78/79 |
|---|---|---|---|---|---|---|---|---|---|---|
| Apple | 244 925 | 243 170 | 317 737 | 272 975 | 276 738 | 315 614 | 364 330 | 292 326 | 370 270 | 379 079 |
| Apricot | 19 600 | 25 140 | 25 272 | 21 067 | 18 145 | 29 470 | 22 760 | 35 014 | 29 401 | 32 793 |
| Avocado | 8 551 | 8 729 | 9 587 | 12 112 | 13 254 | 14 760 | 17 140 | 18 971 | 18 284 | 17 964 |
| Banana | 75 223 | 63 513 | 81 355 | 74 908 | 99 260 | 101 653 | 97 998 | 87 474 | 89 564 | 102 756 |
| Cherry | 625 | 420 | 661 | 643 | 413 | 473 | 408 | 263 | 288 | 129 |
| Fig | 1 645 | 1 594 | 1 627 | 1 511 | 1 483 | 1 541 | 1 442 | 1 475 | 1 357 | – |
| Grape | 752 638 | 855 254 | 830 426 | 850 336 | 749 584 | 883 575 | 894 741 | 739 656 | 1 058 928 | 1 088 239 |
| *Grapefruit* | *87 768* | *99 941* | *123 377* | *117 153* | *113 480* | *84 554* | *87 202* | *82 256* | *111 908* | *99 000* |
| Granadilla | 1 724 | 2 462 | 3 665 | 3 277 | 5 774 | 6 815 | 3 675 | 1 560 | 997 | 689 |
| Guava | 10 992 | 11 164 | 12 939 | 12 709 | 11 631 | 11 734 | 12 925 | 13 769 | 20 716 | 20 409 |
| Lemon | 16 866 | 19 809 | 22 352 | 22 365 | 26 913 | 26 878 | 25 277 | 27 478 | 35 311 | 29 250 |
| Litchi | 924 | 1 077 | 1 200 | 1 031 | 1 548 | 1 200 | 702 | 1 479 | 1 373 | 1 822 |
| Mandarin Hybrids | 13 597 | 19 163 | 18 652 | 14 585 | 23 135 | 13 992 | 19 938 | 17 744 | 17 366 | 22 464 |
| Mango | 10 157 | 6 170 | 12 154 | 9 378 | 8 911 | 4 382 | 13 432 | 8 520 | 15 742 | 16 491 |
| Orange | 505 594 | 498 173 | 545 110 | 512 543 | 571 009 | 534 470 | 579 802 | 485 555 | 580 887 | 507 000 |
| Papaya | 26 723 | 20 859 | 23 181 | 18 201 | 20 415 | 20 633 | 20 010 | 19 784 | 20 338 | 25 093 |
| Peach | 150 311 | 155 986 | 158 892 | 153 318 | 166 655 | 164 500 | 176 561 | 175 237 | 152 561 | 164 100 |
| Pear | 97 417 | 98 119 | 109 065 | 122 865 | 93 920 | 105 770 | 120 708 | 142 355 | 112 067 | 118 817 |
| Pineapple | 189 991 | 173 906 | 187 354 | 174 146 | 193 859 | 177 447 | 181 719 | 158 825 | 167 356 | 202 146 |
| Plum | 6 044 | 6 077 | 9 210 | 5 278 | 6 038 | 7 884 | 9 061 | 12 438 | 6 886 | 8 384 |
| Quince | 857 | 1 139 | 1 025 | 1 191 | 1 246 | 1 294 | 1 278 | 1 177 | 1 389 | 1 210 |

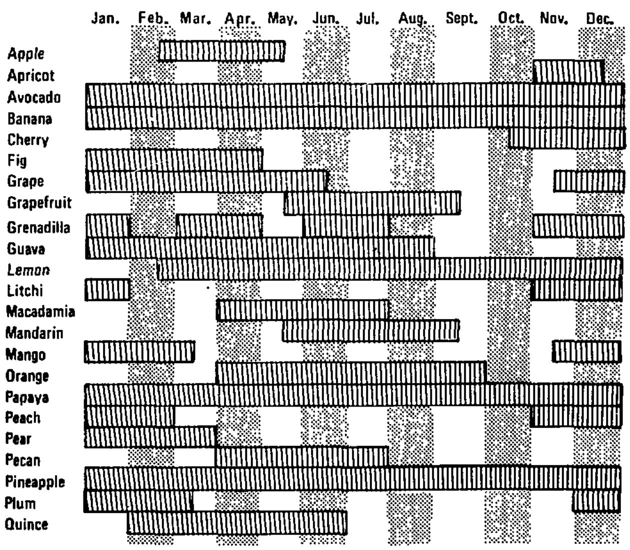



*Fig. 1*
*Availability of fruit in the RSA*

TABLE 8
EXPORT OF SOUTH AFRICAN FRUIT IN TONS

| | 69/70 | 70/71 | 71/72 | 72/73 | 73/74 | 74/75 | 75/76 | 76/77 | 77/78 | 78/79 |
|---|---|---|---|---|---|---|---|---|---|---|
| Apple | 136 334 | 132 174 | 173 049 | 149 790 | 150 835 | 178 438 | 195 338 | 122 867 | 196 295 | – |
| Apricot | 160 | 177 | 175 | 88 | 87 | 67 | 62 | 109 | 149 | – |
| Avocado | 2 115 | 1 864 | 2 628 | 3 335 | 3 960 | 5 315 | 7 011 | 8 343 | 7 962 | 8 650 |
| Cherry | 75 | 32 | 40 | 59 | 60 | 18 | 32 | 14 | 14 | – |
| Grape | 30 488 | 33 760 | 33 379 | 25 698 | 27 755 | 29 353 | 24 911 | 19 150 | 24 810 | – |
| Grapefruit | 60 036 | 55 759 | 64 769 | 66 435 | 61 365 | 60 851 | 62 128 | 66 054 | 60 855 | 67 779 |
| Lemon | 6 340 | 4 603 | 6 391 | 10 859 | 9 810 | 12 425 | 13 993 | 13 110 | 14 565 | 20 130 |
| Litchi | 40 | 112 | 32 | 120 | 72 | 52 | 40 | 88 | 144 | – |
| Mandarin | 37 | 43 | 15 | 14 | 17 | 11 | 6 | 0 | 22 | 36 |
| Mango | 0 | 0 | 161 | 0 | 0 | 14 | 140 | 113 | 545 | 1 173 |
| Orange | 245 266 | 232 886 | 231 281 | 230 997 | 228 913 | 273 119 | 304 031 | 305 065 | 290 853 | 333 705 |
| Papaya | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 56 | 104 | – |
| Peach | 1 391 | 1 184 | 1 187 | 898 | 883 | 654 | 831 | 598 | 465 | – |
| Pear | 28 976 | 30 246 | 37 614 | 33 758 | 23 638 | 30 930 | 36 758 | 40 058 | 36 023 | – |
| Pineapple | 7 021 | 5 223 | 6 612 | 15 643 | 3 874 | 2 597 | 2 294 | 1 986 | 2 058 | 2 807 |
| Plum | 2 257 | 2 393 | 4 015 | 2 238 | 2 773 | 2 994 | 4 123 | 3 182 | 3 265 | – |

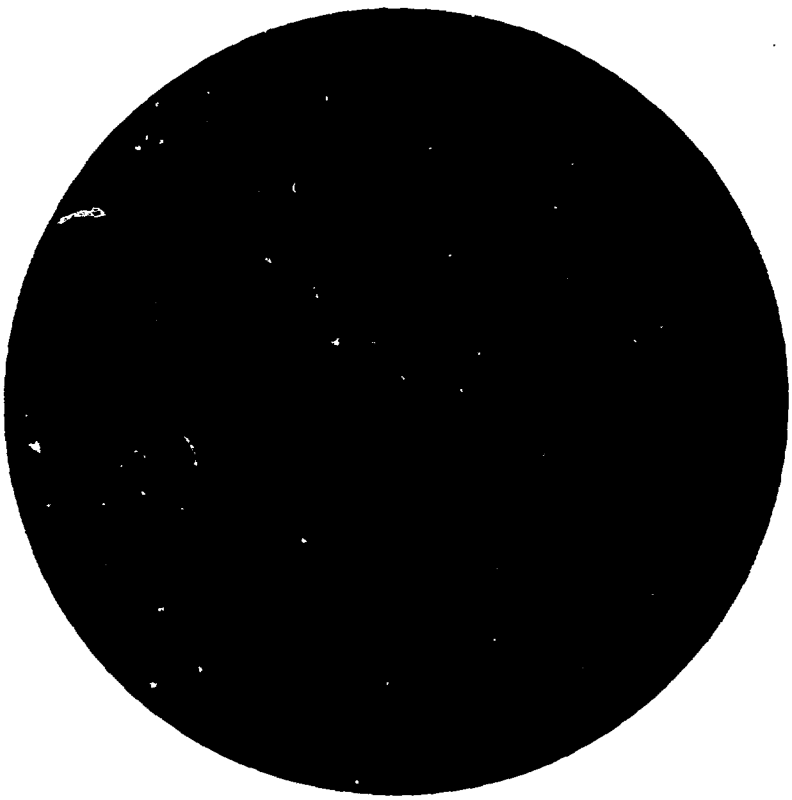
## 7. ACKNOWLEDGEMENTS

My thanks to the Department of Agriculture Economics and Marketing, the Deciduous Fruit Board, the Avocado Growers Association and various officers from the Department of Agricultural Technical Services, for the statistics used in the paper.

## DISCUSSION

**Question:** You mentioned that the entire export market is more or less orientated towards a few commodities. Can the other commodities play an important role, for example, mangoes and papayas, taking into account that they are relatively expensive on the European markets? I believe that, if the prices do not decrease, it will be very difficult to expand the sales of these commodities. Irradiation may play a role in this because it now becomes possible to export by sea shipment. Do you think that the export market can be expanded despite decreases in price?

**Answer:** The export markets for subtropical fruits are indeed wide open. If one investigates the European markets it is clear that more and more subtropical fruits are now being marketed. It was shown that only 1 % of the subtropical and tropical fruits in Europe on the market are really novel fruits. The avocado and mango industries are growing and so are others. It's only a matter of solving the problems which we have. Irradiation could play a very useful role. We sincerely hope that in the years to come, we will be able to export much larger quantities of these fruits. The markets are still wide open and we have very little competition on the world market.



# VEGETABLE PRODUCTION IN SOUTH AFRICA

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## SAMEVATTING

Met 'n bruto waarde van R126-miljoen per jaar, beloop groenteproduksie ongeveer 3,3 % van die totale landbouproduksie van Suid-Afrika. Groente word dwarsoor die land gekweek, nie net gekonsentreerd in afgebakende gebiede nie. In 1978 is ongeveer 1,4-miljoen ton groente geproduseer. Oor 'n tydperk van 10 jaar het die geproduseerde tonnemaat met 3,9 % per jaar vermeerder, wat ongeveer een-derde hoër is as die bevolkingsaanwas in die land.

Die groot verskeidenheid klimaatstreke van die land, insluitend subtropiese gebiede, het deur die hele jaar 'n konstante groentetoevoer aan plaaslike markte tot gevolg sodat invoer asook verlengde bergingstye onnodig is.

In Suid-Afrika word groente uitsluitlik gekweek om in die behoefte van plaaslike markte te voorsien. Slegs 40 000 ton word jaarliks uitgevoer, wat maar net 2,8 % van die totale opbrengs is. Uitvoermoontlikhede verbeter steeds, terwyl verdere uitbreidingsgeleenthede nog onontgin is.

Van die geproduseerde groente word 10 % verwerk. Daar word verwag dat die aanvraag na gedehidreerde groente vinnig sal toeneem in vergelyking met ingemaakte en bevrore groente, alhoewel dit tot dusver agterweë gelaat is.

Voorkeur word aan uie, knoffel, sampioene en spanspek vir stralingsnavorsing gegee.

## ABSTRACT

With a gross value of R126 million per year, vegetable production contributes about 3,3 % to the total gross value of agricultural production in SA. Vegetables are grown throughout the country with almost no evidence of concentrated demarcated production areas. About 1,4 million tons of vegetables were produced in 1978. The increase in tonnage amounts to an average of 3,9 % per year over the last 10 years, which is about one third higher than the population growth of the country.

The wide diversity of climatic subregions in the country, including subtropical areas, results in a stable supply of vegetables on the local markets throughout the year, obviating the need to import vegetables or to store over prolonged periods.

Vegetable production in SA is aimed almost exclusively at supplying the local market. Only about 40 000 tons of vegetables are exported annually which represent 2,8 % of the total crop. Exports do increase steadily but the scope for expansion is still extremely favourable and entirely unexploited.

Ten percent of the vegetables produced are being processed. It is expected that dehydration will grow much faster than canning and freezing, although up to now it has lagged behind.

Onions, garlic, mushrooms and melons are preferred for radiation research.

## 1. INTRODUCTION

According to the latest statistics, the gross value of agricultural production in South Africa amounts to R3 800 million per year Horticultural production contributes R580 million of the total and a further breakdown of the horticultural effort shows that vegetables (excluding potatoes) are responsible for about R126 million per annum. About R82 million worth of vegetables are sold on the 14 major national markets, leaving another R44 million's worth to be handled by processors, lesser markets, direct trading, etc.

Tomatoes are by far the most important vegetable with a gross value of R34 million per annum at the present moment, followed by onions (R20 million), pumpkin and squashes (R16 million), cabbage and related crops (R8,5 million), green peas (R8 million), carrots (R6 million), green beans (R4 million) and R30 million for all the other vegetables together.

## 2. PRODUCTION AREAS AND PRODUCTION POTENTIAL

Vegetables consist of some 20 or more different crops with various climatic requirements. Almost all of them are short-season crops, rendering them suitable for cultivation almost anywhere, even if the particular area has only a short period of suitable climate. They can therefore be "fitted in" when the climate is suitable. Furthermore, the vegetable crops usually have a capacity for wide adaptation, the scope of which is continuously being expanded by plant breeding.

The result of all this is that vegetable crops are being grown throughout the country wherever a small patch of irrigable land is available, with very little evidence of demarcated production areas as in the cases of citrus and deciduous fruit. Exceptions to this general situation do exist, however, as exemplified by the somewhat concentrated tomato production in the subtropical areas of Eastern and Northern Transvaal, onions in the Caledon, Ceres and Venterstad districts of the Cape, green peas in the Marble Hall area of Transvaal and Outeniqua in the Southern Cape, etc.

The greater part of the total vegetable crop is being produced rather opportunistically as secondary or side-line ventures to other main crops or to cattle farming, and in many cases also as temporary ventures. The almost casual nature of the industry and the fact that the growers are scattered throughout the country has a negative effect on operational efficiency and coordination between growers. This is, however, a generalisation, excluding quite a number of permanent producers who operate on the highest possible level of planning and efficiency.

About 1,4 million tons of vegetables were produced in the country in 1978. The average increase in physical volume of production over the past 10 years was 3,9 % per year, which is about one third more than the average population growth. The apparent *per capita* increase in production could be absorbed because of the gradual rise in the *per capita* consumption of vegetables. Growth in the export of fresh vegetables was also evident, but to a lesser extent. The gross value of vegetable crops increases at an average of about 16 % per year, but a recalculation to provide for inflation shrinks this to a real value of 3,7 %. A volume growth of 3,9 % in comparison with a real value increase of 3,7 % implies a growing trend of oversupply.

The vegetable crop is being grown on an estimated 65 000 ha of irrigated land. This total area under vegetables remained rather static for at least the past decade, indicating that the annual growth of almost 4 % in the volume of production was the result of a continuous stepping up in the operational efficiency of the industry. The scope for further improvement in average yields is still so vast that for many years to come no significant expansion of land area for vegetable production will be required. However, at least a doubling of the area currently under vegetables can be effected immediately if called for, by a drastic increase in demand.

## 3. SEASONAL AVAILABILITY

It has been pointed out that vegetable production is scattered throughout South Africa which is a country characterised by an extremely wide diversity of climatic regions and subregions. The advantage of this variation is that vegetables are usually in good supply throughout the year, thus eliminating the necessity for importation or storage over prolonged periods. This is illustrated clearly in Fig. 1.

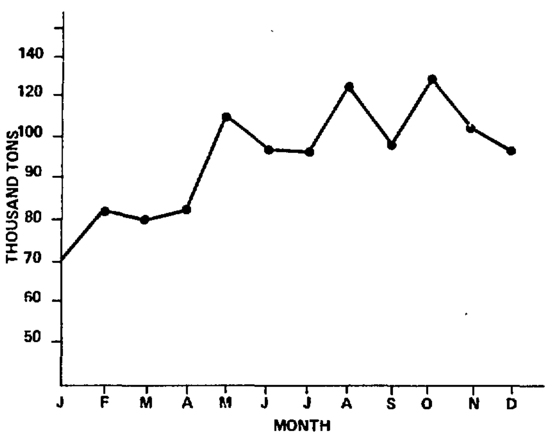


*Figure 1*
*Total mass of vegetables sold monthly on the 14 National Markets in South Africa, 1978*

Naturally, the composition of the spectrum of available vegetables will vary considerably from month to month, but it is also true that the ten most important vegetables will be found on all the markets on any day of the year.

The monthly fluctuation in supply is not the result of a fluctuation in monthly potential. Lack of co-ordination and production planning and occasional adverse weather conditions are the main factors involved. Note for instance the depression in supplies during the late summer (January, February, March) which should be a period of plenty.

The existence of subtropical areas with a relatively frost-free winter offers an advantage to the South African vegetable industry, which is not fully appreciated by the consumers of the country. All the heat-loving summer crops (with few exceptions) can be grown in these areas throughout the winter season, obviating the need for protected cultivation, importation and prolonged storage. The situation is illustrated in Fig. 2.

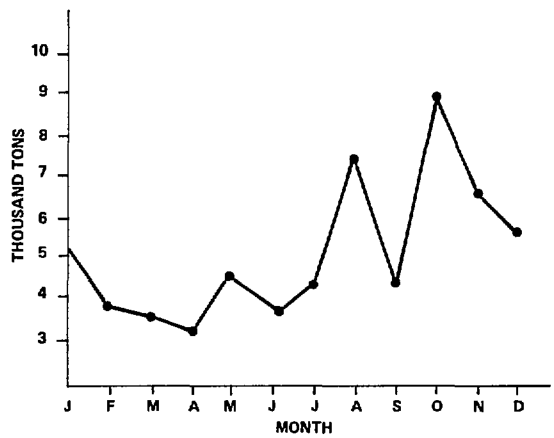


*Figure 2*
*Mass of tomatoes sold monthly on the Johannesburg Market, 1978*

Although the tomato crop is extremely sensitive to temperatures lower than 10 °C, the winter supplies are, if anything, not lower than during the summer months.

Of the major crops, onions and pumpkins are the only ones which are stored to some extent with the object of equalising seasonal availability on the local markets.

Temporary periods of oversupply and the delivery of poor quality vegetables sometimes create problems on the national markets, resulting in stagnation. The wastage is removed daily by the market authorities and amounted to 0,94 % of the total tonnage of vegetables and fruit offered for sale during 1978 on the 14 national markets of South Africa.

## 4. PROTECTED CULTIVATION

There was keen interest in protected cultivation of vegetables in South Africa over the last six years. This was stimulated by the successful production of vegetables in plastic tunnels and other semi-controlled protective structures elsewhere in the world, but particularly in the South of France and the Channel Islands. This production system caught the imagination of the South African public and various manufacturing firms, resulting in a very rapid expansion of protected cultivation. Many vegetable growers as well as newcomers who knew nothing about vegetable production saw in the system an easy wasy to overcome all the vagaries of an uncontrolled environment, as experienced in open field production.

The disillusionment was traumatic and came rather quickly for quite a number of these growers when reality proved that protected cultivation calls for even more intensive care of the crop than in the case of open field production. There are, however, also those who made a tremendous success of the venture on the technological side, but only a very small number of them could show a significant profit. The interest in protected cultivation of vegetables has therefore waned considerably and it is estimated that it contributes less than 0,5 % to the total vegetable crop at present. On account of the higher costs involved in structures and energy needs, vegetables produced under protection can never compete with those from normal field production. It can only be a feasible proposition during periods when field production is non-existent or extremely low, so as to be able to command premium prices. Furthermore, such periods should be predictable. In the South African situation of round the calendar field production, it is therefore small wonder that protected cultivation of vegetables is having such a hard struggle to achieve economic viability. Periods of extremely low supply, which do occur regularly, are entirely unpredictable.

It is also true that the general price levels for vegetables in South Africa are considerably lower than those realised in the countries where protected cultivation is extensively practised. This is illustrated by the data in Table 1.

**TABLE 1**
**COMPARISON OF WHOLESALE PRICES PAID FOR FOUR VEGETABLES ON THE JOHANNESBURG AND PARIS (FRANCE) MARKETS IN 1977**

| Commodity | Johannesburg Market* | | Rungis Market (Paris)** |
|---|---|---|---|
| | Maximum | Average | |
| | SA Cents/kg | SA Cents/kg | SA Cents/kg |
| Tomatoes | 22,7 | 17,9 | 83,6 |
| Cucumbers | 15,4 | 7,5 | 34,4 |
| Green Beans | 25,7 | 17,8 | 145,4 |
| Onions | 13,9 | 10,9 | 10,9 |

*Dept. of Agricultural Economics and Marketing, Pretoria.
**From anonymous European Market Report.

## 5. EXPORT

In contrast with some other horticultural branches such as citrus and deciduous fruit, the South African vegetable industry was never in the past geared to utilise the export markets. Production was aimed almost exclusively at meeting the local demand. Post-harvest deterioration of freshness usually occurs at a much quicker rate with most vegetables than with fruit crops. For this reason, export by sea could not be done successfully except with onions and to some extent also with melons.

The development of the air cargo business over the past two decades has changed the situation drastically and has opened up the European markets for vegetables. The lack of a coordinated export effort and limited air-freight space are, however, serious drawbacks to the exploitation of the lucrative foreign markets. Only about 40 000 tons of fresh vegetables were therefore exported in 1978, representing 2,8 % of the total crop.

Onions were by far the most important vegetable to be exported, contributing about 18 000 tons to the total (17 000 tons by sea). Capsicums, melons and green beans are the more important other export vegetables, although these are far behind onions. A fairly new development is the increase in exports by air to African countries. General increase in exports by air to various countries could be as high as 20 % per year if the problems mentioned earlier can be overcome, i.e. the problem of air-freight space and a lack of coordinated export effort.

## 6. PROCESSING

About 140 000 tons of vegetables were processed in 1978 representing 10 % of the total South African crop. Canning is still by far the most important form of processing, followed by deep-freezing, while only a very small percentage is being dehydrated. As a result of the steeply rising cost of transport of bulky canned products and energy cost in maintaining the cold chain of frozen vegetables, it is foreseen that dehydration of vegetables will become more important in the near future.

Tomatoes, green peas, carrots, green beans and cauliflower are at present the five topmost vegetables handled by processors in South Africa.

## 7. PRIORITIES FOR IRRADIATION

The general situation in South Africa is one of a potentially good and even supply of vegetables throughout the year. However, periods of serious shortages and oversupply do occur often as a result of poor production planning and localised adverse weather conditions. The necessity for irradiation or any other measures taken to prolong the life of fresh vegetables is therefore not as urgent as in many other countries. This, however, does not rule out the fact that quality deterioration, even with the relatively short shelf life required in South Africa, is entirely unsatisfactory and therefore leaves considerable scope for improvement. Attention is focussed only on some of the priorities in this respect.

### 7.1 Onions

(Total crop about 150 000 tons). The onion crop from the northern areas of the country is mostly marketed directly from the lands. The crop grown in the Cape Province on the other hand, consists mainly of "keeper" cultivars which are harvested in January and February and part of which is stored to supply the markets from March to August. It is clear from Fig. 3 that the local market is well supplied with onions throughout the year, but that the highest prices are realised during the months of July, August and September. Storage of Cape onions is aimed at this period of peak demand, for which a storage life of 6 to 7 months is required. Losses due to sprouting, desiccation and decay amount to about 25 % of the original fresh mass of the product

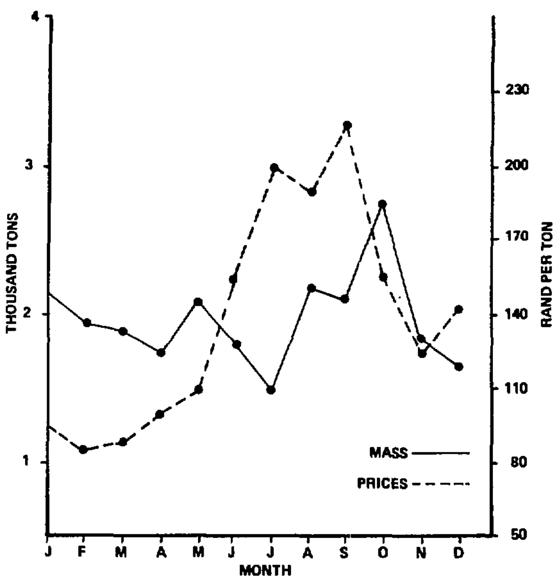


*Figure 3*
*Onions sold monthly on Johannesburg Market, 1978. Mass and prices*

Feasibility studies on the practicability and economy of radiation of Cape onions to prevent sprouting and to control bulb-rotting storage diseases are therefore indicated as a fruitful avenue for future research. This applies to local marketing as the export crop is dispatched immediately after harvesting in January and February.

## 7.2 Garlic

(Total crop about 1 500 tons). In contrast with onions the supply of garlic to the markets is extremely seasonal, reaching a minimum from March to July. The stored crop is highly susceptible to sprouting, desiccation and softening. It is known that radiation of garlic can overcome the problem to a great extent. Further work should be done, particularly with regard to practicability and economy of radiation, considering the minute total tonnage produced in the country. The potential export of garlic appears to be very lucrative, however, and if developed further may result in considerable growth of production.

## 7.3 Melons

(Total crop about 25 000 tons). With the export of melons by boat to Europe a problem of decay in transit is often experienced. Various factors are involved such as over-maturity at harvesting, erratic shipping environment and post-harvest diseases. The export of melons can be expanded significantly if these problems can be overcome, and research is urgently required. Radiation may be one of the measures to be investigated in this respect.

## 7.4 Mushrooms

(Total crop about 4 700 tons). The production of mushrooms is a fairly small but growing industry in South Africa. About 30 % of the crop is marketed fresh. Preliminary work with radiation has shown that both shelf life and general attractiveness of the product are effectively improved. Radiation may therefore be a valuable tool to promote mushroom consumption.

## REFERENCES

The statistics and data presented in the paper were compiled from information obtained from the South African Department of Agricultural Economics and Marketing by way of various personal communications and marketing reports.

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# POTATO PRODUCTION IN SOUTH AFRICA AND THE POTENTIAL USE OF IRRADIATION IN THE POTATO INDUSTRY

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## SAMEVATTING

Die totale jaarlikse aartappelopbrengs in Suid-Afrika is ongeveer 750 000 t met 'n markwaarde van tussen R60- en R80-miljoen. Transvaal is die hoofproduksiegebied (38 %), gevolg deur die Oranje-Vrystaat (27 %), die Kaapprovinsie (25 %) en Natal (10 %) In teenstelling met die meeste Europese lande, is winter- en somerproduksie in al die provinsies, behalwe die Vrystaat, moontlik. Ten spyte van wisselings in voorraad word vars aartappels, sonder onderbreking, dwarsdeur die jaar aan al die belangrike verbruikersgebiede voorsien. In Suid-Afrika word net aartappelmoere vir lang tydperke geberg. Tafelaartappels en dié wat in die verwerkingsnywerheid gebruik word, bereik hul bestemming binne ongeveer twee tot drie weke, maksimum vyf weke, nadat hulle geoes is. Een van die belangrike nadele vir die aartappelnywerheid is die swak houvermoë van die aartappel. In plaaslike omstandighede is verrotting, vergroening en uitloop die belangrikste oorsake van verliese. Bestryding hiervan met behulp van bestraling het alreeds belowende resultate gelewer. Die moontlike gebruik van bestraling in die aartappelnywerheid blyk dus belowend te wees.

## ABSTRACT

The total annual potato production in South Africa is approximately 750 000 t with a market value of between R60 and R80 million. The main production area is the Transvaal (38 %) followed by the Orange Free State (27 %), the Cape Province (25 %) and Natal (10 %). In contrast with most European countries, winter and summer productions are possible in all the provinces except the Orange Free State. Despite fluctuations in supply there is a continuous supply of fresh potatoes throughout the year to all the important consumer areas.

In South Africa, only seed potatoes are stored for any length of time. Table potatoes and those used in the processing industry reach their destinations within about two to three weeks from harvesting with a maximum period of up to five weeks. One of the serious drawbacks in the potato industry is the poor keeping quality of the potato under local conditions. Rotting, greening and sprouting are the most important causes. Control of these by irradiation has already shown promising results. The potential use of irradiation in the potato industry can therefore be seen as very good.

## 1. INTRODUCTION

The potato, along with products of the vine, ranks as the eighth most important agricultural crop in South Africa in terms of gross market value (Fig. 1). The annual gross market value of potatoes amounts to R80 million. The yearly per capita consumption in South Africa is about 22 kg, compared with 54 kg in the USA, 85 kg in Holland, 92 kg in West Germany and 102 kg in the UK. Consumption figures for the RSA, however, can rise significantly in the future, especially due to an intensive campaign the Potato Board is conducting to promote potato consumption by the black sector (Fig. 2).

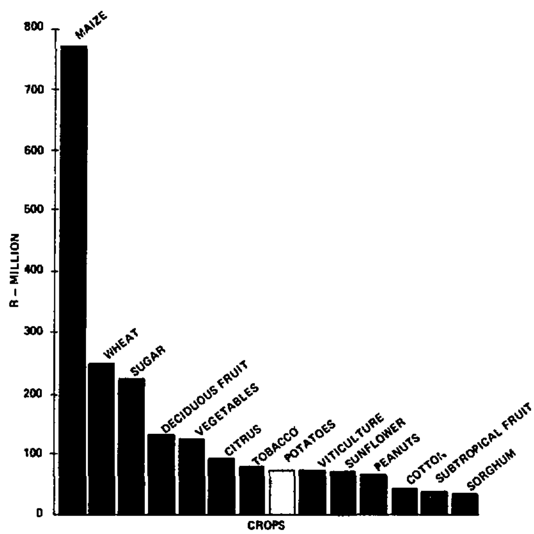


*Fig. 1*
*The gross value of potatoes in comparison with other crops*

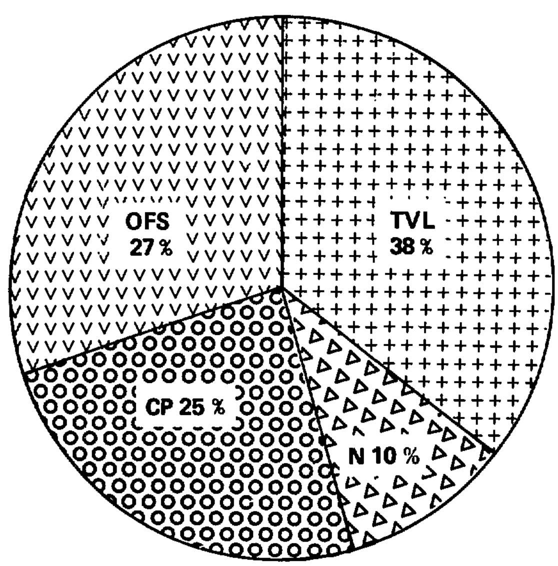


*Fig. 2*
*Potato yields in the four provinces*

Transvaal growers produce 38 % of the total yield, followed by the Orange Free State with 27 %, the Cape Province with 25 % and Natal with 10 %.

In contrast with most of the European countries, potatoes are grown throughout the year in South Africa (Fig. 3). In spite of monthly fluctuations, fresh potatoes reach the table market in all seasons. The result is that, in general, potatoes are not stored for significant periods. It might therefore be expected that we would not experience the normal storage problems such as sprouting and rotting. Unfortunately, this supposition is not valid (Fig. 4). One of the greatest problems in the potato industry in tropical and subtropical climates is poor keeping quality, especially in the summer months. This, of course, is also the problem with other perishable products. Although most potatoes reach the consumer within two to three weeks of harvest, greening, sprouting and rotting can cause serious problems. It is in this area that research has shown that irradiation may be fruitfully harnessed.

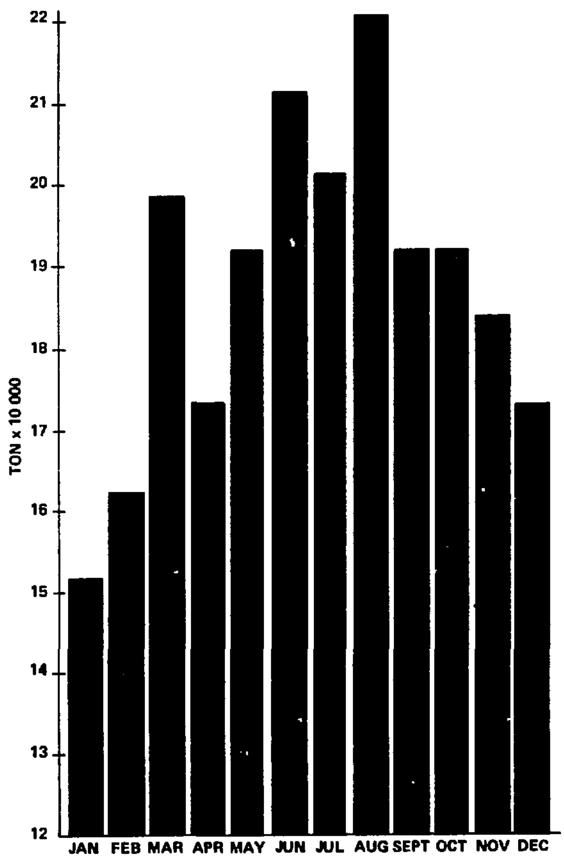


*Fig. 3*
*Average monthly supply of fresh potatoes : 1976 – 78*

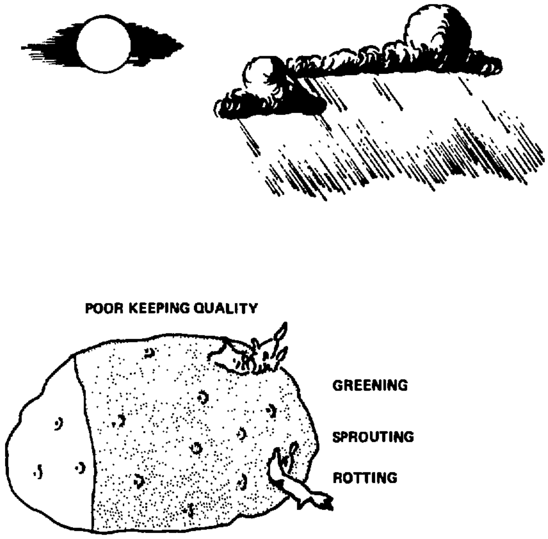


*Fig. 4*
*Subtropical and tropical climates*

**TABLE 1**
**POTENTIAL USE OF IRRADIATION IN THE POTATO INDUSTRY**

| Prevention of | | Effectiveness |
|---|---|---|
| Greening | – table (prepack) | good |
| Sprouting | – seed (storage) | excellent |
| | – table (marketing) | excellent |
| Rotting | – seed (storage) | |
| | – table (export) (distribution) | increases effect of fungicides |

Irradiation can be used to prevent greening, sprouting and in combination with a fungicide treatment can also be used to reduce the process of rotting.

## 2. GREENING

Greening is possibly the most important single factor which limits the shelf life of table potatoes in open or transparent containers. It is a significant problem especially with washed potatoes which are sold in supermarkets in small packs. Under normal conditions greening starts to be a problem after three days in the supermarket. With irradiation, greening can be delayed for nine days, which allows sufficient time to dispose of the product[1].

## 3. SPROUTING

Sprouting or physiological aging, is the most important problem when seed potatoes are cold-stored for periods of ten months or longer. Also, the marketing period of about 80 % of local table potatoes is limited to approximately four to six weeks after haulm die-back, because of physiological aging in the tubers. In both cases outstanding results have already been obtained by irradiation to inhibit sprouting[2].

## 4. ROTTING

Rotting is a serious problem in seed potatoes during storage. Losses of 40 % and more can be experienced. The export of table potatoes to overseas countries has been restricted due to the severe occurrence of rotting during shipping. In addition, the distribution of potatoes from the Northern production areas to the Southern markets during the hot summer months is limited because of the danger of rotting. Although irradiation has hardly any effect on rotting at the maximum safety doses for potatoes, it has been found from experimental work that irradiation plus treatment with a fungicide gives a significantly higher rate of control of rotting than treatment with fungicides alone[3].

Another promising possibility is to control rotting by combining irradiation and the application of phytoalexins[4] Phytoalexins are natural antibiotic substances produced in plant tissue in reaction to infection by pathogens. This treatment has the advantage that the problem of undesirable residues would be excluded.

It is difficult to comment at this stage on the practical applicability of irradiation for control of the problems mentioned. It is sufficient to state that irradiation presents promising possibilities in overcoming some of the problems in the potato industry.

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## DISCUSSION

**Question:** What are your views on greening as a problem in SA? In general, what percentage of the potatoes produced is lost through greening?

**Answer:** Exact figures are not obtainable but a rough estimate is that about 10 % of the potatoes produced in SA is being marketed in supermarkets or in a prepacked form. Therefore, at this stage, we can also expect that this percentage will definitely increase in future because the tendency is to market more and more through supermarkets especially in prepacked containers. We can thus assume that greening will become an increasing problem in future.

**Question:** Are chemicals used at all for sprout inhibition½

**Answer:** In overseas countries, chemicals are used to a large extent for sprout inhibition. In some European countries they have to store most of their table potatoes for long periods and intensive use is made of certain sprout inhibitors. In South Africa the use of sprout inhibitors is very limited. Inhibitors are being used on a limited scale on seed potatoes which must be stored at fairly high temperatures where cold storage facilities are not obtainable

**Question:** Are there any side effects of irradiation on potatoes as far as the texture is concerned?

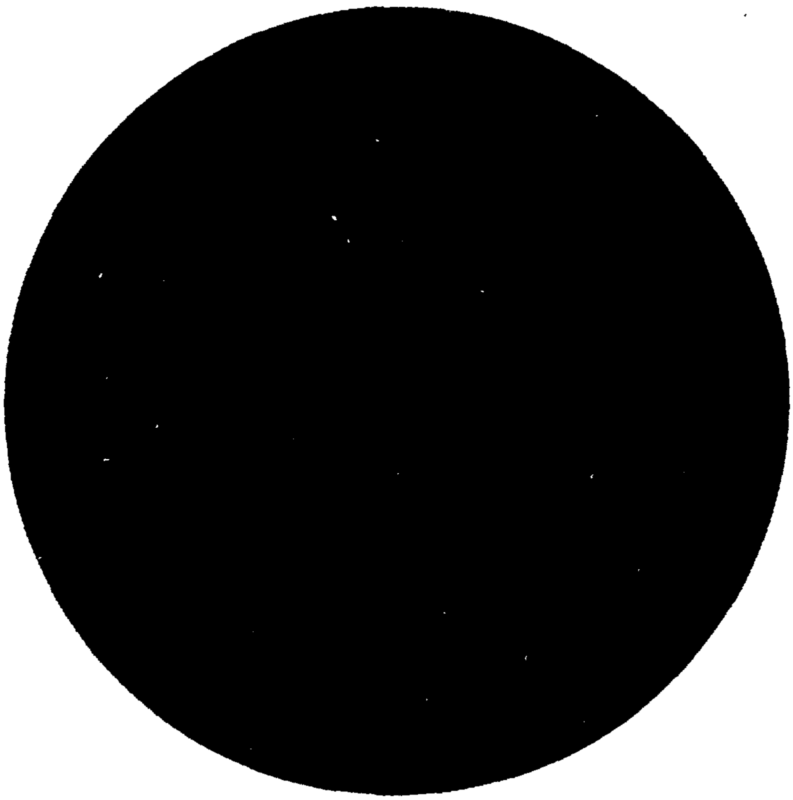
**Answer:** At the recommended dose of approximately 0,2 kGy there is no side effect, but if the dose is increased to ± 0,4 kGy breakdown of the tissue occurs. At the normal dose of 0,2 kGy there are no detrimental effects on the texture.

**Question:** How effective are chemicals in the treatment of greening?

**Answer:** A few chemicals can be used, e.g. the normal bleach chemicals, but these are not being used in any way in the commercial field. They can reduce the greening, but it is insignificant in comparison with the effect of irradiation.

**Question:** Having treated the potatoes for greening, do wrapping materials play any important role in retaining the quality or do they just keep the product clean?

**Answer:** This has been investigated quite intensively by ourselves as well as private enterprise. I can say that all our results, using papers with different colouring to prevent greening, have been very disappointing and at this stage we don't recommend any covering of any colour of paper at all. The expense and the trouble is just not worth the effort.



ZA8000326



# QUANTITATIVE AND QUALITATIVE ASPECTS OF AGRICULTURAL PRODUCTS

P J WESSELS
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## SAMEVATTING

Die volgende aspekte word bespreek:

Die Afdeling Inspeksiedienste se hooffunksie asook sy rol in die bemarking van landbouprodukte;

die rakleeftyd van landbouprodukte: 'n kort oorsig oor huidige metodes met 'n praktiese voorbeeld van verliese gely a.g.v. beperkte houvermoë;

bestraling en hittebehandeling: die voordele van geïnhibeerde mikrobiologiese aktiwiteite en onwenslike chemiese veranderinge uit die oogpunt van gehaltebeheer gesien;

gehaltestandaarde: basiese beginsels van gehaltebeheer;

gevolge van doeltreffende na-oesbehandeling: uitvoer van sagte en sitrusvrugte; die omvang van die probleem van swak houvermoë asook gehaltevereistes; ander vrugte, gehalte- en uitvoerbeperkings en groente; vereistes ten opsigte van hoeveelheid en gehalte;

plaaslike bemarking: vrugte en groente onderworpe aan inspeksie; aspekte van hoeveelheid en gehalte.

## ABSTRACT

The following aspects will be discussed:

The main function of the Division of Inspection Services and its role in the marketing of agricultural products;

the shelf life of agricultural products: short review of present methods with a practical example of losses incurred due to limited keeping quality;

irradiation and heat treatment: advantages of inhibited microbiological activities and undesirable chemical changes from a quality control point of view;

quality standards: the basic principles of quality control;

consequences of effective post-harvest treatment: export of deciduous and citrus fruit; the magnitude of the problem of poor keeping quality and quality requirements; other fruit; quantities and export limitations and vegetables; quantity and quality requirements;

local marketing: fruit and vegetables subjected to inspection; quantity and quality aspects.

## 1. INTRODUCTION

Rising production and marketing costs and the problem of surpluses have accentuated the importance of prolonging the keeping quality of agricultural products in a better-organised marketing system. The Marketing Act, the Dairy Industry Control Act and the Agricultural Export Control Act were promulgated to promote the marketing and distribution of the more important agricultural products on a long-term basis. There is no justification for a misconception that these Acts inhibit or restrict marketing. On the contrary, they aim at preserving existing markets and opening up new markets in the interest of both producers and consumers.

The Division of Inspection Services administers regulations, published under the abovementioned acts, to promote orderly marketing by prescribing quality and other requirements of most processed and unprocessed agricultural products destined for the local and export markets. These regulations are drafted in collaboration with interested parties. To ensure that the prescribed specifications are complied with, inspectors are stationed at certain processing plants, pack houses, markets, ports of export, etc. The success of this whole marketing effort is, however, often marred by the erratic and variable keeping quality and shipping life of certain agricultural products, especially fresh, unprocessed products.

## 2. THE SHELF LIFE OF AGRICULTURAL PRODUCTS

The shipping life and shelf life of agricultural products can be greatly increased by processes such as canning, cooking, dehydration, environmental control, fumigation, disinfection, etc. However, none of these methods is perfect and each method has its economical, nutritive or even harmful drawbacks. It must nevertheless be admitted that none of these methods offers a solution to the problem of distributing fresh produce in a satisfactory condition to the consumer at all times. This again is the main reason why irradiation of fresh and processed farm produce has, over the past few years, received, and is still receiving, such close attention to preserve the inherently desirable qualities of such products.

2.1 In this respect I would like to mention a typical example where it has not been possible to exploit the most profitable markets because, inherently, poor keeping quality has rendered the product unfit for export. From December 1976 to the end of April 1977 abnormal potato shortages occurred all over Europe. Local markets were well supplied to over supplied and prices dropped below R1,50 on the markets for Grade 1 medium quality. The extremely limited quantities of export quality that could be obtained cleared R3,00 to R4,00 for potato producers, more than double the prices realised on local markets. It will be incorrect to accept that a better keeping quality would open unlimited new markets for potatoes. On the contrary, the potato export markets are extremely limited and unpredictable. Nevertheless, this example stresses the fact that prolonged keeping quality can improve prices and facilitate marketing. It is commonly known in the industry that the shelf life of the subtropical fruit, especially avocados, is a very critical and important factor in the marketing chain. The French market, for instance, very soon became saturated when only ripe or soft fruit was offered for sale.

## 3. IRRADIATION AND HEAT TREATMENT

It is claimed that both microbiological activities and undesirable chemical changes in fresh products can to a greater or lesser extent be inhibited by irradiation or by a combination of irradiation and heat treatment. In addition to prolonging the shelf life and shipping life of fresh products, such treatment also seems to render the treated product virtually free form any phytosanitary hazards.

The Republic, with its relatively high temperatures and long distances locally as well as the distances of foreign markets, should benefit considerably if these methods could be applied successfully.

## 4. QUALITY STANDARDS

Fresh fruit and vegetables are graded according to fixed quality standards, which include keeping quality and consumer preference standards.

Quality defects are normally classified as slight, minor or major. Slight and minor defects are normally of a non-progressive type, such as blemishes and healed injuries. These defects are of minor importance as far as post-harvest treatment is concerned. Progressive defects caused by microbial action and enzymatic or chemical changes are normally regarded as major defects and only very small percentages of affected units are tolerated in consignments before they are downgraded or rejected for export. If the defect is infectious, for example, Botrytis rot, the tolerance is extremely small.

Many consignments, mostly of sound fruits for overseas markets deteriorate during transit because of decay. Irradiation could play a very important role, as far as this is concerned, in preventing these major defects.

## 5. CONSEQUENCES OF EFFECTIVE POST-HARVEST TREATMENT

A great deal of research is required to establish the long-term economic implications of post-harvest losses which can be averted by different kinds of irradiation and heat treatment. The following information should, however, give an indication of the magnitude of the problem on hand.

### 5.1 Export

#### 5.1.1 DECIDUOUS AND CITRUS FRUIT

Fruit growers presented 19 million containers of deciduous fruit and 28 million containers of citrus fruit for export during 1977/78. At least 2,2 million of these containers were rejected for export. (See Table 1 for details.) The reasons for these rejections were mainly bruises, injuries, spoilage and insect infestations.

#### 5.1.2 OTHER FRUIT

During the same period 1,9 million containers of avocados were presented for export and 51 000 cartons were rejected mainly as a result of progressive defects. The exports of containers of litchis amounted to only 36 000, mangoes to 98 000 and papayas to only 13 000. Avocados are exported mainly by sea, but litchis, papayas and mangoes are mostly air-freighted because of their extremely limited keeping quality. (See Table 1 for details.) The reasons for rejections were mainly over-ripeness, heat or cold damage, spoilage and injuries.

**TABLE 1**
**INSPECTION RESULTS OF FRUIT AND VEGETABLES SUBMITTED FOR EXPORT**

| DECIDUOUS FRUIT | Inspected | | Rejected |
|---|---|---|---|
| | 1977/78 | 1976/77 | 1977/78 |
| | (Given in thousands of containers) | | |
| Apricots | 29 | 21 | 1 |
| Apples | 10 884 | 7 074 | 327 |
| Grapes | 5 174 | 4 538 | 196 |
| Pears | 2 467 | 2 772 | 58 |
| Peaches and nectarines | 228 | 297 | 14 |
| Plums and prunes | 580 | 625 | 17 |
| TOTAL | 19 362 | 15 327 | 613 |
| CITRUS FRUIT | | | |
| Oranges | 22 376 | 20 482 | 1 382 |
| Grapefruit | 4 265 | 4 851 | 9 168 |
| Lemons | 1 318 | 1 008 | 60 |
| Other | 65 | 35 | 3 |
| TOTAL | 28 024 | 26 376 | 1 613 |
| OTHER FRUIT | | | |
| Avocados | 190 | 1 887 | 51 |
| Cherries | 3 | 3 | – |
| Litchis | 36 | 22 | – |
| Mangoes | 98 | 25 | – |
| Papayas | 13 | 7 | – |
| Pineapples | 205 | 209 | 5 |
| Musk melons | 138 | 70 | 13 |
| Other | 47 | 54 | – |
| TOTAL | 2 441 | 2 277 | 69 |
| VEGETABLES | | | |
| Dry onions | 734 101 | 1 709 848 | 63 685 |
| Asparagus | 40 639 | 6 665 | – |
| Aubergines (eggfruit) | 14 390 | 14 343 | – |
| Capsicums (sweet peppers) | 123 928 | 93 343 | 395 |
| Garlic | 7 432 | 3 402 | – |
| Tomatoes | 50 618 | 36 669 | – |
| Corn on the cob | 33 790 | 15 083 | 148 |
| Lettuce | 18 546 | 17 891 | – |
| Cauliflower | 4 644 | 3 564 | – |
| Beans | 39 622 | 42 753 | 226 |
| Courgettes | 2 038 | 5 893 | – |
| Green onions | 9 144 | 7 533 | – |
| Carrots | 13 738 | 14 138 | – |
| Cucumbers | 1 918 | 2 254 | – |
| Cabbage | 16 970 | 12 804 | – |
| Chillies | 18 828 | 5 705 | – |
| Celery | 1 933 | 1 101 | – |
| Custard marrows | 212 | – | – |
| Potatoes | 1 200 000 | 1 600 000 | 27 877 |
| Other | 31 931 | 41 886 | – |
| TOTAL | 2 364 422 | 3 634 865 | 29 331 |

### 5.1.3 VEGETABLES – EXPORTS

At least 2,3 million containers of vegetables were presented for export. Potatoes and onions, with their better shipping and keeping qualities, represented 1,9 million of this figure. At least 92 300 containers of vegetables were rejected for export. (See Table 1 for details.) Spoilage, over-ripeness, injuries, greening (in the case of potatoes) and bruises were the principal reasons for rejections.

## 6. LOCAL MARKETING

### 6.1 Fruit and Vegetables subjected to Inspection

At the 14 national fresh produce markets 18,5 million containers of deciduous fruit, citrus fruit and avocados were inspected during 1977/78, of which 3,5 million were downgraded to lower grades. On these markets 62 million containers of onions, potatoes and tomatoes were inspected, of which 13 million were downgraded. (See Table 2 for details.) On the controlled markets 50 % of the onions and 16 % of the tomatoes were downgraded. Spoilage, double bulbs, thick necks and sprouting were the principal reasons for the downgrading of onions. The main reasons for the downgrading of tomatoes were spoilage, stem-end cracks, internal cavities and over-ripeness. In the case of potatoes mechanical damage, insect damage, greening and spoilage were some of the most important reasons for downgrading. Greening on the shelves was the most important cause of complaints received from the retail outlets

**TABLE 2**
**INSPECTION RESULTS OF FRUIT AND VEGETABLES FOR LOCAL MARKETS**

| DECIDUOUS FRUIT | Inspected 1977/78 | Inspected 1976/77 | Down-graded 1977/78 |
|---|---|---|---|
| | (Given in thousands of containers) | | |
| Apples | 3 684 | 3 443 | 441 |
| Grapes | 1 451 | 1 354 | 172 |
| Pears | 873 | 986 | 160 |
| Peaches and nectarines | 3 831 | 4 054 | 662 |
| Plums and prunes | 331 | 390 | 45 |
| TOTAL | 10 170 | 10 227 | 1 480 |
| CITRUS | | | |
| Local Market – | | | |
| Oranges | 4 581 | 7 168 | 1 125 |
| Naartjies | 909 | 796 | 106 |
| Grapefruit | 947 | 863 | 117 |
| Lemons | 455 | 450 | 94 |
| TOTAL | 6 892 | 9 277 | 1 442 |
| AVOCADOS | 136 638 | | 331 000 |
| VEGETABLES | | | |
| Local Markets – | | | |
| Dry onions | 8 490 802 | 7 724 963 | 4 779 255 |
| Tomatoes | 21 872 657 | 21 055 291 | 3 601 502 |
| Potatoes | 31 600 000 | 32 700 000 | 14 700 000 |
| TOTAL | 61 963 459 | 61 480 254 | 23 080 757 |

## 7. CONCLUSIONS

(a) According to reports received from field staff of this Division, most export rejections and downgrading on home markets are caused by progressive defects. If these defects can be inhibited, more products will be available for export and a higher percentage of the crop will also be suitable for export. It must also be borne in mind that the abovementioned figures give no indication of the products which have been exported and for one reason or another reached their destinations in an unsatisfactory condition.

(b) The figures indicate how better shipping conditions and keeping quality can open new markets and stimulate production. There are undoubtedly other reasons why vast quantities of citrus and deciduous fruit are exported but the superior keeping qualities of these products are undoubtedly the main reason why 47 million containers were exported, in comparison with only about 2,1 million containers of subtropical fruits.

Even in the case of highly perishable subtropical products the better shipping conditions and superior keeping qualities of avocados make them the major export product amongst the subtropical fruits. A prolonged shelf life stimulates production and exports. If irradiation can inhibit certain undesirable post-harvest activities, as is claimed, it would undoubtedly increase the growers' income and consumers would also benefit from higher qualities.

(c) Although only the superior qualities are selected for export purposes a few million containers submitted for export were nevertheless rejected. It must be inferred that, as a result of progressive defects, a considerable proportion of the Republic's total fresh fruit and vegetable crop does not reach its destination in a satisfactory condition. This inference is corroborated by reports regularly received from abroad and well-founded complaints from local consumers. If the keeping quality problem could be improved, it could mean a considerable financial gain for the country. On the other had, big loses could be incurred if the EEC countries reject our fruit on the basis of inferior quality.

(d) Although this Division has powers to prescribe the marking requirements of certain products, compulsory declaration marks on irradiated products are not anticipated by this Division for local markets at present. It must, however, be pointed out that the Department of Health has the final say in health matters on local markets. As far as export markets are concerned, legislation in the importing country will be the decisive factor.

(e) Cooling and atmospheric control practices have the disadvantage that any interruption in the control systems or shipment delays could be serious for the whole shipload of perishables. Irradiation or a combination of irradiation and the abovementioned methods may offer a solution for this fundamental, practical problem which faces the whole agricultural industry.

(f) In conclusion, I would like to point out that my Division's function in this whole project of irradiation and heat treatment would be limited to evaluations and 'report-backs' on keeping quality, taste and texture qualities. Producing the most suitable cultivars and applying the most successful treatments are, of course, the province of the various researchers. However, as this important aspect of irradiation receives the necessary attention, I am convinced that better coordination of uncontrolled products, e.g. avocados, mangoes, papayas, etc., mainly where supply to overseas markets is concerned, will become more and more important as the program of irradiation proceeds. The success of this venture could be affected adversely if irradiated products are introduced without the highest degree of care and coordination.

## DISCUSSION

**Question:** Would you like to comment on the losses which occur on the distant local markets, for example, the supply of subtropical fruits to Cape Town markets.

**Answer:** I don't have figures for the different markets at hand but it is commonly known that the longer the fruits have to travel the higher the percentage of decay and wastage will be, and therefore the rejections or downgradings, especially in the summer months.

**Question:** Are losses due to damage or disease?

**Answer:** It takes a lot more effort to distinguish between the different types of problems during quality control. Most of these are a combination of the diseases which result in decay. We don't identify the defects but merely classify them as major or minor.

**Question:** Do I understand you correctly? Your Department does not keep figures on the various reasons for rejection, it's just a combination of all these factors together!

**Answer:** If any coordinated organisation would approach us to keep these figures separately it could be done, but in general, to save time and manpower, we don't.

**Comment by Dr Boyazoglu** (SA Embassy, Paris): I would like to add that commodity inspection control is a responsibility to the consumer to ensure good quality of the product on the market. If the problem that has been posed must be studied an arrangement will have to be made between Mr Wessels' Department and the different research establishments concerned. It will have to be a specific spot control, it cannot be done during the normal routine inspection service.

**Comment by Dr van der Linde** (Atomic Energy Board, Pretoria): This is obviously an aspect which should be investigated because it is important, not only on the local market but also on the export market, to know what the reason for spoilage is. It is no good to talk about the advantages of a process to improve quality if bad quality of the product is due to external damage caused by handling.

**Answer:** In my conclusion, I actually asked for more coordinated efforts as far as uncontrolled products are concerned. In the case of fruits controlled by the various Boards we do have these figures because it is coordinated and we were asked for the figures to be available separately. We were not asked for figures for the other products and personally I do not think that we necessarily need them.

# SOUTH AFRICA AS AN INTERNATIONAL SUPPLIER OF AGRICULTURAL PRODUCTS

G PRETORIUS
*Department of Commerce and Consumer Affairs, Pretoria*

## SAMEVATTING

Ten spyte van beperkte hulpbronne en 'n algemene ongunstige klimaat, is Suid-Afrika se landbounywerheid besig om vinniger as die bevolking te groei. Suiker, mielies, oliesaad, sagtevrugte, sitrus en subtropiese vrugte word in voldoende hoeveelhede geproduseer om uitgevoer te word. Ingemaakte produkte word aan meer as sewentig lande verkoop.

Soos in die verlede, sal toenemende struikelblokke met betrekking tot die uitvoer van landbouprodukte oorbrug moet word. Suid-Afrika is geografies ver van die Europese markte verwyder, maar nogtans in 'n gunstige posisie wat die produksieseisoen betref. Weens die bederfbare aard van uitvoerprodukte kan buitelandse bemarkingsmoontlikhede nie ten volle benut word nie. Die hoë koste van lugvervoer bring mee dat uitvoer nog verder onekonomies word. 'n Langer rakleeftyd vir bederfbare produkte sal uitvoerders in staat stel om die produkte per see te verskeep. Hier kom die voedselbestralingstegnologie ter sprake wat veel vir die uitvoerhandel van Suid-Afrika kan beteken.

## ABSTRACT

Despite limited resources and a generally unfavourable climate, South Africa's agricultural industry is expanding more rapidly than the population. Food items which are produced in sufficient quantities to allow for export are sugar, maize, oilseeds, deciduous, citrus and subtropical fruit. Canned produce are sold to more than seventy countries throughout the world.

Export of agricultural products will, as in the past, have to surmount increasing barriers. Although South Africa is geographically far removed from the European market, it is well placed in terms of its production season. Overseas marketing opportunities cannot be fully exploited because of the perishable nature of the products intended for export and as a result of the high cost of air transport. A longer shelf life for perishables will enable exporters to ship them by sea. The benefits which food irradiation technology could bring to South Africa's export trade are obvious.

## 1. INTRODUCTION

Since the earliest days of European settlement at the Cape of Good Hope, agriculture has played a major role in the national economy. Although the proportional contribution of agriculture to the Gross Domestic Product is steadily declining, the agricultural sector is still by far the biggest employer of labour in South Africa. Not only does agriculture provide employment and food for the country's rapidly growing population, but it also earns a substantial amount of foreign exchange, particularly through the export of fruit, maize, sugar and wool. In fact agriculture is second only to mining as an earner of foreign exchange, accounting for nearly 30 % of the total value of South Africa's export other than gold.

## 2. AGRICULTURAL PRODUCTION IN SOUTH AFRICA

In a world where millions of people are faced with famine, South Africa must regard itself as very fortunate in that it is self-sufficient in all but a few of its minor food requirements. Moreover, despite limited resources and a generally unfavourable climate, South Africa's agricultural production is expanding more rapidly than the population. The country is therefore able to offer an increasing percentage of its agricultural output for export. Among the food items which are produced in sufficient quantities to allow exports on a continuous basis are sugar, maize, oilseeds, deciduous fruit, citrus and subtropical fruit as well as vegetables.

South Africa is, of course, not only an exporter of primary agricultural produce, but also of processed products such as canned fruit, vegetables, jams and fruit juices, to name but a few which are sold in more than seventy countries throughout the world.

## 3. EXPORTS

The United Kingdom has traditionally been the principal market for South African agricultural products. However, since the accession of Britain to the EEC in 1973 and the attendant disappearance of Commonwealth preferences, South African exporters have been searching for alternative markets. While some exporters have achieved considerable success in penetrating new markets, others have encountered serious problems, partly as a result of non-tariff trade barriers. Certain countries prescribe such stringent health and phytosanitary requirements that foreign food products are kept out of the market completely. South African fruit and processed foodstuffs have often met with such restrictions even though local sterilising and health standards are maintained at a very high level. South Africa will naturally continue to negotiate on a multilateral and bilateral basis with foreign countries in an effort to gain unrestricted entry into overseas markets for its agricultural exports, but it is possible that the situation will not improve dramatically in the near future. It is nevertheless believed that new marketing opportunities will present themselves and that South Africa's agricultural exports will expand even further in future. The potential for increased exports of fresh vegetables and subtropical fruit other than citrus would appear to be particularly promising. The aggregate demand for these products in Western Europe alone is put at some R450 million per annum. Even though South Africa is geographically far removed from the European market, it is well placed in terms of its production season to meet a substantial part of this demand.

Mention may be made of the services rendered by the overseas trade representative of the Department of Commerce and Consumer Affairs in gauging the market, reporting on buyers' preferences and alas, also dislikes. Technical specifications regarding phytosanitary restrictions and other obstacles placed in the way of the exporter could be obtained by the Department's trade representatives. Where necessary they will consult with officials of the Department of Agricultural Technical Services and Agricultural Economics and Marketing.

## 4. DEVELOPMENT OF NEW MARKETS

New markets that have to be found abroad, cannot be developed overnight as market research is essential, and this should be undertaken before a product can be marketed successfully. Apart from the demand which should exist, aspects such as packaging, labelling, quality and price also play a major role in determining the marketability of a product. It would not be possible to market a commodity if the price is competitive and the quality inferior. The same would apply if the quality were good but the price uncompetitive. The presentation of a product has become a very important factor in marketing. Markets and consumer preferences change and become more sophisticated in relation to the degree of development experienced in the relevant market. In the highly developed countries where the consumer can afford luxuries, product presentation has become one of the most important single factors in selling to the consumer. When selling in bulk, the presentation is not that important. Closely related to this is the shelf life of a product which obviously differs according to the product. Certain subtropical fruits have a shelf life of only 4 or 5 days which can make an important difference to the presentation and marketing of this fruit. Certain innovations have made it possible to market abroad some of these highly perishable products being cultivated in South Africa. Air transport has played a major role in this respect. Unfortunately, this type of transport is rather costly. In addition, it is often difficult to obtain sufficient freight space, especially during the period December to April when passenger traffic is at its peak. The introduction of charter flights has of course been considered as a means of alleviating the space problem but for various reasons it was found to be impracticable. Between May 1978 and April 1979 about 15 000 tons of perishables left South Africa by air destined for overseas markets. It is my impression that this figure represents just about the maximum tonnage of perishable cargo that the airlines can comfortably accommodate at present. If overseas marketing opportunities are to be fully exploited it is imperative that greater use be made of sea transport. At this stage, food irradiation could come into play as it would ensure longer shelf life for perishables such as papayas and mangoes and will thus enable exporters to ship these products by sea, helping to reduce the demand for air-freight space. At the same time transport costs would be reduced and the resultant saving would be passed on to overseas consumers in the form of lower prices. This would certainly stimulate the demand for subtropical fruits such as mangoes and papayas which are currently being sold in Europe as delicacies at prices that few people care to pay.

The acceptability of not only the product as such, but also of the way it has been treated, is also of great importance. It is therefore prudent that innovations such as the irradiation of foodstuffs initially be treated with caution in order to ascertain how the market would react to such an innovation.

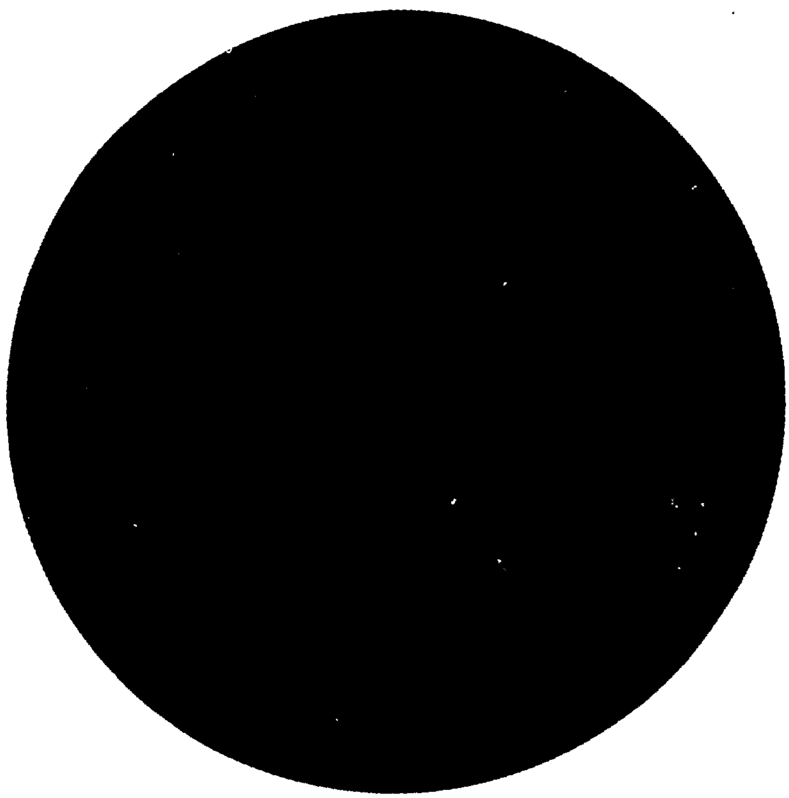
The possible benefits to be derived from food irradiation to the South African producer and exporter are pretty obvious, but I wish to reiterate that ultimately the consumer will decide whether irradiation or any other method of preservation for that matter, is acceptable. To this end it is essential that proper market research, with particular reference to consumer attitudes and preferences especially regarding irradiation, be carried out before suppliers embark on overseas marketing campaigns with irradiated food.

In conclusion, may I once more offer the services of the Department's overseas trade representatives who, no doubt, are in a position to render invaluable services in carrying out the necessary market investigations in order to determine consumer attitudes regarding irradiated foods.

# SESSION IV

## MARKETING

**CHAIRMAN: MR P VERMAAK**
*Letaba Cooperative, Tzaneen*



# REGULATORY ASPECTS OF IRRADIATED FOOD

P N SWANEPOEL
*Environmental Health Services, Department of Health, Pretoria*

## SAMEVATTING

'n Kort oorsig word gegee oor die wetgewing wat die Departement van Gesondheid toepas om die prosessering, vervaardiging en verkoop van voedsel te beheer; die verbod op die verkoop van bestraalde voedsel tensy dit deur die Minister van Gesondheid goedgekeur is; die voorwaardes wat hy vir die verkoop van bestraalde voedsel mag stel; die filosofie vir die klassifisering van bestraling as 'n voedselprosseseringsmetode en nie 'n voedselbymiddel nie; die protokol deur die Departement van Gesondheid vereis wanneer magtiging vir die verkoop van bestraalde voedsel aangevra word; die voorwaardes waarkragtens toksikologiese en ander gegewens wat aan ander regulerende owerhede vir die verkoop van dieselfde of 'n soortgelyke voedsel voorgelê is, in die Republiek van Suid-Afrika aanvaar sal word; die etikettering en bekendstelling van sodanige goedgekeurde bestraalde voedsel; die wenslikheid van eenvormige wetgewing tussen naburige state om sodoende handel in bestraalde voedsel tussen daardie state te vergemaklik; internasionale wetgewing om internasionale handel te vergemaklik.

## ABSTRACT

A short review is given of the legislation administered by the Department of Health which regulates the processing, manufacture and sale of foodstuffs; the prohibition of the sale of irradiated food unless such sale is permitted by the Minister of Health; the conditions which he may stipulate for the sale of irradiated food; the philosophy for the classification of irradiation as a food process and not a food additive; the protocol required by the Department of Health when authorisation for the sale of irradiated food is requested; the conditions under which toxicological and other data which have been submitted to other regulating authorities for the sale of the same or a similar foodstuff will be accepted in the Republic of South Africa; the labelling and advertising of such approved irradiated food; the desirability of uniform legislation between neighbouring states so as to facilitate trade in irradiated food between those states, and finally, international legislation to facilitate international trade

## 1. INTRODUCTION

Irradiated food is no different from other foods in that it has to comply with all the requirements of any food produced and marketed in South Africa. The only difference is that the Department is concerned with the actual process used and the control thereof. For health reasons one cannot sell any foodstuff that is injurious or harmful to man. If it is approved, it must conform to the requirements of the Act.

## 2. SUPPLY AND DEMAND

Since the beginning of time the balance in nature has been carefully maintained by the simple rule of supply and demand, the vital supply factor being the availability of food. No living organism, and that includes man, mammals, birds, fishes and even the smallest micro-organism, can survive and multiply if sufficient food is not available. Without food, survival is impossible. This balance is a thing of the past. How did this imbalance come about? Where has all the food gone?

I do not know all the answers to these questions but some of the factors constituting an important part of the answer are the tremendous advances made in medical science and technology used in combating the once-feared epidemics of infectious and other diseases. The deaths that resulted from these scourges of the past played an important part in ensuring the balance between supply and demand. This was further emphasised by the depopulation of the rural areas as many people moved to the large urban areas seeking employment. Families who were once self-sufficient, now produced no food. This was further aggravated during the Second World War, and the full impact of this was only felt in the post-war years, especially in the new developing countries. Industries are necessary to create new jobs and provide foreign currency, but these jobs did not provide food for the people. As medical science and technology further limited death from disease, the multiplication of man not only increased but gave the world one of its most serious problems to date: the problem of finding food for the teeming masses resulting from the population explosion.

The production of more food on less arable agricultural land became imperative. This can be achieved by the use of scientific farming practices, the application of fertilisers and pesticides to obtain the maximum yield per hectare and the production of as many crops as possible per year. Furthermore, it is necessary that the harvested crop should not only reach the market and consumer, but also the food processor, with a minimum of delay, to ensure that wastage by deterioration or insect infestation in the raw or stored state is kept to a minimum. The Food and Agricultural Organisation of the United Nations and the World Health Organisation state:

"Though estimates by informed experts vary, there is little doubt that millions of tons of food are lost each year, because of inadequate protection against insects, rodents and micro-biological contaminants. A loss of 6 % of the world's cereal harvest would account for 61 million tons, more than 1,5 times the harvest recorded in Africa in 1965. Such losses are especially high in some developing countries where the wasted food is most needed to combat hunger and malnutrition. It is just as important to stop these losses as to increase production. Methods of handling and storage already being used by advanced segments of the food industry could greatly reduce these losses. Combined with good hygienic practices they could improve both the keeping qualities and safety of certain foods."

Though new hazards are being created by the increased use of pesticides, food additives and contamination of the environment by chemicals, most illnesses associated with the ingestion of food have, during recent years, been caused by pathogenic bacteria.

## 3. LEGISLATION

Since food quality, safety and nutritional value can be affected by so many factors, it is imperative that any country wishing to provide its people with a safe food of high quality and high nutritional value, must have the necessary legislation and inspectorate to ensure compliance with the legislation. This legislation must not only be acceptable regionally but also internationally.

The earliest food legislation in South Africa was promulgated in the Public Health Act, Act 36 of 1919, and comprised six sections out of a total of 161 sections. It dealt with articles for human consumption such as public water supplies, meat, milk and other foodstuffs. The most important section on food was the section that dealt with the sale, preparation, storage and transport of milk, dairy products, meat, or other foodstuffs which are not clean, wholesome, sound and free from disease, contamination or infection. Furthermore, it stressed that no person shall collect, prepare, manufacture, keep, transmit or expose for sale, any such article without taking adequate measures to prevent it from being infected or contaminated. This Act has been repealed and the Health Act, Act 63 of 1977, is now in force. The relevant sections are 35, 36 and 37. The Public Health Act of 1919 was followed ten years later by the Foods, Drugs and Disinfectants Act, Act 13 of 1929. The regulations promulgated under this Act were also aimed primarily at safeguarding the health of the public but, in addition, the following important objectives were included: the prevention of adulteration, fraud and misrepresentation in regard to food, the promotion and encouragement of honest production in trade, and the use of wholesome and unadulterated agricultural products. It is interesting to note that many of the quality standards of today's foods were promulgated under this Act.

However, it became obvious to the Department of Health that, as a result of the modern advance in food technology and the concomitant rapid growth of the food processing industry in order to keep pace with the demand for processed and later convenience foods in industrialised societies and large cities, the 1929 Act had become outdated. It was thus repealed and replaced by the Foodstuffs, Cosmetics and Disinfectants Act, Act 54 of 1972. One would have expected the Department to have consolidated the two Acts of the past into one, but a close study of the two Acts, the Health Act, Act 63 of 1977, and the Foodstuffs, Cosmetics and Disinfectants Act, Act 54 of 1972, reveals that although certain aspects of food production and marketing are common to both Acts, the major function of each is to legislate for different aspects of the food industry. In the Health Act, Act 63 of 1977, the sections dealing specifically with food are sections 35, 36 and 37 (of these, section 35 is the most important).

**ACT 63 OF 1977**
*Section 35. (1)*
*The Minister may make regulations relating to –*

*(a) the control, restriction or prohibition of the use of any premises for purposes connected with the handling, processing, production, manufacturing, packing, storing, preparing, displaying, sale or serving of food, and to the provision of a sewerage and drainage system for, and water, washing and sanitary conveniences, lighting and ventilation at such premises;*

*(b) the structural requirements to which any building on such premises shall conform and the material which shall be used in the construction thereof;*

*(c) the standards and requirements to which apparatus, equipment, storing spaces and working surfaces and places employed in connection with the handling of food, and the cleansing of the aforementioned facilities, the manner of transport of various foodstuffs, the holders in which food is stored, processed, displayed or transported and the clothing worn by persons handling food, shall conform;*

*(d) the regulation, control, restriction or prohibition of the use of food selling automatons, and to the requirements to which the place shall conform where food intended for sale in such automatons is prepared, the manner of identification by dating of such food, the manner of transport of food to such automatons, the replenishing of food in such automatons, the material which shall be used for the packaging of food intended for sale in such automatons, the manner of storing food so packaged, the protection against pollution and decay of food in such automatons and the siting of such automatons;*

*(e) the examination of, and the control and supervision of the manufacture, preparation, storage, keeping and dispatch of, any article of food intended for sale in or export from the Republic, and the prohibition of the manufacture, preparation, storage, keeping, dispatch, or sale in or export from the Republic of any article of food which is, or contains an ingredient which is, diseased or unsound or unfit for human consumption, or which has been exposed to any infection or contamination;*

*(f) the conditions subject to which any article of food referred to in subsection (4) may be sold;*

*(g) the prohibition of the importation into the Republic of any article of food which is not clean, sound and free from decay or any infection or contamination, and the seizure, and disposal by destruction or otherwise, of any such article of food so imported;*

*(h) the preparation, manufacture, importation, storage or sale of or trade in articles of food which are packed in airtight containers or otherwise preserved, and the marking of any such article of food with the date of manufacture or preparation thereof.*

**ACT 63 OF 1977**
*Section 36.*
*The Minister may, after consultation with the Minister of Agriculture and the Minister of Water Affairs, make*

*regulations relating to –*

*(a) the regulation, control, restriction or prohibition of the supply for human consumption of molluscs or fish originating from mollusc nurseries, fish breeding stations or fish farms;*

*(b) the purity, chemical composition and source of, and the addition of substances to, water used in the cultivation or breeding of molluscs or fish intended for human consumption and the location of mollusc nurseries or fish breeding stations or fish farms;*

*(c) the regulation, control, restriction or prohibition of the cultivation, breeding, storage or transport of molluscs or fish cultivated or bred for the purposes of human consumption.*

**ACT 63 OF 1977**

*Section 37.*

*The Minister may, after consultation with the Minister of Water Affairs and, in the case of paragraph (m), also in consultation with the Minister of Finance, make, in respect of water intended for human use or food processing, regulations relating to the regulation, control, restriction or prohibition of the provision of such water originating from any source specified in such regulations or of the blending of such water originating from different sources specified in such regulations.*

An analysis of this legislation shows that it is nearly totally concerned with premises of food preparation or manufacture and those aspects directly related to these matters and to seafoods supplied from mollusc nurseries, fish farms or fish breeding stations. This legislation is responsible for the hygienic handling and packing of food in harmless packing material and containers.

The Foodstuffs, Cosmetics and Disinfectants Act, Act 54 of 1972, legislates *inter alia* for the sale of foodstuffs to the consumer. Section 2 of the Act is the relevant section.

**ACT 54 OF 1972**

*Section 2(1)*

*Subject to the provision of subsection (2) and section 6, any person shall be guilty of an offence –*

*(a) if he sells, or manufactures or imports for sale, any foodstuff, cosmetic or disinfectant –*

*(i) which contains or has been treated with a prohibited substance; or*

*(ii) which contains a particular substance in a greater measure than that permitted by regulation or has been treated with a substance containing a particular substance in a greater measure than that permitted by regulation; or*

*(iii) which does not comply with any standard of composition, strength, purity or quality prescribed by regulation for or in respect of it or any standard so prescribed for or in respect of any of its other attributes; or*

*(iv) the sale of which is prohibited by regulation; or*

*(b) if he sells, or manufactures or imports for sale, any foodstuff or cosmetic –*

*(i) which is contaminated, impure or decayed, or is in terms of any regulation deemed to be, harmful or injurious to human health; or*

*(ii) which contains or has been treated with a contaminated, impure or decayed substance or a substance which is, or is in terms of any regulation deemed to be, harmful or injurious to human health; or*

*(c) if he sells, or manufactures or imports for sale, any foodstuff –*

*(i) which contains or has been treated with a substance not present in any such foodstuff when it is in a normal, pure and sound condition; or*

*(ii) to which any substance has been added so as to increase the mass or volume of such foodstuff with the object to deceive; or*

*(iii) from which any substance or ingredient has been abstracted, removed or omitted with the result that its nutritive value or other properties, in comparison with those of such a foodstuff in a normal, pure and sound condition, are diminished or otherwise detrimentally affected; or*

*(iv) which has been treated in such manner that its damaged or unsound condition or inferior quality is concealed whether entirely or partly.*

*Section 2(2)*

*The provisions of subsection (1)(c) shall not apply with reference to the sale, manufacture or importation of a foodstuff –*

*(a) which contains or has been treated with a substance which is not harmful or injurious to human health and the addition or presence of which is necessary for the manufacture of such foodstuff as an article of commerce in a fit condition or form to be packed, stored, conveyed, used or consumed, and is not intended to deceive or mislead any buyer by increasing the mass or volume or concealing or lowering the quality of such foodstuff; or*

*(b) which contains, but in no greater measure than that permitted by regulation (if any), a foreign substance which is unavoidably present in such foodstuff as a result of the process of its collection or manufacture; or*

*(c) from which a substance has been abstracted or removed, if such abstraction or removal is necessary for the manufacture of such foodstuff as an article of commerce in a fit condition or form to be packed, stored, conveyed, used or consumed, or has been effected in accordance with the provisions of the regulations.*

**ACT 54 OF 1972**

*Section 4.*

*Subject to the provisions of section 6, any person shall be guilty of an offence if he –*

*(a) employs or uses a prohibited process or method or a prohibited appliance or container or other prohibited object in or in connection with the manufacture, treatment, packing, labelling, storage or conveyance of any foodstuff, cosmetic or disinfectant; or*

*(b) uses a prohibited appliance or container or other prohibited object for or in the preparation, serving or administering of any foodstuff or cosmetic in the course or as part of any trade or business; or*

*(c) sells or imports for sale any foodstuff, cosmetic or disinfectant in or in connection with the manufacture, treatment, packing, labelling, storage or conveyance of which a prohibited process or method or a prohibited appliance or container or any other prohibited object has been employed or used.*

**ACT 54 OF 1972**

*Section 5.(1)*

*Subject to the provisions of subsection (2) and section 6, any person shall be guilty of an offence if he –*

*(a) publishes a false or misleading advertisement of any foodstuff, cosmetic or disinfectant; or*

*(b) for purposes of sale, describes any foodstuff, cosmetic or disinfectant in a manner which is false or misleading as regards its origin, nature, substance, composition, quality, strength, nutritive value or other properties or the time, mode or place of its manufacture; or*

*(c) sells, or imports for sale, any foodstuff, cosmetic or disinfectant described in the manner aforesaid.*

*Section 5.(2)*

*The provisions of subsection (1) shall not be deemed to prohibit the description of any foodstuff by, or its sale or importation under, a geographical name which is generally accepted as a generic term for a particular type or variety of such foodstuff, provided the foodstuff described by or sold or imported under the name in question is of the type or variety indicated by that name.*

Section 15 empowers the Minister to promulgate regulations necessary to implement the Act. I intend to refer only to those subsections which are directly concerned with the control of irradiated food.

**ACT 54 OF 1972**

*Section 15.(1)*

*The Minister may make regulations –*

*(a) prescribing the nature and composition of any foodstuff, cosmetic or disinfectant, or standards for the composition, strength, purity or quality or any other attribute of any foodstuff, cosmetic or disinfectant or any ingredient or part of a foodstuff, cosmetic or disinfectant;*

*(b) prescribing, prohibiting, restricting or otherwise regulating –*

*(i) the use or employment of any substance or any appliance, container or other object or any process or method for, in or in connection with the manufacture, treatment, packing, labelling, storage, conveyance, serving or administering of any foodstuff, cosmetic or disinfectant; or*

*(ii) the abstraction or removal of any substance from any foodstuff;*

*(c) prescribing the circumstances under which or the manner in which the fact that a particular substance, process or method has been used or employed for, in or in connection with the manufacture or treatment of any foodstuff, cosmetic or disinfectant or the fact that any substance has been abstracted or removed from any foodstuff, shall be revealed to a buyer of the article in question;*

*(d) prescribing any foreign substance, or the nature of foreign substances, that may be considered as unavoidably present in any foodstuff or cosmetic as a result of the process of its collection, manufacture or treatment, or the greatest measure in which any such substance or substances of such nature may be present in any foodstuff or cosmetic;*

*(e) prescribing any foodstuff, cosmetic or substance as a foodstuff, cosmetic or substance which shall for the purposes of this Act be deemed to be harmful or injurious to human health;*

*(h) prescribing the name under which any particular foodstuff, cosmetic or disinfectant may be sold, or prohibiting the sale of any particular foodstuff, cosmetic or disinfectant under a name other than a name so prescribed or under a specified name;*

*(i) prohibiting, restricting or otherwise regulating the manufacture, importation, possession, sale or use of any appliance, container or other object –*

*(i) which is or can be used, or is intended or destined for use, in or in connection with the manufacture, treatment, packing, labelling, storage, conveyance, serving or administering of any foodstuff or cosmetic and which is in such a condition, or which consists of or contains or has been treated with any substance of such nature, that if it should come into contact with any foodstuff or cosmetic, such foodstuff or cosmetic would thereby become or is likely thereby to become harmful or injurious to human health; or*

*(ii) which is or can be used or employed, or is intended or destined for use or employment, in or in connection with a prohibited process or method of manufacture, treatment, packing, labelling, storage or conveyance of any foodstuff, cosmetic or disinfectant;*

*(j) prescribing, prohibiting, restricting or otherwise regulating –*

*(i) the packing of any foodstuff, cosmetic or disinfectant or the packing of any such article in a specified manner or in a manner other than a specified manner; or*

*(m) prescribing powers or duties to be exercised or performed by an inspector, including powers or duties in connection with the obtaining or transmitting of samples for analysis or examination, or otherwise dealing with samples for the purposes of this Act;*

*(n) prescribing powers or duties to be performed or exercised by an analyst, methods of analysis or examination of samples for the purposes of this Act, the form of any certificate or report to be furnished in connection with such analysis or examination, or the nature or arrangement of particulars to be reflected in such a certificate or report.*

**ACT 54 OF 1972**

*Section 15.(3)*

*Regulations made under subsection (1)(n) may for the analysis or examination of a sample prescribe any method* *set out in any publication which in the opinion of the Minister is generally recognized as authoritative.*

**ACT 54 OF 1972**
*Section 15.(6)*
*The Minister shall, not less than three months before making any regulation under this Act, cause the text of the proposed regulation to be published in the "Gazette" together with a notice declaring his intention to make such a regulation and inviting interested persons to furnish him with any comments on, or representations they may wish to make in regard to, the proposed regulation.*

**ACT 54 OF 1972**
*Section 15.(7)*
*The provisions of subsection (6) shall not apply in respect of –*

*(a) a regulation which, after the provisions of that subsection have been complied with, has been amended by the Minister in consequence of comments or representations received by him in pursuance of the notice published in terms of that subsection;*

*(b) Any regulation in respect of which the Minister is of the opinion that the public interest requires it to be made without delay.*

The Department of Health is empowered by the above two Acts to promulgate regulations that will include all aspects of food nandling, manufacture, packing and labelling and so ensure that the product bought by the consumer will be hygienic, wholesome and nutritious.

When it became evident to the Department of Health that atomic energy could be utilized for irradiation of food, an in-depth study of all available information of the effects of irradiating food was undertaken. The decision of the Department was that the effect of nuclear energy used in the radiation of food was similar to that of other food processes using heat energy from different sources. The results were all dependent on the intensity and duration of the energy supplied. *Food irradiation was classified as a process and not as a food additive.* The Department realised, however, that special regulations would have to be promulgated to ensure the safety and wholesomeness of irradiated food and to satisfy the consumer. During February 1974 the following regulation was published under the Foodstuffs, Cosmetics and Disinfectants Act, Act 54 of 1972.

**ACT 54 OF 1972**
*IRRADIATED FOODSTUFFS*
*DEFINITIONS*
*(1) For the purposes of this regulation –*
*'Irradiation' means the purposeful exposure to ionising radiation and 'Irradiated' has a corresponding meaning; and*

*'Ionising radiation' means radiation capable of producing ions directly or indirectly in its passage through matter.*

*PROHIBITION*
*(2) A foodstuff which has been irradiated shall not be sold unless the Minister has in writing approved the sale of that irradiated foodstuff.*

It must be stressed that this regulation was not promulgated to prohibit the irradiation of food and the sale thereof, but to ensure the wholesomeness and safety of the food to man, before the Minister approves the sale thereof. In the application to the Department of Health for permission to market irradiated food, complete data on the animal toxicological and feeding studies will have to be submitted. The following must also be furnished: the type of irradiator, whether the radiation is produced by radionuclides or by a linear accelerator, the type of food irradiated, the minimum and maximum doses used, the end result that will be achieved by the process, and the advantages of irradiation as compared with other food processes. Data obtained from similar food product irradiations in other countries may also be submitted to substantiate the original data generated in South Africa.

After evaluation of the data, the Minister will, if satisfied that the product is safe and wholesome, give written approval for the sale thereof to the applicant. The approval will be subject to conditions laid down by the Minister in his written approval.

The licensing authority for the irradiator may be either the Atomic Energy Board or the Department of Health, depending on the type of radiation source. The three principal types of radiation sources are:

(i) essentially mono-energetic gamma radiation from radionuclides such as cobalt-60 or cesium-137 (1,25 MeV and 0,66 MeV respectively);
(ii) bremsstrahlung or X-radiation from accelerators (~ 0,2 to 10 MeV);
(iii) electron beams from accelerators (~ 3 to 10 MeV).

When the radiation source is a radionuclide, the irradiator must be licensed and the staff must comply with the regulations promulgated under the Atomic Energy Act, Act 90 of 1967. These regulations also apply to medical users as the Atomic Energy Board is the authority responsible for licensing the use of radionuclides.

Although licensed by the Atomic Energy Board, the irradiator must also be approved by the Department of Health, as it must comply with all the requirements of Act 63 of 1977 and Act 54 of 1972 for the hygienic handling of food.

Irradiators using radiation sources from irradiators of types (ii) and (iii) are licensed by the Department of Health under the Hazardous Substances Act, Act 15 of 1973. The relevant sections are the following:

**ACT 15 OF 1973**
*Section 2.(1)*
*The Minister may, subject to the provisions of subsections (2) and (3), by notice in the Gazette, declare –*
*(b) any electronic product to be a Group III hazardous substance; and*

*(c) subject to the approval of the Minister of Mines, any radioactive material to be a Group IV hazardous substance.*

*Section 2.(2)*
*(a) If the Minister intends to declare any electronic product to be a Group III hazardous substance or any radioactive material to be a Group IV hazardous*

*substance, he shall cause to be published in the Gazette a notice of his intention to do so and in such notice invite interested persons to submit to the Secretary any comments and representations they may wish to make in connection therewith.*

*(b) A period of not less than three months shall elapse between the publication of such a notice and any relevant declaration under subsection (1).*

**ACT 15 OF 1973**

*Section 3.*

*The provisions of subsection (2) shall not apply in respect of –*

*(a) an amendment of any proposed declaration in pursuance of a notice published in terms of that subsection; and*

*(b) any declaration in respect of which the Minister is of the opinion that the public interest requires that it be made without delay.*

*The following definitions qualify Group III and IV hazardous substances:*

*"Electronic Product" means –*

*(a) any manufactured or assembled product which, when in operation –*

*(i) contains or acts as part of an electric circuit; and*

*(ii) emits (or in the absence of effective shielding or other controls would emit) electronic product radiation; or*

*(b) Any manufactured or assembled article which is intended for use as a component, part or accessory of a product described in paragraph (a) and which, when in operation, emits (or in the absence of effective shielding or other controls would emit) such radiation;*

*"Electronic Product Radiation" means –*

*(a) any ionizing or non-ionizing electro-magnetic or particulate radiation; or*

*(b) any sonic, infrasonic or ultrasonic wave which is emitted from an electronic product as the result of the operation of an electric circuit in such product;*

*"Radioactive Material" means any substance, other than source material or special nuclear material as defined in the Atomic Energy Act, 1967 (Act 90 of 1967), which consists of, or contains any radioactive nuclide, whether natural or artificial, and whose specific activity exceeds 0,002 microcurie per gram of chemical element and which has a total activity of more than 0,1 microcurie.*

**ACT 90 OF 1967**

*Section 3.(1)*

*Subject to the provisions of subsection (2) no person shall –*

*(a) use, operate or apply any Group III hazardous substance unless it is registered under section 4(b) and otherwise than subject to the conditions prescribed or determined by the Secretary;*

*(b) install or keep installed any Group III hazardous substance on any premises unless such premises is registered in terms of section 4(c), and otherwise than subject to the conditions prescribed or determined by the Secretary.*

**ACT 90 OF 1967**

*Section 4.*

*The Secretary may on application in the prescribed manner and on payment of the prescribed fee (if any) and subject to the prescribed conditions and such further conditions as the Secretary may in each case determine –*

*(a) register any Group III hazardous substance for the purposes of this Act;*

*(b) register any premises as premises on which a Group III hazardous substance may be installed.*

**ACT 90 OF 1967**

*Section 8.(1)*

*The Secretary may appoint any person he may deem fit as an inspector for –*

*Group III and Group IV hazardous substances, and any such inspector shall, in respect of any substance in respect of which he has been so appointed, and subject to the control of the Secretary, be vested with the powers, duties and functions conferred or imposed on an inspector by this Act.*

**ACT 90 OF 1967**

*Section 29.(1)*

*The Minister may make regulations –*

*(a) authorizing, regulating, controlling, restricting or prohibiting the –*

*(i) manufacture;*

*(ii) modification;*

*(iii) importation;*

*(iv) storage;*

*(v) transportation; or*

*(vi) dumping and other disposal, of any grouped hazardous substance or class of grouped hazardous substances;*

*(b) regulating, controlling, restricting or prohibiting the application of a grouped hazardous substance for any specific purpose;*

*(c) providing for the keeping of records and the submission of statistics and reports relating to –*

*(i) the manufacture, operation, application, modification, use or sale of grouped hazardous substances;*

*(ii) the premises on which grouped hazardous substances are used, sold or installed; or*

*(iii) persons employed in connection with or in control of Group III hazardous substances;*

*(d) prescribing the conditions under which persons involved in the operation or use of a Group III hazardous substance may be employed;*

*(e) prescribing the duties and responsibilities of any person in control of a Group III hazardous substance or any premises on which such hazardous substance has been or is being used or of any person employed in*

*connection with the operation of such a substance, and generally for the protection of any person from the harmful effects of exposure to radiation emanating from any Group III hazardous substance;*

*(f) providing for the appointment of such committees as he may consider necessary, for the purpose of advising the Secretary on any matter concerning any Group III hazardous substance, the calling of meetings of any such committee, the quorum for and procedure at such meetings and the remuneration and allowances, conditions of service and tenure of office of members of any such committee who are not in the full-time employment of the state.*

**ACT 90 OF 1967**
*Section 29.(3)*
*Different regulations may be made in respect of different types, classes or categories of grouped hazardous substances, or different classes or categories of premises, or different classes or categories of persons in control of Group III hazardous substances have been installed, or different classes or categories of persons employed in connection with the operation of any Group III hazardous substance.*

**ACT 90 OF 1967**
*Section 29.(9)*
*(a) If the Minister intends to make any regulation under this Act, he shall cause the text of the proposed regulation to be published in the Gazette together with a notice declaring his intention to make such a regulation and inviting interested persons to submit to the Secretary any comments and representations they may wish to make in connection therewith.*

*(b) A period of not less than three months shall elapse between the publication of such text and the publication of the regulation in question.*

**ACT 90 OF 1967**
*Section 29(10)*
*The provisions of subsection (9) shall not apply in respect of –*
*(a) an amendment of a proposed regulation in pursuance of the notice published in terms of that subsection; and*

*(b) any regulation in respect of which the Minister is of the opinion that the public interest requires that it be made without delay.*

The conditions imposed by the Minister will be the following for a radionuclide source, the only source used in the Republic.

**SOURCE**

(i) The date and size of the source to be recorded in the Source Record Book at the start of the commission of the facility.

(ii) The geometry of the source to be recorded.

(iii) If the size and geometry of the source are changed, the Minister must be notified and approval once again obtained.

**DOSIMETRY**

Routine dosimetry must be carried out daily and the measurement recorded

**PRODUCT**

(i) The incoming product must be stored away from the irradiated product.

(ii) The irradiated product must bear a label which will indicate that the product has been irradiated.

(iii) Where possible a visual colour-change radiation indicator should be affixed to each product pack for identification of irradiated and non-irradiated products.

(iv) A record book must be kept showing the date, the type of source, the product being irradiated and the dose received.

(v) The approval document will also stipulate the size of the source for which approval is given, as well as the maximum and minimum dose to be given, and also that an inspector of the Department of Health may inspect the irradiator at any time but at least once a year.

Once the Draft Code of Practice for the operation of radiation facilities used for the treatment of foods has been approved by the Codex Alimentarius Commission, the Department will recommend to the Minister of Health, that he incorporates the Code of Practice in the Conditions of Approval for the sale of irradiated food.

In conclusion, one can only stress the urgent need for regional legislation that will enable trade in irradiated food to take place across regional boundaries and once this has been achieved, international legislation should follow so that irradiated food may be sold internationally in the same way as food processed by means of other food processing methods. Food is too precious to be wasted and food produced today must be used to its maximum.

## DISCUSSION

**Question:** You mentioned that you would specify a maximum and minimum dose. Would this be available to the consumer or not?

**Answer:** No, I don't think it would be available to the consumer because in many other processes we don't mention the temperature of sterilisation in a retort. We do not inform the consumer of the temperature at which milk is pasteurised. The maximum and minimum dose is submitted in the application. We have carefully investigated this to establish the effects of higher doses and, in underdosing, it is obvious that one is not going to get the required effect So this is for the processor only and for the Department's information.

**Question:** I think it was decided at the recent meeting of the Codex Alimentarius Commission to do away with the lower dose limit, i.e. requiring a minimum dose. This is a very dangerous situation for two reasons: firstly, the commodities would not behave as one would expect them to and, secondly, it would open the way for people to claim that commodities have been irradiated without this perhaps being the case. What would your Department's view be on this?

**Answer:** We would probably insist on a minimum dose because we insist on dosimetry on the product being irradiated. If we did not have a lower dose we would not know whether it was successful or not. I think there is a limit at which no effect would be perceived. Most effects are dose-related, for example, one could boil a potato in lukewarm water but there must be some heat. It should be the same with radiation and the Department should require a minimum as well as a maximum dose.

**Question:** Could you tell me how you are going to monitor the amount of irradiation in cases where the maximum has been exceeded?

**Answer:** I forgot to add that if any irradiation plant has been approved by the Department we have the full right to inspect that unit at any time or at least once a month. There must be a dosimeter to measure the received dose. Our inspectors are specially qualified – they are fully-fledged medical physicists who know everything about radiation dosimetry and they have the full right to put any product through the process to see that the correct dose is given. There also has to be a graph of the fall of activity of the radionuclide and how the time of irradiation must be extended to give the product the full dose. There is full control of this aspect.

**Question:** How would you react if somebody claimed that he sold natural food which had not been irradiated, in other words to try and create a converse-reaction advertisement in this respect?

**Answer:** We will tell them that in accordance with the Foodstuffs Act, no food may be sold that is injurious or harmful to man. Therefore only food may be sold which is useful to man, and nobody will be allowed to sell irradiated food if it is harmful. He would not be allowed to make claims like this. It would be taken up with the Advertising Standards of South Africa. There are standards to ensure that the advertisements are not misleading or that unfair advantages are taken of competitors. The advertising of medicine is controlled by a certain clause which states that one may not advertise that a medicine is harmful or has certain side-effects as compared with their own drug. This type of advertisement is not allowed by our Department.

ZA8000329



# STATEGY FOR THE MARKET TESTING OF IRRADIATED FOOD IN SOUTH AFRICA

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## SAMEVATTING

'n Omvattende stategie is vir die kommersialisering van voedselbestraling nodig. 'n Plan vir die bemarking van bestraalde voedsel in Suid-Afrika word in breë trekke bespreek, asook die organisering van bemarkingsproefnemings vir plaaslike en buitelandse markte

## ABSTRACT

In order to commercialise the process of food irradiation it is necessary to implement an overall strategy. In this presentation a basic outline of the strategy for the marketing of irradiated food in South Africa is given and the organisation of market testing for both local and export markets is discussed.

## 1. INTRODUCTION

Although a number of clearances have been granted since 1958 for various food items in many countries by their respective health authorities, very little commercialisation of the process of food irradiation has taken place up to now. Several reasons have been advanced to explain the relatively slow acceptance by industry of this process, especially in view of the fact that more money, research, scientific and technical effort have been spent on food irradiation in the past quarter of a century than on any other food preservation process.

A panel of experts who met in Vienna in 1974 presented the following reasons for the lagging practical implementation of the process of food irradiation:

(a) the lack of international general clearances for irradiated food items;

(b) the fact that food irradiation is still considered to be a food additive;

(c) the fact that irradiated commodities should be labelled as such whereas chemically-treated foodstuffs do not require a corresponding label; and

(d) the lack of knowledge regarding the irradiation process in the food industry and on the part of the public in general.

Since this date two very important developments took place which can be considered a major breakthrough for this process. In 1976 an international committee of 13 experts, assisted by 5 scientific advisors and convened jointly by the Food and Agricultural Organisation (FAO), the International Atomic Energy Agency (IAEA) and the World Health Organisation (WHO), evaluated evidence for the wholesomeness of nine irradiated food commodities.

The committee agreed to consider food irradiation as a process rather than the previous approach that irradiation adds something to the treated food and should therefore be considered as a food additive rather than a process. On the grounds of all the results and data presented to them, they recommended five food items, *viz.* potatoes, wheat, chicken, papaya and strawberries, for unconditional clearances and the three commodities, rice, fish and onion for "provisional" approval.

As far as labelling is concerned, an important meeting took place in November 1977 in the Netherlands. This meeting was attended by an Advisory Group on International Acceptance of Irradiated Food convened jointly by the FAO/IAEA/WHO with participation of NEA(OECD) representatives. The Advisory Group was of the opinion that the labelling of irradiated food should fulfil two functions, *viz.* furnishing of information to the retailer and consumer on the one hand, and to the wholesale trade and national authorities on the other hand. As far as the wholesale trade and national authorities are concerned, it was suggested that labelling should take the form of an internationally-agreed-upon coding system furnishing, at very least, information on the batch identification, country of processing, date of processing and identification of the irradiation facility. The form of labelling to be adopted for the retail trade and the consumer was, in the view of the Advisory Group, a matter for consideration by the Codex Alimentarius Commission.

Members of Codex who attended the meeting, however, expressed the view that in their opinion no more additional labelling should be expected than that required for all other food preservation processes.

Since this date, further progress has been made and it is confidently predicted that the draft Standard and Code of Practice on Food Irradiation would be sent to the Codex Alimentarius Commission at the end of 1979 and that the Commission would advance the draft to step 9 in the Codex procedure, after which it would be sent to the various member countries for acceptance.

Due to these developments there are two main obstacles now remaining in the way of full commercialisation of the process *viz.* the lack of proof that the process offers real economic benefits, especially in the light of the high capital investment necessary for establishing an irradiation facility, and secondly, the uncertainty regarding the acceptance of irradiated commodities by the consumer. Due to these reasons it is highly unlikely that private enterprise in South Africa as well as in other countries, will, at this stage, venture into an undertaking about which so many uncertainties exist.

The developed countries are looking to the developing countries to introduce this process, but a problem arises in that some of these latter countries maintain that they are not going to be used as guinea-pigs and are not prepared to pioneer the process. It would appear, therefore, that irradiation of foodstuffs will have to be fully investigated and developed first in the technologically advanced countries. We have therefore decided on the following strategy to demonstrate to the consumer and the food industry the advantages of the process of food irradiation.

## 2. STRATEGY FOR THE MARKETING OF IRRADIATED FOODS

In order to demonstrate to the food industry the advantages of food irradiation and the economic viability of the process and simultaneously to test consumer response towards irradiated food items, it was decided to conduct an extensive marketing campaign for a period of at least two seasons. However, before we could commence with the trial marketing it was necessary to plan a comprehensive strategy for the commercialisation of food irradiation in South Africa. The strategy decided upon was based on the experience derived from several limited trial-marketing campaigns conducted in various countries during the past decade[1–7] and incidentally has much in common with the various steps outlined by Lapidot[2], which can be considered as a summary of the different factors influencing the introduction of a new technology. The strategy for the commercialisation of food irradiation in South Africa can be outlined as follows:

(a) Formation of a coordinating committee to determine priorities and coordinate all activities involved in food irradiation research.

(b) Selection of commodities which may best offer economic benefits, and outlining of a research and development program

(c) Execution of the research and development program, including simulated local (and if necessary overseas) marketing trials.

(d) Meeting of regulatory requirements such as clearances and labelling.

(e) Upscaling of experiments and facilities to pilot-plant stage.

(f) Establishing close collaboration between the research bodies on the one hand and the prepackers and retail outlets on the other hand.

(g) Information compaign involving the press (newpapers and journals), radio and television.

(h) Trial marketing of irradiated food(s) on a continued basis with the simultaneous furnishing of information to the consumer and various consumer bodies.

(i) Evaluation of marketing trials and consumer response.

(j) National symposium on food irradiation to inform the food industry about the techno-economic factors involved in the processing of irradiated foods.

(k) Provision of a service to interested individual farmers, cooperatives and companies in the food industry.

(l) Transfer of technology to the food industry.

(m) Export of irradiated foods.

Let us now consider these various steps in greater detail.

### 2.1 Formation and Functions of Coordinating Advisory Committee

The food research program in our country is a joint undertaking of the Atomic Energy Board and the Department of Agricultural Technical Services and our participation in the International Food Irradiation Project (IFIP) is a combined venture of these two bodies. In order to establish priorities and coordinate all research in the field of food irradiation, it was decided to form a Coordinating Advisory Committee consisting of members of the two bodies mentioned previously, as well as members of the Department of Trade and Consumer Affairs and the Department of Agricultural Economics and Marketing. This committee decided right from the outset to follow the developments and guidelines of international bodies such as IFIP, the Joint Expert Committee (JECFI) of the FAO/IAEA/WHO and the Codex Alimentarius Commission.

### 2.2 Selection of Commodities

As far as our research and development program is concerned it was decided to concentrate on those commodities which may offer the best economic benefits for South Africa, seen from both a local as well as an export viewpoint, the latter due to the fact that South Africa is, according to statistics, the sixth most important food exporting country in the world.

It has often been pointed out that the population growth of 2,6 % per annum in South Africa is one of the highest in the world, and that our population will double to 40 million by the end of the century and is expected to double again to 80 million within a further generation. It has also been calculated that of the remaining land for agriculture in South Africa only 15 % is suitable for cultivation and only 3 % can be regarded as soil with a high potential. It is therefore argued that in order to feed the growing population it is absolutely necessary to develop production methods to the utmost.

Figure 1 shows the *per capita* production of several commodities up to the year 2000, based on the extrapolated figures for the population growth and the projected figures for the growth of production. From this it can be seen that up to the end of the century, South Africa will not experience any serious problems to feed its population. However, the food and agricultural situation in South Africa cannot be separated from that in other countries in Africa but should be seen as closely bound to Africa as a whole where the food production is steadily declining by 2 % per annum. From Fig. 2 it can be seen that South Africa with only 6 % of the total population of Africa and 1,6 % of the economically active population produces 37 % of the maize, 17 % of the potatoes, 14 % of the beef and 9 % of the fruit. It is thus clear that even a small percentage of produce loss in South Africa constitutes an important fraction of the available supply. It has been calculated that the value of the present total loss of agricultural produce in South Africa amounts to more than R500 million per annum and R70 million per annum for fresh produce. Therefore every effort should be made not only to increase production, but also to preserve the crops already harvested which will lead to the opening up of new markets and the distribution of quality foods to areas where the demand exists. Attention should also be given to the improvement of food quality through improved sanitary measures in order to provide for the anticipated greater demand for quality food, together with the reduced use of chemicals for export foods in order to comply with health regulations and stringent quarantine requirements of the health authorities of various countries for imported foods.

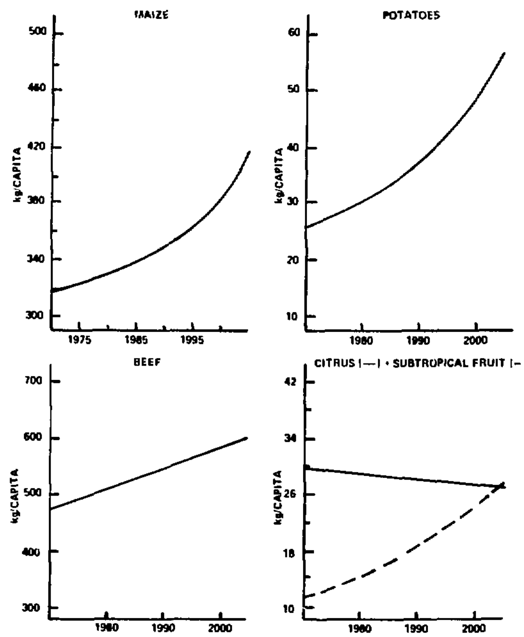


*Figure 1*
*Projected* **per capita** *production figures for four commodities up the year 2000.*

The following is a summary of the most important potential applications of this technique in South Africa:

(a) Export is undoubtedly the most important possibility for the application of this new technique. During 1977 South Africa exported produce to the value of approximately R13 000 million. Nearly 32 % of the total valuta earned (gold excluded) comes from agricultural produce. Therefore, every effort should be made to improve the quality of the produce.

(b) On the local market one of the biggest losses in fresh produce is due to greening in potatoes which may amount to between R2 million and R3 million per annum. Irradiation may be used effectively to combat this problem. The situation with regard to fresh fruit and poultry has been discussed in previous papers. Meat is also a very important food item. It is still the most important food item in the South African household. This is well illustrated when we consider the figure of R1 600 million as the gross domestic expenditure on this food item which represents 32 % of the total expenditure.

(c) Another important area where irradiation can be used is as an alternative to chemical additives, e.g. methyl bromide, ethylene oxide, etc., which are currently being critically reviewed not only in America but also in many other countries. This may be very important in the case of spices in future years.

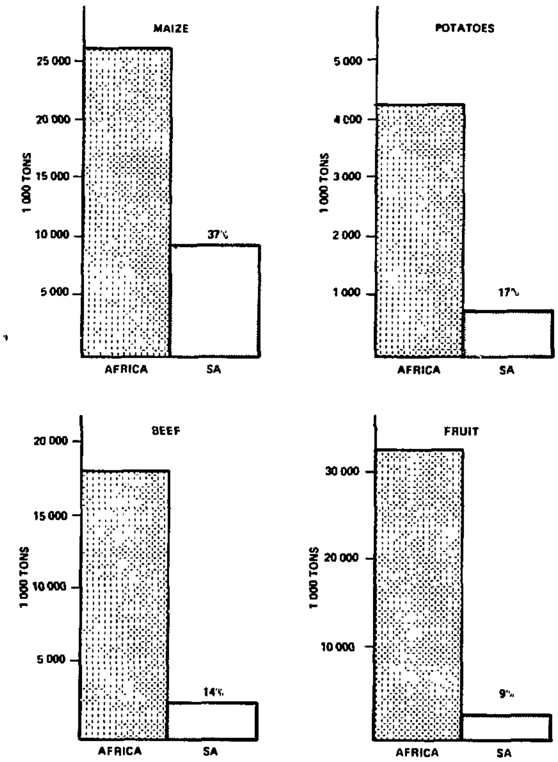


*Figure 2*
*Comparison between South Africa and Africa as a whole for production of various commodities*

In South Africa, the two most important grain products are maize and wheat, with an annual production of 10 million and 2 million tons respectively. Both these grains are treated with chemicals in order to reduce losses after harvest which can be as high as R50 million for maize and R10 million in the case of wheat. It may be possible to consider the use of irradiation as a method for the disinfestation of grain.

## 3. COORDINATION IN MARKETING TRIALS

Our experience with trial shipments of irradiated papayas and mangoes to various overseas laboratories for assessment has shown the importance of standardised assessment procedures. Therefore, we believe that it is extremely important to coordinate not only the evaluation and assessment experiments, but even more important, the actual trial marketing of irradiated products on the markets of the countries which are importers of the commodities concerned. The main advantages of this approach can be summarised as follows:

(a) A foundation can be laid for future multi-lateral agreements between interested countries.

(b) The regulatory standards as set out by the Codex Alimentarius Commission can be implemented.

(c) Confidence can be gained by the exporters and importers, and protection afforded against criticism by other food exporting concerns who may feel that their position is jeopardised by the introduction of the irradiation process.

(d) The exporting countries will be protected so that the use of the irradiation process cannot be held against them.

(e) The eventual export marketing of irradiated produce on a commercial scale will be carried out by qualified importing agents who will possess the necessary techno-economic knowledge so that the correct procedures can be followed.

I would, therefore, like to plead for the establishment of such a coordination committee for both export as well as for local marketing. This will ensure that the correct information is given to the consumer, press, etc. right at the outset of the campaign in order to avoid possible adverse criticism developing at a later stage.

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# TESTS WITH THE RETAILING OF SEVERAL IRRADIATED FOODS IN SOUTH AFRICA

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## SAMEVATTING

'n Bemarkingsveldtog is 'n paar dae na die vrystelling van verskeie bestraalde produkte in Suid-Afrika aangepak. Die veldtog van agt maande het 20 supermarkte in die Pretoria-Johannesburggebied betrek, waartydens bestraalde aartappels, aarbeie, papajas en mango's bemark is. 'n Positiewe reaksie (88 – 95 %) is van verbruikers ontvang as gevolg van bestraling se doeltreffende bestryding van aarbei- en mangosiektes asook vertraging van rypwording van papajas en vergroening van aartappels.

Verskeie probleme is tydens hierdie veldtog ondervind, naamlik die onverskillige houding van die kleinhandelpersoneel, swak hantering, onvoldoende bergingsfasiliteite en die voorsiening van swakgehaltevoedsel deur die primêre verskaffer. Klem word gelê op die behoefte aan 'n goedbeplande bemarkingsveldtog. Daar moet toepaslike inligting oor die voordele en beperkings van bestraling voor, tydens en na die veldtog aan die verbruiker, kleinhandelaar en nyweraar verskaf word. Indien so 'n veldtog nie suksesvol uitgevoer word nie, kan kommersialisering nie oorweeg word nie.

## ABSTRACT

A marketing trial was launched within a few days following the granting of clearances for several irradiated products in South Africa. Irradiated potatoes, strawberries, papayas and mangoes were marketed. The trial included 20 supermarkets in the Pretoria-Johannesburg area over a period of eight months. The effectiveness of irradiation in reducing disease in strawberries and mangoes as well as over-ripening in papayas and greening in potatoes, was reflected in the positive response (88 – 95 %) of consumers.

Several prolems were encountered during these trials. These included the indifferent attitude of retail staff, poor handling, inadequate storage facilities and the supply of inferior quality food by the primary supplier. Emphasis is placed on the need for a well-formulated marketing campaign including the dissemination of relevant information before and during the trial as well as a follow-up program aimed at the education of the consumer, retailer and industrialist as to the benefits and limitations of irradiation Unless this is successfully carried out, commercialisation cannot be considered.

## 1. INTRODUCTION

Developments in the food irradiation program in South Africa have reached the stage in recent months where several irradiated food items have received full clearance; these include potatoes, mangoes, papayas, strawberries, onions, garlic and chicken. The first four products have been selected for precommercial market testing. Marketing trials have previously been conducted in several countries including Hungary, Czechoslovakia, Holland, Italy, Israel and Germany[6 – 12]. This information served as an excellent basis for our local marketing trials. The main objectives of the current trials in South Africa have been to

- show the advantages of the radurisation process to the press, the public and the food industry
- determine consumer reaction to the marketing of various irradiated food items
- attempt to pinpoint possible problem areas in the transport, marketing and display of irradiated produce.

## 2. ADVANTAGES OF RADURISATION IN THE MARKETING TESTS

Before one can assess the results of the marketing trial it is necessary to define the objectives of the marketing campaign in order not only to test consumer reaction but, equally important, to determine whether the results obtained in the laboratory can be realised under commercial conditions. For this reason it is necessary to discuss in some detail the various commodities and the advantages to be gained from irradiation.

### 2.1 Potatoes

Sprouting in potatoes can be controlled with chemicals such as IPC (isopropyl-N-phenylcarbamate) and CIPC (isopropyl-N-(3-chlorophenyl)-carbamate) Irradiation is particularly effective in this respect and has the advantage that there are no foreign residues and, unlike the chemical sprout inhibitors, irradiation controls both internal and external sprouting. A third method of sprout inhibition is cold storage, but this is often not feasible as adequate facilities are generally not available for the large quantities of potatoes needed for commercial purposes.

Although sprouting is not regarded much of a problem by officials in the potato industry in South Africa, a thorough investigation would probably reveal heavy losses suffered by the consumer as a result of potatoes sprouting in pockets held at ambient temperatures. It was also brought to our attention that one of the largest potato-chip producers in this country would prefer to buy potatoes during the in-season peaks when prices are low, and store them for four months or longer at refrigerated temperatures, provided that sprouting could be overcome. In the same way several large potato cooperatives have confirmed the need to store potatoes for several months in order to guarantee a steady supply for a proposed flour-production scheme. The result would also be a levelling of price fluctuations which are at present being experienced with fresh potatoes.

Probably a more serious problem in South Africa is that potatoes which are exposed to the light turn green due to the formation of chlorophyll. In supermarkets with continuous lighting, this can occur within 2 to 3 days. Such potatoes are unattractive to the consumer and besides this, they have a bitter taste due to solanine, an alkaloid, which often develops concurrently with the chlorophyll[4]. Excellent control of this problem has been obtained with irradiation doses of 0,15 to 0,20 kGy which effectively increases the display life of potatoes in supermarkets from 3 to 8 d and often longer. This is significant when one considers that the majority of potatoes sold in supermarkets in this country are presented in 3 to 5 kg packs covered in PVC over-wrap or netlon bags and, as such, are totally exposed to the light. As an example, one of the larger prepackers in the country supplies 3 300 t of potatoes per year in these smaller packs.

## 2.2 Mangoes

With the introduction of fibreless mangoes into South Africa in recent years, this industry has become increasingly important as shown by the large plantings of the new cultivars It is predicted that the yields will be several times higher within the next two to three years[1].

Due to the fairly perishable nature of this fruit and the long transport distances involved, especially with overseas shipments, the task of supplying good quality mangoes to the market becomes a problem, mainly because of mango weevil infestations, fungal diseases and over-ripening of the fruit. Fortunately these problems can be satisfactorily controlled with a combined hot-water dip treatment at 55 °C for 5 min plus irradiation at 0,75 kGy[1, 5].

The mango weevil, in particular, may cause severe losses in stored mango fruits. The eggs are laid on young fruits in the orchard and the emerging larvae penetrate to the pip. Any damage at this time is repaired and becomes invisible during the growth of the fruit. At a later stage the adult weevil leaves the seed and tunnels through the edible portion of the fruit, thereby causing considerable damage to the fruit. The late cultivars, including several of the important fibreless varieties, are especially vulnerable to attack. Besides posing a problem for sea-shipped mangoes, the weevil also causes losses on the local market, especially during the late summer period which coincides with the peak production period. Irradiation treatment will either kill the weevil within the pip or so debilitate the insect that it is no longer able to cause any further damage.

The two major diseases causing serious losses in mangoes in South Africa are anthracnose and soft brown rot. Anthracnose usually becomes severe as the fruits ripen under ambient temperatures (local markets), whereas soft brown rot normally develops under prolonged periods of cold storage, *viz.* during sea exports to Europe. Excellent control of these two diseases has been obtained under local and overseas market conditions by a combination of heat treatment and irradiation[1, 5].

Irradiation has the additional advantage of significantly slowing down the ripening rate of mangoes, thereby reducing the risk of losses from over-ripening, especially under conditions of prolonged storage, i.e. during transport to distant markets.

## 2.3 Papayas

The main post-harvest problems affecting papayas in storage are fungal diseases and over-ripening. The development of this industry in South Africa has been severely restricted as a result of fruit losses due to decay and fruit collapse. Only limited quantities of papayas are exported at present and these have to be air-freighted. Sea-shipment involves prolonged storage and is not possible due to the poor keeping quality of the untreated fruit.

Fortunately, as in the case of mangoes, these problems can be adequately controlled by a combination of irradiation and heat treatment. In several large-scale market trials it was clearly demonstrated that irradiated fruits can reach distant local markets during the summer season with a minimum of loss. In the same way, simulated shipping trials have shown that it is now feasible (as with mangoes) to ship these fruits to overseas markets with a minimum of risk to the exporter[2].

## 2.4 Strawberries

Three main fungal diseases affect the post-harvest storage of strawberries, *viz.* Rhizopus rot, anthracnose and Botrytis rot. The former two diseases are a problem at ambient temperatures in summer, while Botrytis rot usually develops under refrigeration temperatures. Severe losses may be experienced, particularly from Rhizopus rot, under local market conditions in South Africa, especially since the temperature increases from September to December. Satisfactory control of anthracnose and Rhizopus rot in strawberries has been obtained with a combination of a mild, moist heat treatment (50 °C for 10 min) followed by irradiation, or irradiation alone at 2 kGy [3]. It would appear from studies conducted locally and overseas that Botrytis rot is adequately controlled with irradiation doses of 2 to 3 kGy [13, 14]. Under the present marketing conditions in South Africa, Botrytis rot does not appear to be a major problem at his stage and this is the reason why the main emphasis has been placed on the control of Rhizopus rot.

# 3. ARRANGEMENTS PRIOR TO THE COMMENCEMENT OF THE MARKET TRIALS

A basis for the organisation of the trials was laid by establishing contact with producers, prepackers and supermarket managers so as to arrange for the timeous supply, transport and display of irradiated produce in certain selected supermarkets. At the same time those involved were fully informed regarding this new technology (as previously stated) through periodic visits to the facility at Pelindaba and by means of an audiovisual program outlining the food irradiation program. In this way excellent cooperation was obtained with the various parties concerned.

All the food items were irradiated at the two radiation centres in South Africa Subtropical fruits, *viz.* mangoes and papayas, were heat-treated in the pack-house prior to irradiation in the pool facility at Tzaneen in the Northern Transvaal Lowveld. Because of the closer proximity of the main potato and strawberry-producing areas, these two commodities were irradiated in the research loop of an AECL facility at Pelindaba, near Pretoria.

All irradiated products were marked with the Radura label (which depicts high quality), either at the irradiation centre, or, in cases where the packs were broken down into smaller units (e.g. potatoes), at the prepacker. In the case of highly perishable items such as strawberries, a colour-coding system was developed so as to enable the fruit and vegetable manager to separate fresh from older stock.

The transport and distribution of the commodities were undertaken either by the grower or the prepacker. In this respect close liaison was maintained between all parties concerned in order to avoid either an under-supply or over-supply in the various supermarkets. Most of the initial arrangements were coordinated through the Atomic Energy Board.

The display in the stores was done in close cooperation with the supermarket managers and involved the arrangement of posters (with the Radura emblem). These outlined the advantages of irradiation treatment and were judiciously positioned with regard to the produce displayed. Where possible, the irradiated items were placed alongside the untreated commodities, thus giving the housewife the opportunity of making valid comparisons under similar lighting, temperature and display conditions.

Information desks were set up in several stores and trained personnel from the Atomic Energy Board were on hand to answer questions on a full-time basis for the first 6 to 8 weeks of the trial and thereafter on a regular basis every 7 to 14 days. During this period irradiated food items were offered to the public for taste testing and the names of those persons buying irradiated produce were taken, together with their phone numbers and the date of purchase.

Lists were also available at other points in the stores such as at the cash tills and entrances to and exits from the fruit and vegetable sections. Within a few weeks after purchasing the items each person was contacted telephonically and the following questions were asked:

(a) Did you specifically notice the Radura label on the product?

(b) Do you understand the significance of this label and the advantages obtained with this process?

(c) How long was the Radura product kept at your home and what were the specific storage conditions? How does this compare with untreated products bought now or perhaps with those bought in the past?

(d) Are there any comments you wish to make regarding the appearance (i.e. damage marks, colour, disease and insects) as well as freshness, texture or taste of the Radura product in comparison with the untreated commodities?

(e) Would you buy Radura products again?

These questions were kept as simple and as short as possible to ensure that the main issues such as keeping quality and taste would not be clouded with a great deal of unnecessary information.

## 4. RESULTS OF CONSUMER RESPONSE

During the first eight months of the marketing trial, 133 t of potatoes, 20 t of mangoes, 20 t of papayas and 7 t of strawberries were irradiated prior to despatch and sold through 20 supermarket stores in Pretoria and Johannesburg. Several hundred consumers were contacted telephonically during this period and the results are given with regard to the following irradiated products.

### 4.1 Potatoes

Results show that 95 % of the consumers responded favourably to the irradiation of potatoes. The majority reported no taste differences compared with the untreated product. Several consumers kept the potatoes for periods in excess of 20 days, with excellent results. Typical examples of customer remarks are given in Table 1.

**TABLE 1**
**CUSTOMER REMARKS ON IRRADIATED POTATOES**

| Keeping time* | Comments |
|---|---|
| 2 – 3 days | 1 No taste difference. 2. Excellent. 3. Very nice, very fresh. 4. Same as normal. 5. Satisfied. 6. Same as normal. 7. The same as untreated. 8. Not yet green. 9. Same as normal. 10. Excellent – still fresh. 11. Fine. 12. No objections. 13. Very nice (crisp when peeled) did not go brown when cooked. 14. Glassy – but accept this is the type of potato. |
| 14 – 15 days | 15. Very good – promising method. 16. Prefer to buy Radura potatoes. 17. Kept very well when boiled and chips – very nice. 18. Very good. 19. Good. 20. Cooks easier, turned green but did not sprout. |
| 20 – 21 days | 21. Good. 22. Not yet green or sprouted – keep well. 23. Good, still fresh, not yet green or sprouting. 24. Good. |

**Refers to the time the product was kept by the consumer before consumption.*

### 4.2 Strawberries

Of those consumers who had bought Radura strawberries, 88 % reacted positively. It is interesting to note that the response varied from 66 % to 100 %, depending on the particular store. Possible reasons for these differences are discussed under the section FACTORS INFLUENCING COMMERCIAL ACCEPTANCE. In several cases Radura strawberries were kept for periods in excess of 12 days.

### 4.3 Papayas

A serious quality problem was experienced from time to time with papayas, which had nothing to do with the irradiation process (see under section FACTORS INFLUENCING COMMERCIAL ACCEPTANCE). However, notwithstanding the quality problems experienced with the papayas, the consumer response to the irradiation of papayas was very encouraging. The quality of the untreated papayas was generally so poor that even with the problem regarding external appearance, Radura papayas were still much better and more acceptable for marketing as they were less prone to disease and over-ripening than the untreated fruit. Over 93 % of the consumers reacted favourably to Radura papayas. In some cases the fruit was kept for 14 to 16 days and the consumers were highly satisfied with the quality.

### 4.4 Mangoes

Over 94 % of the persons contacted were in favour of irradiated mangoes and the majority stated that they would definitely buy Radura mangoes in the future. In some cases, the treated mangoes had been kept for two to three weeks by the housewife, with highly satisfactory results.

Details of consumer response in regard to the three test fruits were recorded in a way similar to that of the potatoes in Table 1. From the results of all four irradiated commodities, it is obvious that no major taste differences were noted between irradiated and untreated products. There is also a distinct tendency for the consumer comments to become more favourably orientated towards the irradiated products the longer the food items were kept. This is to be expected as the beneficial effects of irradiation regarding disease and insect control as well as over-ripening in the fruit and sprouting and greening in potatoes will often only be noticed after the products have been kept for several days.

## 5. FACTORS INFLUENCING COMMERCIAL ACCEPTANCE

During the eight-month marketing trial serious problems developed, especially with regard to the supply and display of certain irradiated produce. It was soon realised that these were typical of the complications which would be experienced in a commercial operation. Each problem was carefully investigated and a list of guidelines was drawn up for the producers, prepackers and retailers handling Radura products. Some of the main problems experienced and our recommendations in this regard, are outlined below.

### 5.1 Information

The staff of the retail outlets handling the Radura products should be fully informed regarding the objective of the marketing campaign. We also recommend very strongly that the personnel should be in a position to give the necessary information regarding this process to the public if and when required to do so. It is very important to have their enthusiastic support in order to offset possible indifferent attitudes which could have an undesirable negative effect on the public. Care should be taken to ensure that the staff do not consider this as just another product and therefore an extra burden. It is also important that those involved in the marketing trial should not interfere with the display and arrangements in the stores. All new arrangements and suggestions for the improvement of the display should be discussed either with the manager or a responsible person appointed by him.

### 5.2 Ordering of Radura Produce

It is absolutely necessary that the quantities of Radura products ordered from the prepackers should form part of the total order. They should not be an additional lot which could lead to over-supply and therefore a burden to the head of the fruit and vegetable section, and thus interfere with the normal sales. This should be done in order to avoid the possibility of Radura products being held back and other goods sold first. The advantages of an extended shelf life would thus not be passed on to the consumer, because the products would have deteriorated considerably by the time they come on display.

### 5.3 Handling

Due to the fact that the Radura process is a new concept, it is imperative that all goods displayed with the Radura label must be in an excellent condition. It was noticed that perishable commodities such as strawberries were badly handled in certain cases. It should be realised that Radura products should be treated in the same way as untreated products. However, when the Radura products are damaged by mishandling, the beneficial effects of the process are virtually eliminated and the idea of presenting a high-quality product is consequently nullified.

### 5.4 Separate Display

It is essential that the Radura products be displayed separately from the untreated produce. It was noticed that, especially with regard to small potato packs, untreated potatoes which had started to sprout or had turned green were often indiscriminately thrown into a display of Radura potatoes, thus virtually negating the impact one is endeavouring to have on the housewife.

The Radura emblem posters should be displayed in a prominent position with regard to the produce displayed.

In cases where the product has been damaged (e.g. papayas and strawberries are very prone to mechanical injury) it would be advisable to remove the item from display to prevent the wrong impression being gained by the consumer. In other words, only the very best quality products should be displayed.

## 5.5 Storage Conditions

It is important that the optimal storage temperatures be maintained, especially for perishable products such as strawberries for which the ideal storage temperature is between 1 and 5 °C. It was noticed that strawberries were often not being stored at these temperatures prior to being displayed in the supermarkets It is known that strawberries deteriorate very rapidly when subjected to radical temperature changes. The removal of small lots from cold storage only when needed would largely help to overcome this problem.

It was also noticed that the handling of strawberries in cold storage rooms leaves a lot to be desired. The boxes were often packed so high that the punnets in the lower boxes were badly damaged.

## 5.6 Price Fluctuations

In certain stores the Radura products were sold at a higher price compared with that of the untreated products. There is no reason for this as at this stage the products are being irradiated without cost to the retailer. In some cases the difference was as much as 20 c on a single item. It is unfair that the Radura products are subjected to such a price disadvantage and this practice should therefore be discontinued.

## 5.7 Quality of Product to be Irradiated

It is very important that only high-quality products be sent to the facility for treatment. Radiation cannot improve the quality of a bad product. It is a preservation process and therefore acts as a preventative and not a cure! In view of this, specific consideration should be given to the compilation of minimum standards to be applied at the receiving depot of every food-irradiation plant. For example, subtropical fruits such as mangoes and papayas should be carefully examined for blemishes and damage, as well as the stage of maturity of the fruit prior to treatment. It is suggested that these quality standards be set as guidelines for the food producers, prepackers and retailers.

## 6. CONCLUSIONS

The results of the trial marketing campaign have shown that if the correct information is supplied at the right time, the consumer is prepared to accept irradiated foods. Obviously, efforts have to be made in future to reach a wider spectrum of the population in South Africa.

An important feature of these trials is that various problem areas regarding commercialisation have been highlighted. An expanded experimental stage is necessary during which large quantities of foods are treated and distributed in order to test this process for an extended period under commercial conditions. We therefore suggest that before embarking on an investment of several million rands, the first step towards commercialisation should be the erection of an irradiator capable of treating ton quantities of produce. However, in those countries where due to health, malnutrition and other socio-economic reasons, an urgent need exists for more and better food, the erection of a large facility could perhaps be justified at an earlier stage.

Once the consumer acceptance has been fully tested and demonstrated, and most of the technical and techno-economic problems have been thoroughly studied, the time would be right to hold a national symposium in order to acquaint the food industry with the advantages of this process.

After such a symposium, sufficient interest should have been generated in the food industry and a stage reached where there is a specific demand for an irradiation service facility. This facility should be for the benefit of producers, cooperatives, prepackers, retailers, etc. The final stage would then involve the transfer of the technology to private enterprise with the construction of fully commercial irradiators.

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## DISCUSSION

**Question:** Were you also able to obtain the opinions and comments of those consumers who did not buy the Radura products?

**Answer:** Of the small percentage of the public who would not buy Radura products, there were basically two reactions:

1. A few people had received cobalt treatment in hospital and were not convinced of the safety of this treatment for foodstuffs and

2. A certain sector of the public would not buy Radura products as they were looking for produce which had been marked down in price as a result of damage, over-ripening or decay. This had nothing to do with their rejecting the Radura produce.

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# FOOD IRRADIATION – THE RETAILER'S VIEW

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## SAMEVATTING

Besendings bestraalde en nie-bestraalde aarbeie is gedurende Oktober–November 1978 in drie takke van OK Bazaars te koop aangebied. Monsters was ook aan nagebootste winkeltoestande blootgestel en die rakleeftyd van beide die bestraalde en nie-bestraalde pakkies is bepaal. Die bestraalde pakkies was tot die 15de dag nog onaangetas terwyl die nie-bestraalde pakkies al op die 7de dag tekens van bederf begin toon het. Hulle was op die 14de dag heeltemal oortrek met swamme. Die reaksie van die publiek was oor die algemeen een van belangstelling. Die bemoedigende verkope het dit ook weerspieël.

Bergingsproewe is in Maart 1979 op groen en ryp Keitt-mango's uitgevoer. Resultate het 'n duidelike verlenging van die rakleeftyd van die bestraalde mango's getoon. Die gehalte van vars mango's word deur antraknose, sagte bruin vrot en mangokewers benadeel. Hierdie probleme is doeltreffend deur bestraling beheer.

Bestraling is nie 'n wondermiddel nie en moet nie as 'n plaasvervanger van ander voedselpreserveringsmetodes gesien word nie. Enige toekomstige bemarkingsproewe moet uitsluitlik met bestraalde vrugte uitgevoer word. Die koper moet die geleentheid gebied word om die vrugte van hoë gehalte te sien sonder om dit met vrugte, so naby aan oorryp dat die prys verlaag is, te kan vergelyk.

Hierdie proewe sal op veel groter skaal voortgesit word.

## ABSTRACT

During October–November 1978 consignments of irradiated and non-irradiated strawberries were offered for sale in three branches of OK Bazaars. Samples were also subjected to simulated store conditions and the shelf life of both irradiated and non-irradiated packs determined. Irradiated packs were unaffected by decay until the 15th day of storage while the non-irradiated packs started to show signs of decay on the 7th day and were totally contaminated with fungus by the 14th day. In general, the response from the public was one of extreme interest and was to a large extent reflected in the encouraging sales.

In March 1979, storage trials were carried out on green and ripe Keitt mangoes. The results of the trials show a marked increase in the shelf life of irradiated mangoes. The problems which exist with regard to the quality of fresh mangoes, namely anthracnose, soft brown rot and mango weevil, were all effectively controlled by irradiation.

It must be realised that irradiation is no panacea and is not a substitute for other methods of food preservation. Any future marketing trials must be carried out using exclusively irradiated fruit. The customer must have the opportunity of "seeing" the better fruit and not comparing it with other fruit which may be so near over-ripening on display that the price may have been reduced.

The trials are to be continued on a much larger scale.

## 1. INTRODUCTION

The demonstration of the wholesomeness of irradiated food has long been regarded as the key factor upon which the fate of commercial food-irradiation processing depends. This is indeed correct, because it is of paramount importance that public health authorities be fully assured that such a new food processing method does not pose any health hazards to the consumer. Consequently, enormous efforts and resources have been devoted to the wholesomeness-testing of numerous irradiated foods and food constituents over the past years.

Despite all these endeavours, the fear continues to be expressed that the "wholesomeness question" will remain the "stumbling block" to future developments, irrespective of the overwhelmingly positive evidence for the wholesomeness of irradiated food. As toxicological requirements continue to become more stringent, so more evidence of wholesomeness is being required.

Seven irradiated food products were granted full clearance by the Government Departments which protect the health of our nation: the Department of Mines, the Department of Agricultural Economics and Marketing and the Department of Health, on 31 August, 1978. This indicates that these fears need no longer be expressed.

This does not, of course, imply that there is no need for further research, as there will always be gaps in our knowledge and questions will remain to be answered, but it is essential that we keep abreast of current technology. In this connection it is interesting to note that no other food processing method has been subjected to such close toxicological scrutiny.

I would like to divide this presentation into two sections:

(a) the results of the laboratory and field trials at the OK Bazaars;
(b) the marketing mechanism and opportunity.

## 2. THE RESULTS OF THE LABORATORY AND FIELD TRIALS AT THE OK BAZAARS

The benefits of irradiation were first brought to our attention last year, when Dr Brodrick of the Atomic Energy Board presented a paper at the South African Association of Food Science and Technology (SAAFoST) Congress in Durban, outlining the work being carried out at Pelindaba. We were very interested in these developments and were quick to realise the benefits which could be achieved in retailing irradiated fruits and the increased shelf life (or state of optimum freshness) which could be passed on to the consumer. We expressed our willingness to carry out consumer trials in our stores once commercial-scale productions were under way.

During the period October – November 1978, consignments of irradiated and non-irradiated strawberries were offered for sale in three of our stores, namely, Randburg, Rosebank and Sandton City. The strawberries were supplied to the store pre-packed in polystyrene trays and covered with filmwrap. All packs were coded with the date of harvest and those having received irradiation treatment were marked with a "Radura" sign.

Samples from the above consignment were sent to our laboratory where they were subjected to simulated store conditions and the shelf life of both irradiated and non-irradiated packs determined.

The basic problem with retailing fresh pre-packed strawberries is the rapid onset of post-harvest decay due mainly to "Botrytis cinerea". Losses as high as 25 % have been encountered, especially when the fruits are in a ripe condition. The consumer is, therefore, faced with a degree of uncertainty regarding the period in which to consume the product, or how long the product will last in her refrigerator.

The results of our trials, under ideal laboratory storage conditions, showed that the irradiated packs were unaffected by decay until the 15th day of storage, whereas the non-irradiated packs started to show signs on the 7th day and were totally contaminated by the 14th day. By the use of irradiation, the shelf life of freshly picked strawberries can be increased by a further 10 days (see Fig. 1).

In March this year, further storage trials were carried out in our laboratories on green and ripe Keitt mangoes. As with the strawberries, a certain portion of each consignment had been subjected to heat treatment followed by irradiation. Storage trials were conducted at ambient temperature (25 °C) and 20 °C with a relative humidity of 65 %. Periodically the mangoes were examined for signs of disease.

It is pertinent, at this stage, to mention the problems which currently exist with regard to the quality of fresh mangoes. During the spring when the fruit is small and green, the adult mango weevil lays its eggs in a slight incision in the fruit's skin. The mature fruit usually shows no signs of the presence or activity of the larvae which are feeding on the seed. The only time when this is discovered is when the consumer cuts open the fruit. Incidence of mango weevil is still reported to be very high and has on occasion been found in 95 % of all fruits examined. Other problems are those of anthracnose and soft brown rot. Infected areas increase rapidly in size, becoming black, and the flesh of the fruit softens and becomes discoloured. The fungus will continue developing on mature fruits which are only slightly infected at the time of picking, resulting in breakdown before reaching the consumer.

The results of our storage trials show a marked increase in the shelf life of irradiated mangoes with no signs of anthracnose, soft brown rot, or mango weevil. Some

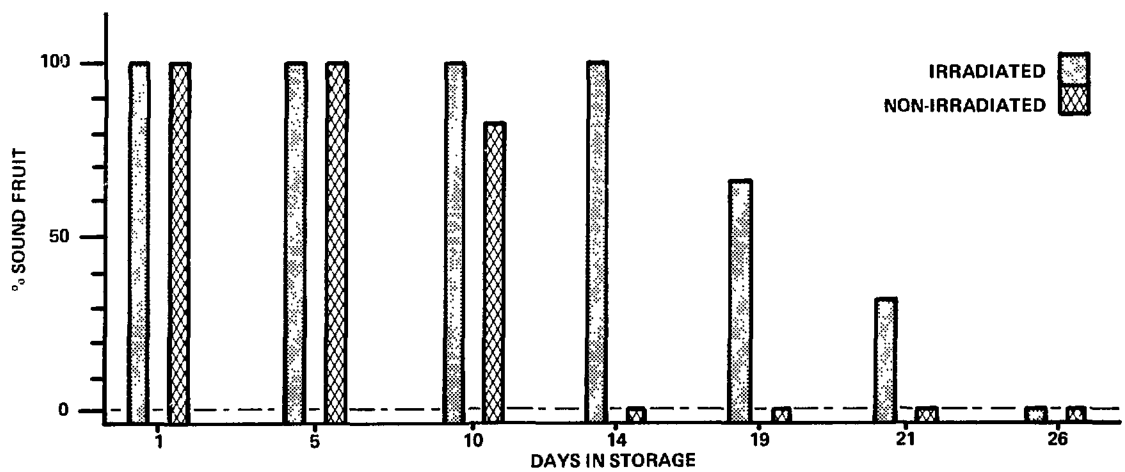



*Fig. 1*
*Strawberry Storage Trials at 4 °C*

In one instance the non-irradiated strawberries had a shelf life of seven days. In other circumstances the shelf life of non-irradiated strawberries was as low as one and two days, whereas the shelf life of the irradiated strawberries from the same stock was consistently 14 to 15 days.

During the period which these packs were on sale in our stores, leaflets, made available by the Atomic Energy Board, were issued to the public to draw their attention to the benefits of radurisation for certain fruit and vegetable products. Generally, the response from the public was one of extreme interest and was to a large extent reflected in the encouraging sales.

phytotoxic defects were noted in the irradiated packs, but it was found that this only affected the skin surface and not the flesh of the fruit. The phytotoxic damage was later identified and found to be due to a faulty packing house procedure which, we understand, has since been corrected.

It is interesting to compare, at this stage, the marketing requirements of these two products. Strawberries require a longer shelf life for consumer choice and acceptability. Mangoes do not require a longer shelf life but require the elimination of the weevil, which may spoil apparently sound fruit. This is not shown up until the consumer cuts open the fruit, hence a dissatisfied customer. Irradiation eliminates this hazard and reduces the possibility of fungal diseases. Therefore, the consumer requirements for these two products are different and radiation satisfies both of these requirements; hence, there is a major advantage to the consumer

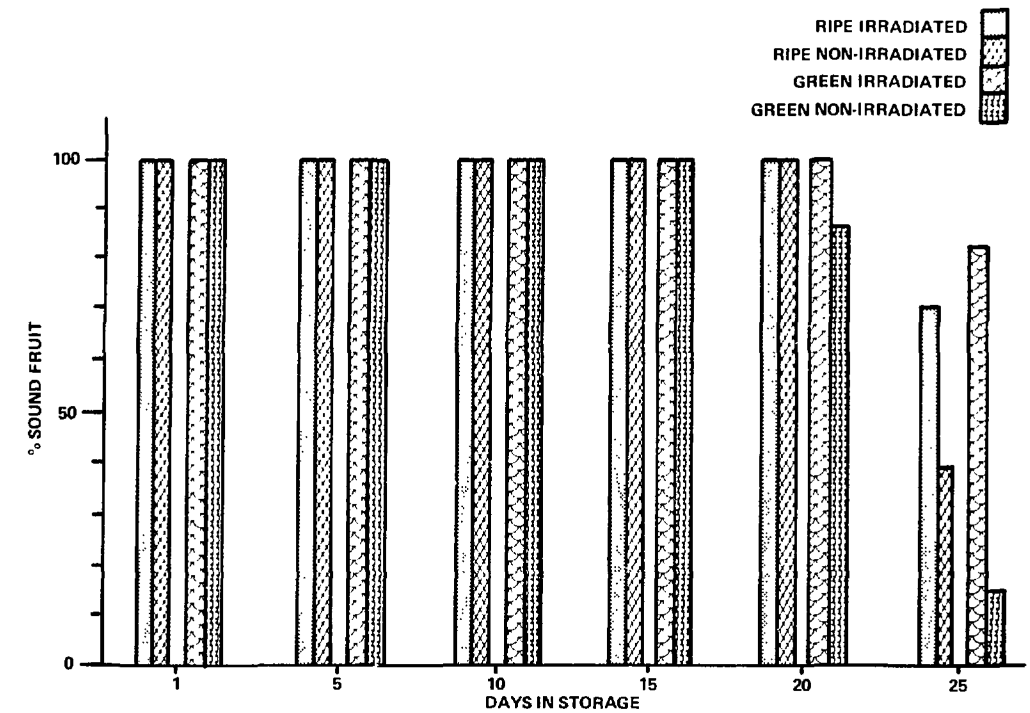



*Fig. 2*
*Mango Storage Trials at 25 °C*

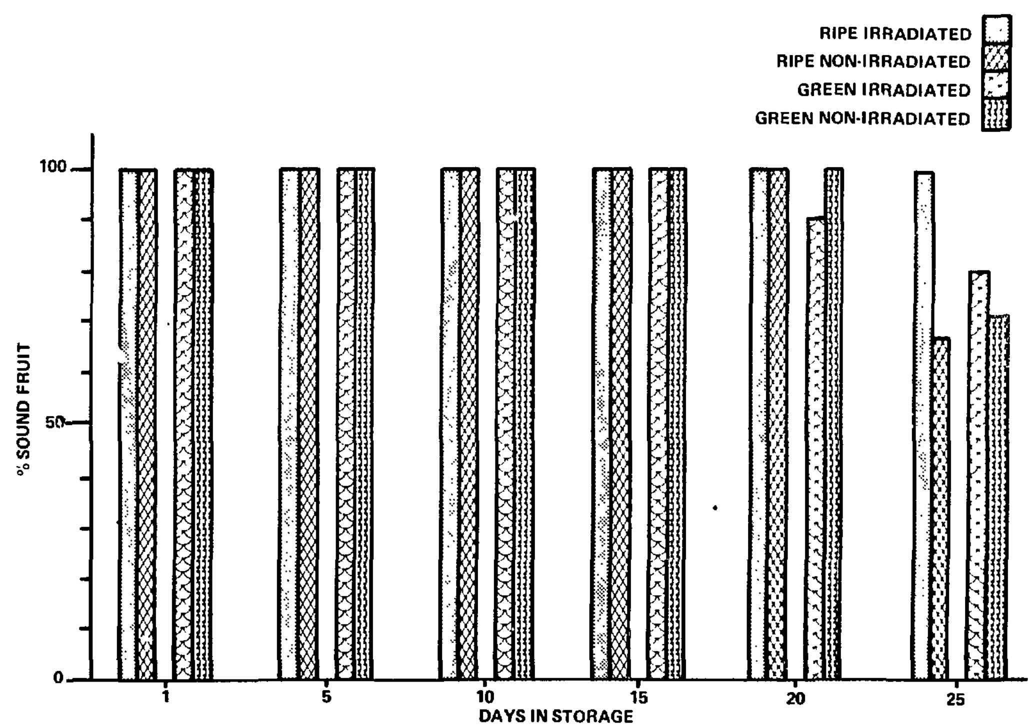



*Fig. 3*
*Mango Storage Trials at 20 °C*

## 3. THE MARKETING MECHANISM AND OPPORTUNITY

The benefits of irradiation are still somewhat in the infancy stage and, doubtless, future developments and advantages will become more apparent as technology improves. However, these benefits must not be considered replacements for product quality, nor for poor handling and storage techniques. It is essential that only first-class quality products are selected for irradiation and that the handling of these products from farm to kitchen be carried out with the same alacrity as is currently employed with our normal perishable lines. It is important to remember that irradiation is no panacea and is not a substitute for refrigeration, gas storage or other methods of food preservation. It is an additional technique which, when used with one or other of the above, can only, in the end, benefit the consumer.

The OK takes its retailing responsibility very seriously because it knows that its customers accept that anything it sells must be wholesome, safe and at its optimum consumer acceptability.

Few retailers have the ability to check or understand such requirements and many pay lip service to quality. It is only a retailer like the OK, who has invested in qualified staff, that can offer this type of guarantee to the consumer. This guarantee can only be enforced when the technical division has teeth and the man at the top agrees to quality.

The OK Bazaars has its own laboratories, technologists and scientists and is able to investigate for itself the acceptability and feasibility of any new process or product.

It is important to explain this aspect to understand the marketing trials. The marketing trials were very successful in our stores and we received no adverse reaction from the customers. However, I believe that this was partly due to the fact that our customers accept that the OK would not sell any product which the OK had not tested and found acceptable.

Irradiated fruit was sold side by side with non-irradiated fruit. Any future marketing trials must be carried out exclusively using irradiated fruit. The reason for this must be to test, in total, consumer acceptance. This may only be measured by increased sales over the previous period.

Larger quantities must be available to saturate the market for the retail outlet. The customer has the opportunity of "seeing" the better fruit and not comparing with other fruit, which may be so near over-ripening on display, having passed its best, that the price may have been reduced in order to clear the products. The housewife will quickly see the advantages and know that the quality will last until her important dinner party.

Trials must be carefully controlled to ensure that growers pick at optimum conditions, that field heat is removed, that it is processed and transported as quickly as possible from farm to consumer. Irradiation is only a process and is no excuse for sloppy handling or extended delivery times: it is a tool which is used to provide "optimum freshness" to the housewife. It is not a fairy's wand to make bad fruit good. Any process, and improvements which that process provides, is only successful when good quality raw materials are used.

Irradiation must now take its place amongst other methods of preservation. For any product one or several of these processes may be necessary.

Our trials, as I have previously stated, were a great success and we shall continue these, with the assistance of the Atomic Energy Board, this coming year, on a much larger scale. The commercial implications and possible economic benefits are considerable. These are as follows:

(a) The customer is able to buy fruit at optimum freshness and with guaranteed quality.
(b) Less wastage at every stage in the chain from grower to consumer.
(c) Less wastage means lower costs.
(d) More encouragement to our farmers to grow larger seasonal crops.
(e) The possibility of increasing exports and offering different products to overseas markets.

It is imperative that we continue to build a strong South African economy. We must seek additional export opportunities whenever we can. South African fruit is renowned throughout the world for its fine quality. Irradiation now gives us the opportunity to investigate exporting fresh fruits that are relatively unknown in Europe and America. We can extend our agricultural economy and satisfy new markets.

South Africa has taken the world lead by instituting trial marketing of irradiated fruits. I suspect that other countries will not be far behind; therefore, we must support and capitalise on this opportunity, not only for our local market, but also for our export markets.

Finally, I would like to acknowledge my colleague Mr Elms for his meticulous evaluation of the laboratory trials. I would also like to thank Mr Meyer Kahn, the Managing Director of the OK Bazaars for permission to present this paper.

## DISCUSSION

**Question:** I have not gained an estimate of the cost of irradiation. I understand that at this stage it is very much the experimental type of process that is still being undertaken. Have you made any estimate yet of the monetary value of the longer shelf life and also the other benefits of the irradiated product?

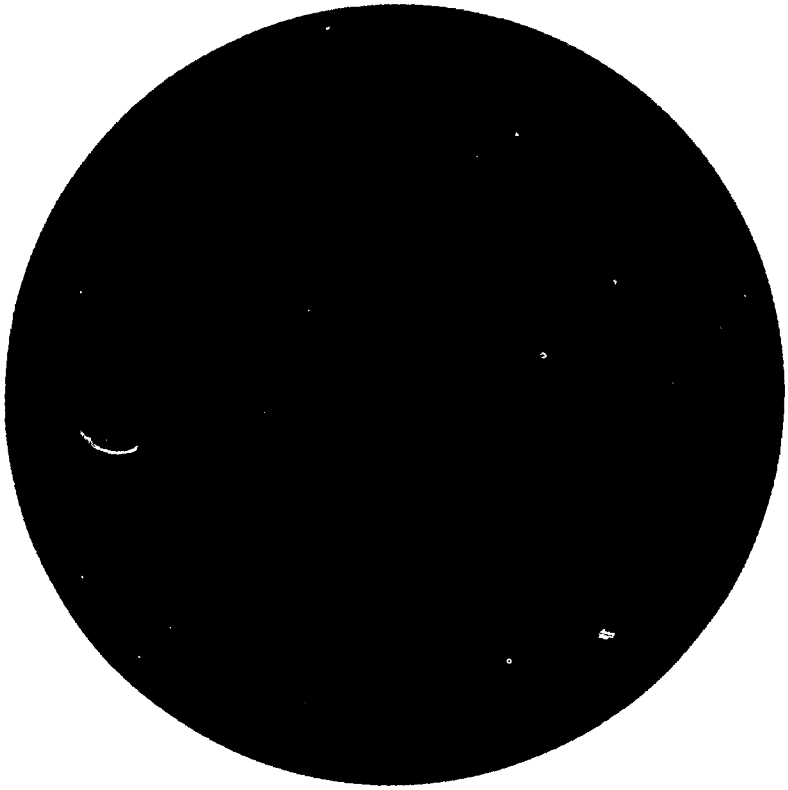
**Answer:** I would like to answer in a different way and compare it to the situation that was found in Britain some six to ten years ago. Tomatoes were grown in various parts of England and in Holland and those tomatoes were brought to the counter of *Marks and Spencer* in 24 hours by ship. It was found that better tomatoes could be grown in different parts of the world, but in order to get them there it was necessary to use air transport. Air transport, as we all know, is extraordinarily expensive. The better tomatoes were flown in from those countries and they were on the counter within 8 hours of picking. The additional cost in those days was the equivalent of one shilling over and above that of the local tomatoes. Those tomatoes always sold first and the local ones sold last. I think the consumer always recognises quality. The consumer is a very intelligent person who cannot be fooled and who is prepared to pay when there is an improvement in quality.

**Question:** You therefore assume that the consumer will be willing to pay whatever the increased price may be for this type of process.

**Answer:** I consider that a consumer will always pay for quality, however I do not believe that any process can be used in order to increase the price higher than a reasonable amount.

**Question:** My impression, speaking for my own household, is that very little food is wasted through decay. So I am not quite convinced that preservation by means of irradiation is really of great benefit to the consumer. However, my impression is that most of the advantages are for the retailer. Shouldn't much of this advantage go to the consumer in the form of a cheaper price?

**Answer:** I agree and cannot comment. Any process must be used to obtain the cheapest price possible. I disagree with your first comment. Obviously in so far as you can say the same about gas storage, about refrigeration, except that many of these have been accepted from time immemorial. Irradiation now gives us another tool that will undoubtedly improve the quality of foodstuffs. I think you are quite right, some retailers will, of course, use an extended shelf life for their own benefit but the more enlightened retailer won't do that because he wants to provide his goods at the optimum quality and optimum freshness for his consumer. A satisfied customer buying at optimum freshness in a store means that she will come again to buy again. Obviously too, with any process one wishes to apply it at the lowest possible price.

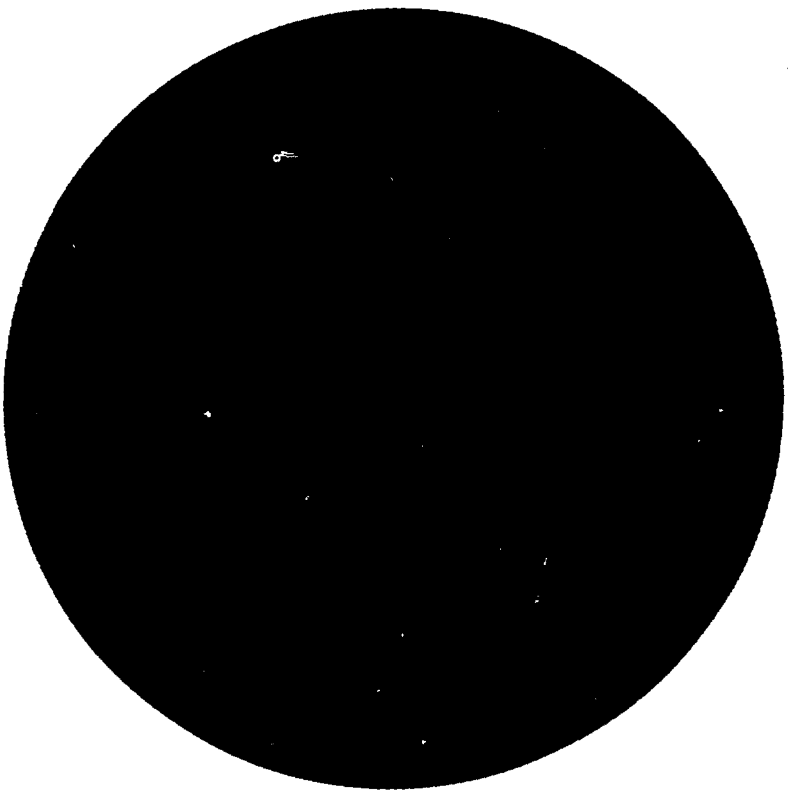


**Afternoon**

## SESSION V

## RADIATION FACILITIES – COSTS AND PLANT DESIGN

**CHAIRMAN: DR W J DE WET**
*Director: Chemistry Division, Atomic Energy Board, Pretoria*



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# THE TECHNO-ECONOMIC ASPECTS OF GAMMA-RADIATION PROCESSING

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## SAMEVATTING

Die afgelope paar jaar se toename in kommersiële stralingsprosessering asook die vername rol wat gammabestralers in hierdie verband gespeel het, word bespreek. In Suid-Afrika word die ontwikkeling en huidige status van gammastralingsprosessering op industriële gebied in oënskou geneem

Die vele faktore wat die ontwerp en bedryf van 'n kommersiële gammabestraler kan beïnvloed word gedek. Besondere aandag word aan die invloed van produkdigtheid, stralingsdosisvereistes, dosis-eenvormigheidsverhouding en produkdeurvoer op die tegno-ekonomiese struktuur van so 'n proses geskenk. Die spesifieke vereistes van 'n bepaalde stralingsproses lê sekere beperkings op die buigsaamheid van gammabestralerontwerp en dus is veelvuldige bestralers vandag 'n uitsondering in die nywerheid.

Om die invloed van hierdie prosesveranderlikes op die ekonomie van gammastralingsprosessering te verduidelik, word die kostestruktuur van 'n ooppoelaanleg en 'n kommersieel beskikbare bestraler vergelyk. Alhoewel 'n ooppoel-betralingsaanleg, in teenstelling met die kommersiële bestraler, aanvanklik 'n beskeie kapitaalbelegging vereis, skep dit probleme soos produkhantering, gehalteversekering, swak energiebenutting en oormatige arbeidsvereistes as gevolg van die feit dat dit 'n lotproses is. Hierdie nadele veroorsaak dat dit 'n onaantreklike onderneming is, behalwe in sekere spesifieke omstandighede.

'n Aantal moontlike riglyne vir die evaluering van die toepassing van gammastralingsprosessering as 'n tegniek, word voorgestel.

## ABSTRACT

The growth of commercial radiation processing over the past few years is examined and the prominent role which gamma irradiators play in this respect is discussed. The development and present status of gamma radiation processing on an industrial scale in South Africa is also briefly discussed.

The many variables affecting the design and running of a commercial gamma irradiator are briefly discussed. Special attention is paid to the influence of product density, irradiation dose requirements, dose uniformity ratio and product throughput on the techno-economic structure of such a process. The specific requirements of a particular radiation process impose certain limitations on the flexibility in gamma irradiator design, and consequently, multipurpose irradiators are the exception in industry today.

To illustrate the influence of these process variables on the economics of gamma radiation processing, the cost structure of an open-pool facility and a commercially available irradiator are contrasted. Although an open-pool irradiation facility requires a modest initial capital investment, the problems associated with product handling, quality assurance because of the batch nature of the process, poor energy utilisation and excessive labour requirements, as opposed to the commercial irradiator, make it an unattractive proposition except in certain specific circumstances.

A number of guidelines are presented to assist people in evaluating the possibility of introducing gamma radiation processing as a technique.

## 1. INTRODUCTION

Although it may be said that radiation processing was oversold in the early days of atomic energy, testimony to the potential value of this relatively new technology is given by the growing number of private companies now involved in using radiation as part of their production procedures. Both isotopic irradiation facilities and electron accelerators are playing a very important role today in industry and every day adds new applications to the already wide field of radiation processing.

Because industry is loathe to disclose its involvement in radiation processing, it is extremely difficult to obtain an accurate picture of the present status of radiation processing. In Table 1 the status of industrial radiation processing during 1977 is given for a number of countries[1] From this Table it immediately follows that most of the activity at present closely involves the field of polymers. It is furthermore apparent from this Table that the radiation sterilisation of medical products plays a prominent role in current industrial radiation processing for the countries named – a situation which is also applicable to South Africa. The utilisation of gamma radiation in the sterilisation of medical supplies clearly demonstrates the dramatic increase in the application of radiation in industry. In the USA, for example, the installed cobalt-60 increased from a value of 9,7 MCi in 1977 to a value of more than 19 MCi in 1978[2]. Similarly, the installed cobalt-60 in the Pelindaba plant increased from a value of 0,5 MCi in 1978 to its present value of more than 1,0 MCi – making this irradiator one of the largest service irradiation facilities in the world.

The gross annual turnover for radiation processing in the USA was estimated to be 650 million dollars for 1977/1978 – a remarkable achievement for an industry that is still relatively young[3].

Considering the capital-intensive nature of radiation processing, the process variables of this technology have to be very carefully defined and evaluated in order to exploit its commercial potential and to ensure its economic viability. The aim of this paper is, therefore, to discuss the important parameters of gamma-radiation processing and to demonstrate the important bearing which the technical aspects of this technology have on the economics of this technique.

TABLE 1
THE PRESENT (1977) STATUS OF
INDUSTRIAL RADIATION PROCESSING

| Nature of Application | Number of Private Industries in | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | USA | Japan | France | Australia New Zealand | Taiwan | Germany | Belgium | Italy | Sweden |
| Radiation Modification of Polymers (Cross-linking, Degrading, etc.) | 20 | 12 | 4 | 2 | 1 | 1 | 1 | 0 | 0 |
| Radiation Polymer-isation (Curing of Coatings and Adhesives, Wood-Polymer Composites, etc.) | 6 | 7 | 1 | 0 | 1 | 1 | 0 | 0 | 1 |
| Radiation Graft Copoly-Merisation (Textiles) | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Radiation Sterilisation | 16 | 3 | 3 | 3 | 1 | 3 | 1 | 2 | 0 |
| Food Preservation and Disinfestation for Human Consumption | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Others | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## 2. FUNDAMENTAL ASPECTS OF GAMMA-IRRADIATOR DESIGN

Because of the rather complex nature of the principles involved in gamma-irradiator design, we will elucidate the more important concepts of this topic by employing a *highly simplified model* and discuss the influence which some of these process parameters have on the techno-economic aspects of gamma-radiation processing.

Consider a cobalt-60 irradiator in the form of a thin slab in which the radioactive cobalt isotopes are distributed homogeneously throughout the source plaque as indicated in Fig. 1. At a distance x from this source plaque we have our target to be irradiated in the form of a rectangular product carrier or plant package and we assume that this plant package has a target thickness D. The densities of the absorbing material between the source and the target and that of the target itself, are $d_1$ and $d_2$ respectively. In all industrial gamma-irradiators the density of the target material is higher than that of the surrounding material (air), except in the case of pool-irradiators where the product carrier is surrounded by water, this means that $d_2 \gg d_1$. We know that the radiation intensity of a gamma-radiation field decreases exponentially with an increase in distance for the source, as shown in Fig. 1. The higher the density of the absorbing material, the steeper will the slope of the curve be. Assuming that the target material has a higher density than the absorbing material surrounding the target, the slope of the curve AB in the target will be steeper than the rest of the curve.

In radiation processing the most important parameter is the absorbed radiation dose required to obtain a specific desired radiation change. In addition to the absorbed radiation dose it is also important to know what variation in this absorbed radiation dose is acceptable. This variation in absorbed radiation dose in an irradiated material is quantified by the dose-uniformity ratio (U), giving the ratio between the maximum absorbed radiation dose and the minimum absorbed radiation dose in a specific irradiated material with a given source geometry. At a constant product density the dose-uniformity ratio will remain constant with a fixed irradiator geometry. In order to change the value of U to acceptable values, we have to modify the irradiator geometry for that specific product. In our simplified irradiator model the dose-uniformity ratio is given by the ratio between the radiation intensities $I_A$ and $I_B$ in Fig. 1. The ideal is to have a value of U as close to unity as possible, which implies that the absorbed radiation dose is homogeneously distributed throughout the target material. This, in turn, will lead to the most favourable utilisation of the radiant energy and process economics.

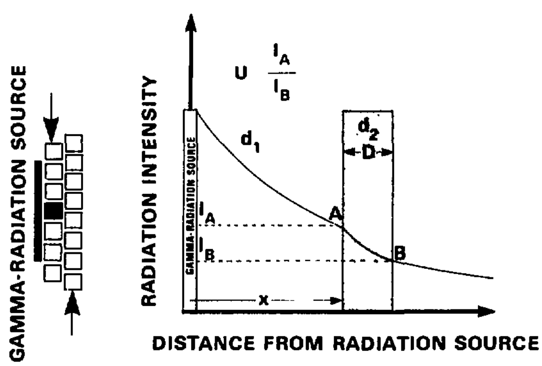


*Fig. 1*
*A simplified gamma-irradiator model*

To improve the economics of a specific radiation process, we thus always aim at designing the irradiator in such a way that U is as close to unity as possible, because this implies less overdosing and the closer we can remain to the specified minimum absorbed radiation dose, the better our process economics. In some cases it is imperative that a certain maximum absorbed radiation dose is not exceeded because of material stability towards radiation or because of regulatory restrictions. In such cases we are forced to lower values of U for reasons other than economics alone.

Let us have a brief look at the factors influencing the dose-uniformity ratio and their interdependence. The dose-uniformity ratio can be changed in a number of ways:

(a) By moving our target away from the radiation source to lower radiation-intensity levels, a pronounced decrease in U can be obtained. This method, however, has the disadvantage that it leads to a poor source-energy utilisation and process economics, because more radiant energy is absorbed in the space between the irradiator and the target.

(b) By reducing the thickness (D) of our target it is also possible to lower U. This implies that less product can be treated at a single irradiation position and we have to add additional rows of product carriers to improve the process economics. In practice this implies a more complex source-pass process which can affect the plant reliability. However, this technique to lower U is widely employed in modern industrial irradiators.

(c) By reducing the bulk density of our target material ($d_2$) a similar improvement in U may be obtained. In practice, however, the product density is fixed and only small variations around this value are possible.

(d) By turning our target through 180° after half of the absorbed radiation dose was administered, a pronounced improvement in U can be obtained. This method is employed in all large industrial gamma-irradiators by passing the product carrier along both sides of the source plaque in such a way that the side of the product carrier which is the closest to the source plaque at one side of the source, is the furthest away moving along the other side of the source plaque. It immediately follows that this method enables us to utilise the radiation emitted on both sides of the source plaque with the added economic benefits associated with this.

Another very important aspect of gamma-radiation processing is the fact that the radioactive cobalt-60 used as the radiation source emits radiation continuously and this process cannot be affected by external means. Although this contributes largely to the exceptionally good reliability of such irradiators, it also implies that, in order to obtain good process economics, gamma-irradiators should be used on a 24 h basis throughout the year. To reduce the labour component of running such irradiators and to enhance the process reliability, most of the current industrial irradiators can run automatically up to 24 h without any attendance. This necessitates the installation of elaborate and expensive product-handling equipment and the storage facilities for product which is processed when the plant is not manned.

## 3. FACTORS TO BE CONSIDERED IN GAMMA-IRRADIATOR DESIGN

It follows from the discussion in the previous paragraph that because of the interdependence of the various factors influencing the desired absorbed radiation dose and dose-uniformity ratio, an irradiator has to be designed with a specific process in mind in order to optimise the radiation-process economics. To determine the optimum gamma-irradiator design for a specific radiation process, the following parameters must be known by the irradiator designer:

(a) The size of the product carrier that has to be used. In some cases it may be necessary to deviate from the size of product carriers currently used for the product to be irradiated.

(b) The bulk-density of the product to be irradiated and the anticipated variation in this density.

(c) The highest acceptable dose-uniformity ratio for the specific process. In the case of certain irradiation processes the maximum and minimum absorbed radiation dose levels are laid down by law and are thus mandatory.

(d) The weekly and annual throughput anticipated as this will determine the required processing capacity of the irradiator to be designed.

(e) The nature of the product flow-pattern. If there is a big variation in the product flow, provision has to be made for certain production peaks to be handled. In this respect it has to be pointed out that such peaks in irradiator demands can lead to very poor process economics because of the inefficient use of the radiant energy.

(f) The anticipated annual growth in production and the anticipated maximum processing capacity of the irradiator.

(g) The storage facilities required for unattended operation of the irradiator and the plant operation with regard to shifts per day.

(h) The facilities required for the processing of the product apart from the radiation processing and how the irradiator will fit into an existing building and the production lines.

These parameters determine the design of the biological shield in which the irradiator is housed, the maximum mechanical speed required for the product conveyors, the capacity of the source rack in which the radioactive sources will be housed, the length of the external storage conveyors, and the labour requirements for handling the product.

It is probably appropriate at this point to sound a word of warning against the popular belief that "multi-purpose" irradiators can be employed to improve the utilisation of an irradiator and as a result the overall radiation process economics. Considering the fact that an irradiator is designed to specific radiation process parameters, it is clear that the radiation efficiency will suffer if a number of different radiation processes are attempted on the same irradiator. For research purposes such irradiators are obviously very valuable, but the author is unaware of any "multi-purpose" irradiator that is currently used successfully by private industry anywhere in the world. In many cases it has proved to be economically meaningful to erect a second dedicated irradiator next to an existing facility, possibly sharing one wall of the biological shield. In this regard it should also be mentioned that from a regulatory point of view certain radiation processes cannot be carried out by one irradiator, e.g. it is highly unlikely that a manufacturer of disposable medical products will be enthusiastic about having his product irradiated and stored at the same irradiation facility where potatoes are irradiated – for reasons that are obvious.

## 4. THE COST OF RADIATION PROCESSING

There are few aspects of gamma-radiation processing causing more controversy than the costs involved in using radiation in a specific process. Without any fear of contradiction it may be stated that ionising radiation is at present a very expensive form of energy and, accordingly, the economic benefits of introducing radiation as part of a production line should be carefully evaluated. However, the mere fact that radiation processing is used increasingly by private industries worldwide testifies to the economic advantages that can be realised by using this new technique.

As it is virtually impossible to cost a process without making certain assumptions, it was decided to cost the running of both a commercially available industrial irradiator and an open-pool irradiator for an irradiation dose of 5 kGy, a product density of 300 kg/m$^3$, a maximum dose-uniformity ratio of 1,4 and for running times of 7 000 h per year, the latter implying a total running time of 80 % of the year. The capital investment required for the installation of these two irradiators is given in Table 2 In calculating the processing costs for the two types of irradiators, the capital investment was amortised over 10 years at an annual interest rate of 11 % in the case of the mechanical components of the irradiators, whilst buildings were amortised at the same interest rate over 20 years. The cost of land was not included and no provision was made for the administrative costs involved in running the irradiators.

**TABLE 2**
**CAPITAL REQUIREMENTS FOR RADIATION PROCESSING**
**(Figures for July 1979 in South African Rand)**

| | AECL JS-8400 Irradiator | Open-Pool Irradiator |
|---|---|---|
| Irradiator and Associated Mechanical Equipment | 283 535 | 62 500 |
| Buildings | 69 672 | 18 255 |
| 100 kCi Cobalt-60 | 68 000 | 100 000 |
| Total | 421 207 | 180 755 |

In Fig. 2 the production capacities of the two irradiators as a function of the installed cobalt-60 is presented. An open-pool irradiator has a very poor energy utilisation compared with the industrial irradiator – for the same amount of installed cobalt-60 the latter can process about four times more product than the open-pool irradiator.

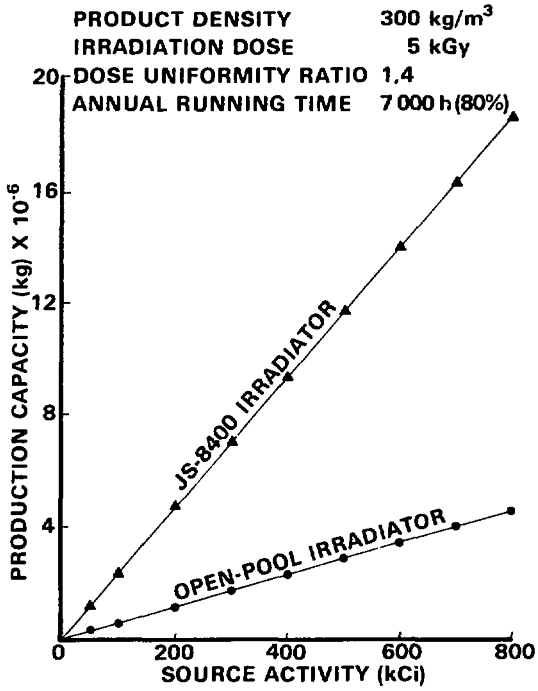


*Fig. 2*
*The production capacities of an open-pool irradiator and an industrial irradiator as a function of the amount of cobalt-60 installed*

The production costs for the radiation processing carried out under the conditions stated earlier are presented in Fig. 3 as a function of the installed cobalt-60 in the two types of irradiators. It clearly follows that the radiation processing costs per kg of product is much higher in the case of an open-pool irradiator than in the case of the industrial irradiator. This figure also demonstrates the effect of the processing capacity of an irradiator on the production costs – because of the capital-intensive nature of an irradiator, there is a marked drop in processing costs with an increase in product handled. This explains why pool irradiators are not popular in radiation processing, except in those cases where they are used because of technical considerations, e.g. in the manufacture of wood-polymer composites.

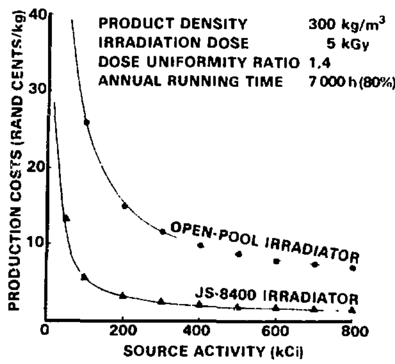


*Fig. 3*
*The production costs for an open-pool irradiator and an industrial irradiator as a function of the amount of cobalt-60 installed*

Although the capital required for an open-pool irradiator is only 43 % of that of an industrial irradiator (JS-8400 from AECL), the production costs are 465 % higher (at 200 kCi). The main reason for this, apart from the poorer radiation untilisation in the case of the pool irradiator, can be traced to the labour-intensive nature of a pool irradiator. In Fig. 4 we have analysed the operating costs of the two types of irradiators, and the high labour component in the case of the open-pool irradiator is clear. This can be traced to the fact that very little automation can be introduced in the case of a pool irradiator and it must be manned whenever running.

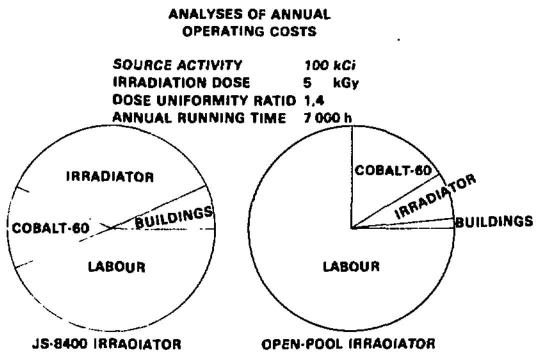


*Fig. 4*

*Analyses of annual operating costs for an open-pool irradiator and an industrial irradiator*

Another very important fact which follows from Fig. 4 is that the cost of cobalt-60 constitutes only 15 % of the overall operating costs. As the desired radiation dose is closely associated with the amount of cobalt-60 required, we notice that a change in the required radiation dose has a relatively unimportant influence on the radiation processing costs – reducing the radiation dose by a factor two will most definitely not halve the processing costs!

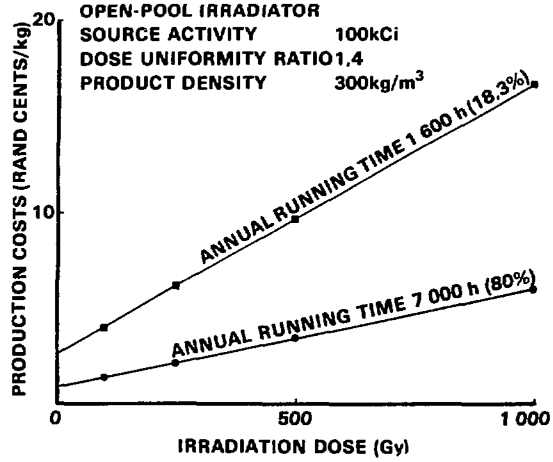


*Fig. 5*

*The production costs for an open-pool irradiator with an installed cobalt-60 activity of 100 kCi as a function of the irradiation dose at different annual running times*

As open-pool irradiators are currently used locally to irradiate relatively large consignments of various foodstuffs at absorbed radiation doses below 1 000 Gy, we have also calculated the processing costs for this type of irradiator with a cobalt-60 load of 100 kCi, a product density of 300 kg/m$^3$ and a dose-uniformity ratio not exceeding 1,4, as a function of the required absorbed radiation dose. These results are presented in Fig. 5 for annual running times of both 1 600 h and 7 000 h. We again notice that the utilisation of the irradiator has a pronounced effect on the production costs.

## 5. CONCLUSION

Although gamma-radiation processing is still in its infancy on the time scale of industrial utilisation of new techniques, there can be little doubt that its time has arrived and if the radiation technologist bases his enthusiasm on sound economics a bright future for radiation processing lies ahead of us.

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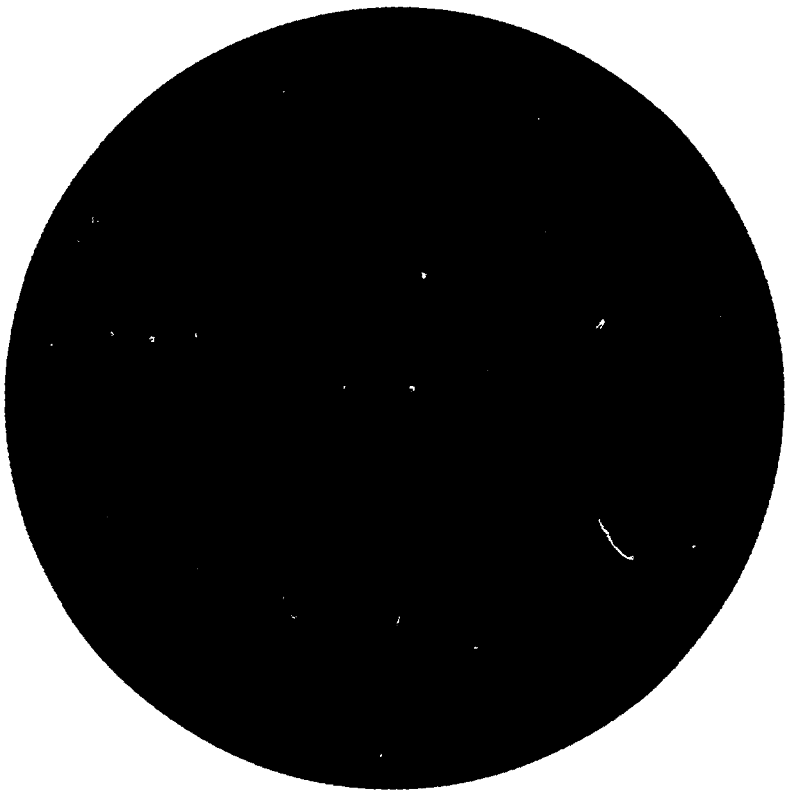

# THE OPERATION OF A PILOT-PLANT POOL FACILITY

R E LUNT
*Letaba Cooperative, Tzaneen*

## SAMEVATTING

Resultate van navorsing wat op Pelindaba en deur die Navorsingsinstituut vir Sitrus en Subtropiese Vrugte te Nelspruit uitgevoer is, het aangedui dat dit uit 'n tegnologiese oogpunt moontlik is om kommersiële bestraling van subtropiese vrugte soos mango's, papajas en waarskynlik ook avokado's en lietsjies uit te voer. Vir hierdie doel is 'n poeltipe gammabestraler in Februarie 1977 in Tzaneen geopen.

Die basiese doelwit van die aanvooraanleg was om die praktiese uitvoerbaarheid van die toekomstige kommersialisering van bestraalde produkte te bepaal. Aandag sal aan die volgende belangrike aspekte geskenk word:

die geskikste plek vir die oprigting van so 'n aanleg; die doeltreffendheid van 'n poeltipe bestraler en veral die gebruik daarvan vir verskeie kommoditeite asook die ekonomiese voordele wat daaruit spruit; die verskillende probleme wat tydens bedryf mag opduik wat onderhoud en toesig betref, asook praktiese probleme rakende dosismeting in 'n lotproses; herorganisasie van die algemene na-oeshantering van produkte om vir bestraling voorsiening te maak; en verbruikersreaksie ten opsigte van bestraalde produkte.

Die doel van hierdie referaat is om sekere riglyne neer te lê en om spesifieke probleme in die bedryf van 'n poeltipeaanleg uit te lig.

## ABSTRACT

The results of research conducted at Pelindaba and at the Citrus and Subtropical Fruit Research Institute at Nelspruit have indicated that from a technological point of view it should be possible to undertake the commercial irradiation of subtropical fruits including mangoes, papayas and possibly avocados and litchis. With this in mind, an open-pool gamma irradiator was opened at Tzaneen in February 1977.

The basic objective of this pilot-plant facility was to determine practical factors involved in the future commercialisation of irradiated products. Important points warranting further consideration were: the correct siting of the facility; the effectiveness of the pool-type irradiator for certain specific applications for various commodities and the economic benefits that could be derived; the various problems which may arise in the operation and maintenance of such a plant, as well as the practical problems with regard to dosimetry for batch operation; organisational aspects involved in the incorporation of irradiation into the standard post-harvest operation for various products from harvest up to the point of sale; and consumer reaction to irradiated products.

The purpose of this paper is to present certain guidelines and to highlight specific problems relating to the operation of an open-pool facility.

## 1. INTRODUCTION

The results of research conducted at Pelindaba and at the Citrus and Subtropical Fruit Research Institute at Nelspruit have previously indicated that from a technological point of view it should be possible to undertake the commercial irradiation of subtropical fruits including mangoes, papayas, and possibly avocados and litchis.

With this in mind, an open-pool gamma irradiator was opened at our premises in Tzaneen in February 1977. This was a joint venture of both the AEB and the Letaba Cooperative.

The basic objective of this pilot-plant facility was to determine and evaluate practical factors involved in the future commercialisation of irradiated products.

The important points warranting consideration were:

(a) The correct siting of such a facility.

(b) Identification and evaluation of problems which might arise in the operation, maintenance and monitoring of such a plant.

(c) Organisational aspects.

(d) The effectiveness of a pool-type irradiator for specific applications.

(e) Testing consumer reaction to Radura products.

In the preceding papers we have had in-depth discussions on techno-economic aspects, the local marketing campaign and consumer-response studies. I feel, therefore, that this paper should, rather, reflect the 'trouble-shooting' aspects of the pilot-plant operation, thereby highlighting a few aspects of the pool-type irradiator that warrant consideration, should one wish to erect such a plant.

## 2. THE CORRECT SITING OF THE FACILITY

There are many practical, economic and convenience factors that will ultimately determine the site for specific plants.

As far as subtropical fruits are concerned, the effect of both hot-water dipping and subsequent irradiation in the control of plant micro-organisms has already been established, and furthermore, the best results were obtained with a minimum delay between harvest and treatment. A further consideration in deciding on the siting of our plant was the knowledge that subtropical fruits are very sensitive to handling and transport damage, except when packed in a marketing package specially designed for the fruit. Although the irradiation process can and does take place in the final packaged form, the treatment with hot water definitely does not. The fact that the installation required for the hot-water treatment is not normally available on farms and also that it is expensive to construct, were further considerations in favour of siting the facility in the proximity of the major production area. Further aspects such as returning empty transport containers to the growers added weight to the decision.

For products such as onions, potatoes and garlic which are irradiated only and where the time from harvesting to treatment is not that critical, siting can be viewed in a totally different light. Maximum utilisation of the plant would be the deciding factor with these commodities, and a plant could best be sited at a major terminal such as a municipal market where a continuous flow of produce which are not seasonally bound, could be expected.

Large concerns, for example in the poultry industry, could site a plant at their own production centre, purely for their own use.

## 3. OPERATION OF THE PLANT (Fig. 1)

followed by final irradiation;
(v) removing the products from the containers for despatch.

(b) Maintenance is at a minimum; only door seals which do degenerate with continuous irradiation have to be replaced regularly.

(c) Cleaning the pool water, however, is a problem. As a safeguard against the total emptying of the pool, circulation of water is from the top of the pool with the return at the bottom; this, however, is ineffective in agitating heavier particles of dust over the depth of the pool (6 m) and consequently, deposits have settled against the walls and floor of the pool.

(d) Vacuum-cleaning of the pool under supervision on a regular basis will have to be considered for pools in areas where a high level of particle contaminants is present.

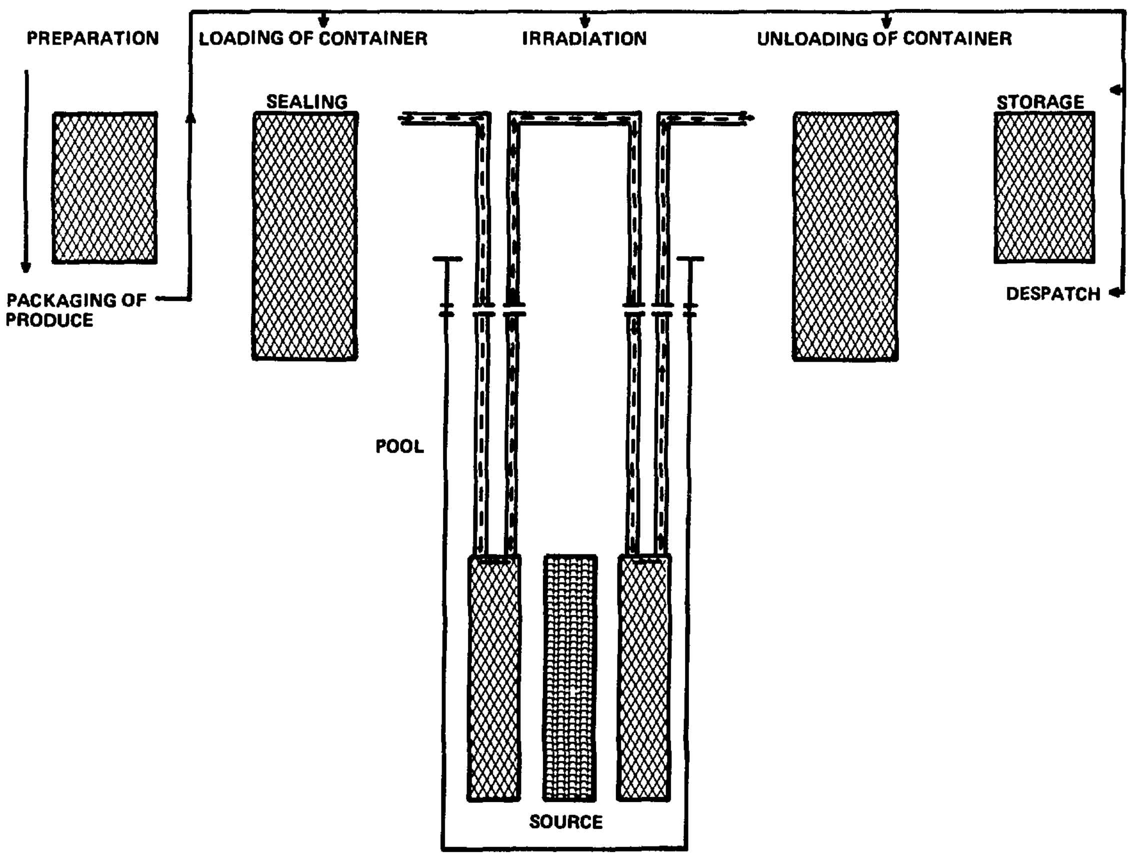


*Figure 1*
*Schematic representation of the operation of a pool facility*

(a) The actual operation is obviously very straightforward and consists basically of the following activities:

(i) filling the containers with the prepared packed produce;
(ii) sealing the doors of the containers and placing them at the poolside;
(iii) submerging the containers for half of the treatment time;
(iv) raising, rotating or transferring the containers

(e) Dosimetry under, for instance, semi-commercial conditions, warrants considerable thought, as the present method and spectrophotometric evaluation of the ferri-ferro sulphate solution, although accurate in itself, poses some problems. Before being submerged each container is fitted with two small glass containers with reagent, coded in the same way as the specific batch. These cells are positioned in such a way that they receive the maximum and minimum doses in the specific source-container arrangements. These are afterwards evaluated to determine the dose received by the batch in question.

In an analysis of our results, the following have emerged:

(i) Time involved

With an average daily production of around 15 and more containers, some 30 analyses have to be done. The current dosimeter (super Fricke solution)[1] requires accurate dilution prior to spectrophotometric analysis. Suffice it to say that this is time-consuming. In addition, variations in doses occur which can be related to the chance placement of the cell in a void position with respect to the product content, or conversely, in front of a solid mass of product. As a result, one is inclined to treat variations in results with less respect than they deserve.

(ii) Objectives of dosimetry

Under semi-commercial conditions the purpose of dosimetry would be to establish beyond any doubt that the operator is treating the products within the limits of dose requirements, from both a regulatory as well as effectivity point of view. An efficient checking system is required; under these circumstances it is not the purpose to gather scientific data.

This is neither the time nor the place for further speculation on dosimetry methods, but let it be fully understood that I consider the continuous and accurate monitoring of a pool-type plant to be vitally important.

## 4. ORGANISATIONAL ASPECTS

One must accept the fact that the advantages to be gained from irradiation are for the benefit of the wholesalers, distributors and retailers of perishable fruits, and therefore organisational aspects extend, in my opinion, only as far as these concerns.

Two phases can be distinguished in this respect:

(a) from the producer to the irradiation facility; and

(b) from this facility, after irradiation, to the distributors and retailers.

Although there were many factors involved in the various problems that arose, I would like to highlight some of the aspects that could generally be expected, while bearing in mind that each commodity has its own set of pet problems.

(a) One of the first minor hurdles to be overcome was what we called the "Miracle-cure Syndrome" with respect to the growers. They all too easily believed that irradiation would turn third-grade fruit into first-grade fruit.

(b) Because of retardation of senescence, fruit could be harvested in a much more mature condition and, as a matter of fact, this had to be done in certain instances. Otherwise the fruit would not ripen at all, especially when a colder winter climate is experienced.

(c) The more mature fruit, however, demanded more sophisticated handling because of their susceptibility to post-harvest handling damage (which increases with maturity). It was therefore necessary to set maturity standards for the harvesting of the various commodities. Continued research is necessary to solve this problem.

(d) Time, as such, is another important factor to be considered. In the case of garlic where, for effective control of sprouting (for obvious marketing benefits) the garlic has to be treated with as little delay as possible after harvesting. In a plant, hard-pressed to handle 4 t of this product every 24 h, it is of paramount importance to have both the cooperation of the growers and a well-planned and coordinated flow of produce to the plant.

From an organisational point of view, the phase from the irradiator to the distributors and retailers posed its own problems.

(a) Firstly, far more effective communication had to be maintained specifically at pilot-plant production level with distribution and sales outlets, in order to advance consumer predictions, especially in the initial promotion stages where the overflow of treated fruit was not put on the normal markets.

(b) Secondly, the state of ripeness required by sales outlets at any given time had to be well coordinated with due regard to the accompanying delay between the sales outlet and the producer's orchard.

## 5. EFFECTIVENESS OF A POOL-TYPE IRRADIATOR FOR TREATMENT OF VARIOUS COMMODITIES

The following findings are based on our experience with a fully manual facility designed for general pilot-plant application to a range of possible products. Obviously, for "tailor-made" automatic plants some observations are not applicable. In our experience, a time-utilisation-based problem, relating to commodities requiring high- and low-dose treatments in the same plant, emerged.

Our plant consists of the pool and source with four submersible water-tight containers, one overhead gantry with an electric hoist, and a $^{60}Co$ source of approximately 50 kCi delivering an average dose rate of about 0,65 kGy/h, housed in a building with a single entrance and exit, and, as stated, completely manually operated. We are, therefore, limited to a batch-type operation. The preparation time concerns the filling of the containers, the sealing of the doors and the placing of the containers at the poolside. Optimum use of this plant is achieved when the preparation period is approximately equal to the halved dose time. Obviously, if the irradiation time is longer than the preparation time, one is still making maximum use of the given source. When half of the irradiation time is less than the preparation period the answer is obvious.

The specific design of the submersible containers is an important consideration. The containers should be designed to effectively accommodate the standard package for the specific or various commodities submitted for treatment. There are many solutions to the problem of maximum volumetric use of the container, and these should be borne in mind when designing a new plant.

p22p4

| | PRODUCT | PRODUCTION PER 10 h (kg) | TOTAL IRRADIATION TIME (min) |
|---|---|---|---|
| A | Papaya<br>Mango | 800<br>1 000 | 68<br>68 |
| B | Garlic<br>Potato | 2 000<br>2 000 | 11<br>17 |

*Figure 2*
*Production figures for Letaba facility*

Group A Although effective use was made of the available source, the high dose levels (for the given source strength) result in reduced mass of treated product. The 20 % reduction in the production of papayas, stems from the fact that the package design does not suit the internal dimensions of the container as effectively as does the mango package, both receiving the same dose.

Group B Although the irradiation time is one-fifth of that of the A group, production is only double the above as the preparation time, in this case, is longer than the half dose time for the same source and optimum use is, therefore, not made of the available source.

The physical act of packing the product into the container and the handling of the containers which includes the sealing of the doors leave much room for improvement. Such improvements have been incorporated by the AEB in its new pool facility. A pool-type plant may be effective for the treatment of certain commodities, in cases where large amounts of the end product are not a prerequisite, such as a high-value product that could absorb a higher irradiation cost. Furthermore, mono-product or similar dose commodities may be advantageously treated in this type of plant.

An all-year-round utilisation of the plant is another important factor in the consideration of the effectiveness of a pool plant.

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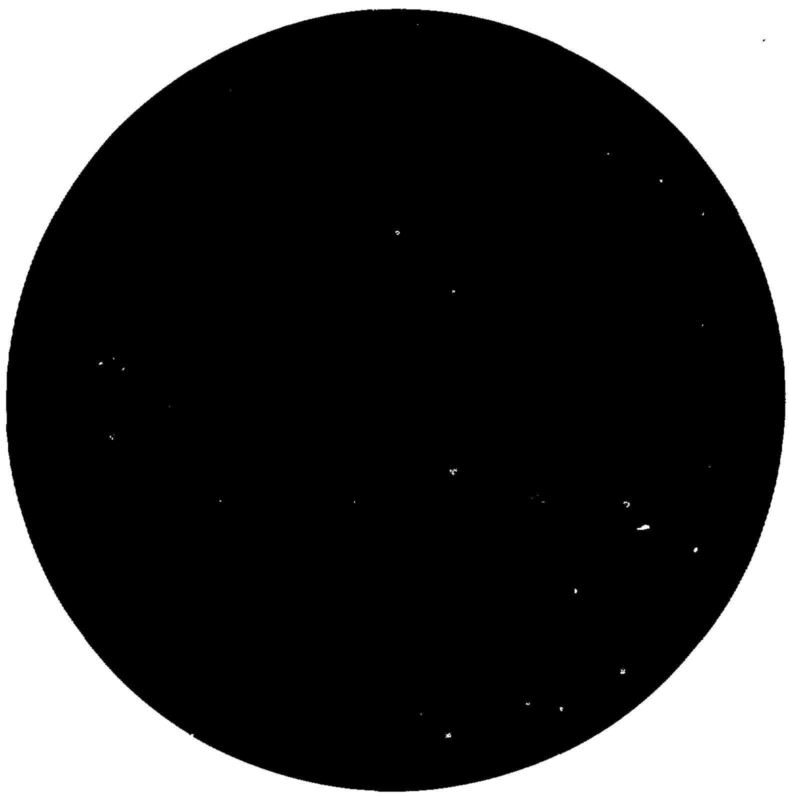
## PANEL DISCUSSION

**CHAIRMAN: DR P S ELIAS**

*International Food Irradiation Project,*
*Karlsruhe, Federal Republic of Germany*



# PANEL DISCUSSION

P S Elias – *Wholesomeness aspects;* P N Swanepoel – *Health and legal aspects;* W J de Wet – *Precommercial phase and radiation facilities;* J H Grobler – *Fruits;* H J van der Linde – *Miscellaneous commodities.*

**Dr P S ELIAS** *(IFIP, Federal Republic of Germany)*

In this panel discussion we will try to bring together the main points discussed during the Symposium.

My allocated area for this discussion is the wholesomeness aspects of irradiated food. There are three points to consider:

(a) nutritional aspects
(b) microbiological aspects and
(c) toxicological aspects.

The nutritional quality of irradiated food shows no significant changes at doses less than 10 kGy. In cases of vitamins which are sensitive to irradiation (e.g. vitamin E) these can be replaced. So, replacement of lost vitamins is the only point which we must bear in mind.

In relation to microbiology, irradiation is very effective in cleaning up the microbiological problems in food. This can have tremendous public-health significance, especially in the case of pathogens such as *Salmonella*.

On the toxicological side, all the large numbers of animal tests that have been done on a very wide variety of foods over the past 25 years, many of them long-term, have not shown any significant adverse effects. In particular, what we are looking for is the evidence of cancer production or mutagenicity – none of this has been observed. For this reason, the 1976 Joint Expert Committee approved five commodities as being totally wholesome after irradiation. Provisional clearance is a hedge that is always used by any committee because they say that we cannot predict what the full results are going to be, so they cannot give a full clearance, but a provisional one. If they had though that the ongoing studies would come out with something bad, they wouldn't have given a provisional clearance for these commodities. The fact that they refused to look at mushrooms is not that they thought that irradiated mushrooms are going to be poisonous or toxic. The consideration in this case was the comparison of the data available for assessment with the quality of the data available for other commodities. And this is a problem that is facing us all the time in toxicology. The data obtained 10 years ago are not as good as those obtained by the most recent protocol and one cannot really ask people every 10 years to re-do the data they have done because 10 years ago one used a slightly less elaborate protocol. If you remember that a long-term study today would extend to almost 5 years and that the cost would be about ten times more, it would be an unbearable burden to request this. For this reason we have ceased demanding long-term animal testing of irradiated material. We do want some animal tests and screening for subchronic effects, screening for one generation for very obvious toxicity (something that one probably couldn't predict), and if it comes out clean, we can use the short-term test for picking up carcinogicity or mutagenicity. In this way we can assure the national authorities that radiation has not introduced anything into the food which is dangerous from the point of view of wholesomeness.

I would further like to remind you briefly of the treatment of commodities in which microbial spoilage frequently occurs. Dried and fresh fish: where these commodities have been treated by irradiation the results indicate that the shelf life can be prolonged and the microbiological spoilage reduced. This procedure could be usefully considered in these particular circumstances. Meat and poultry: The American efforts in this regard are concerned with sterilisation rather than radurisation, the latter which is merely a form of reducing microbial spoilage and getting rid of the pathogens. In the case of poultry, this is a very obvious advantage and is something to consider, particularly because it is now an accepted procedure in the Netherlands and similarly over here (South Africa).

**DR P N SWANEPOEL** *(Departement of Health, Pretoria)*

We have, in this country, recognised irradiation as a process. To control this process, we put a total prohibition, unless it is approved by the Minister, which gives the Department of Health the total control over the irradiation of food products. Even in the case of isotopes, which are controlled by the Atomic Energy Board, we have the full right to prescribe the necessary procedures required by us for that unit and to carry out inspections of the facilities. For example, in the case of a linear accelerator, the total construction and licensing will be in the hands of the Department of Health. This does not present any difficulties because the necessary know-how exists in the Department. We also want to ensure that the consumer is given all possible information on the product. We have accepted the Radura emblem as an indication that the product has been irradiated. Regarding the requirements at the facility itself, the Minister has framed quite a number of good regulations very close to the Codex Alimentarius' requirements. It is self-explanatory that all foodstuffs must comply with all the other aspects of the Foodstuffs Act, i.e. the hygiene, handling, transportation, etc., as well as the fact that containers must not introduce anything into the foodstuffs. It has to comply with all the normal foodstuff regulations and inferior products cannot in any way be submitted.

**DR W J DE WET** *(Atomic Energy Board, Pretoira)*

Although a great deal has been said about the pre-commercial marketing investigation, I would nevertheless like to add a few more points. Apart from the accurate proof of the safety of irradiated foods, two other important aspects or prerequisites should precede the full commercialisation:

(a) It should be ascertained beyond doubt whether there is any inherent consumer dislike towards irradiated foods. From results obtained so far, this does not seem to present any serious problems at all.

(b) It must be established that consumers are generally convinced and through their favourable disposition about that (also the food industry), that specific consumer benefits, such as better average quality and improved keeping quality brought about by the irradiation treatment are rated substantial enough to prompt consumers to buy such products. Results discussed this morning by Dr Brodrick support this point and the outcome of our investigations have been rather positive seeing that 90 % of the customers confirmed that they are convinced about improved quality and keeping quality for the four commodities marketed so far.

(c) The technological research and development results obtained in the laboratories should be tested as thoroughly as possible over an adequate period of time in practice to discover any unforseen technological hitches. This also involves compatibility of the technology with existing practices, from harvesting to retailing, as well as to the optimisation of agro-technical factors related to the production or supply of products.

(d) Increasing emphasis should further be placed on a better definition of benefits in each particular case, whether that be related to consumer benefits or to commercial or national benefits. In this regard, reduced losses, broader markets (both local and export) are considered very important.

(e) Further consideration should be given to simulated storage and shipping experiments as well as to actual trial shipments, all followed by expert evaluations. Ideally, in the future interest of the technology, multi-lateral marketing investigations under the supervision of an international non-governmental agency are certainly most desirable. Indications are that such developments may take place in the near future in Europe specifically, in which South Africa has also been invited to participate.

(f) Several commodities should be used to create sufficient impact, interest and confidence in the marketing of irradiated products. It is important to note that in Europe most of the countries have clearances only for onions and potatoes, whereas seven products have been unconditionally cleared in South Africa. South Africa can make a contribution to the European effort and *vice versa*.

(g) A further point is the question of quality. Although only top quality produce would obviously be preferred, it must be remembered that this technology can be viable only if a wide market can be established for irradiated produce, which would entail a large volume to support a considerable capital outlay.

(h) To obtain further substantiation of results already obtained, the present marketing investigation started in this country should be continued until about 1981 at the expanded level at present being considered. In the light of the decisions taken by the 1980 expert committee, further promotional steps may follow, e.g. the supply of a limited irradiation service at a reasonable fee to interested parties. Assistance regarding technology transfer will locally remain one of our duties, including benefit-to-cost analyses, studies in collaboration with the private sector, and advice on technical and operational aspects of irradiation facilities.

**DR J H GROBLER** *(Citrus and Subtropical Fruit Research Institute, Nelspruit)*

The production of fruit in South Africa is rising rapidly and the export of fruit to countries overseas is also expanding at a terrific rate. For example, 1,73 million cases of avocados were exported last year, against 2,27 million cases this year, i.e. an increase of more than 30 %. One of the main problems, especially with subtropical fruits, is the inherent perishability of the fruits.

Their susceptibility to cold damage during cold-temperature transport complicates this matter further. Most of these fruits cannot be transported at very low temperatures but at temperatures of about 7 °C with the result that they ripen and perish faster. The main point is to get these fruits to the consumer in a condition acceptable to him. There are many ways of doing this. There are many chemicals which could be used, but these are going out of fashion and we should be looking at other ways of doing it. One of the new methods coming to the foreground is the irradiation of fruit. It must be realised that irradiation will not improve the fruit, but will merely keep it in the condition that it was at the time of picking. Our aim should be to get the fruit in that condition to the consumer.

The results for export and internal fruit so far obtained at the Letaba pilot plant, are most encouraging. We can hope that in future, with more experience and more experimental work, we will have a method of sending fruit to arrive at distant markets in an acceptable condition.

**DR H J VAN DER LINDE** *(Atomic Energy Board, Pretoria)*

I would like to emphasise the necessity to expand the precommercial phase. Our results, so far, indicate that we need more information on public acceptance and more information on the products which show the best benefit by irradiation treatment. For that purpose the trials should be expanded to make large enough quantities available in order to obtain true average values of results throughout the country and not only in a certain part e.g. the Witwatersrand area, as has so far been the case. To do this, it is very important to have a committee to coordinate these trials. This committee should include members from the retailers and pre-packers. These people should be afforded protection by this committee. Minimum quality requirements, which are also realistic, must also be determined. Irradiation has a role to play as far as the average-quality food is concerned. However, it is impossible at this stage, where two commodities are being sold at the same time, viz. Radura products and non-irradiated products, to show the benefits and convince the consumer to buy the irradiated products, unless the quality is better. According to the Codex Alimentarius Commission, all irradiated foods have to be labelled. This means that we are putting a label on something which is safe, which is actually ridiculous. The suggested committee should of course include people connected with the advertising field as well as public-relations experts.

**Question:** It appears that it is impractical to irradiate fish at sea and there will be some delay in getting the fish ashore (which could be up to eight days) and we would expect a further two to five days shelf life. Would it be possible to irradiate the fish at that stage, and what sort of extended shelf life might be expected from it?

**Dr P S Elias:** If fish is irradiated after having been on ice on the ships for eight days one will probably reduce the microbial contamination quite considerably so that there would be a further extension of about seven or eight days that will bring it up to fifteen days which is considered possible either with crushed ice or with irradiation at that stage. The only thing that you might improve is the actual microbial quality of the material as it is unloaded. Then there is the long transport between the port and the fish markets. So we have a bit of a problem in getting the fish in a good condition to the retail outlets. In the German experiments use was made of an X-ray irradiation source which was the only one they could accommodate on the ship and that is not particularly suitable for treating the catch in the proper manner. Therefore, their unsatisfactory results were probably as a result of the poor facility.

**Comment by Mr C P N Webb** (OK Bazaars, Johannesburg). I believe that it is every grower's intention to grow good quality fruits. He necessarily tries to harvest at the correct time to ensure this optimum quality. It must be realised that a product which is diseased or overripe should not be offered for irradiation.

**Dr P S Elias:** This is in fact a point raised by Dr van der Linde. He suggested a committee to set the standards of food to be irradiated.

**Dr W J de Wet:** One must realise that, for economical reasons, the throughput at a facility is also important and the cut-off point for the acceptability of a product must be clearly defined. There are obviously a number of parameters which will determine the cut-off point, and these will need further attention.

**Comment by Dr L Milne** (Department of Agricultural Technical Services, Nelspruit). I agree with Dr van der Linde about having a committee which has representation from some marketing authorities. I was interested to hear about the amount of fruit which had been radurised and marketed in South Africa, but I had not seen much publicity regarding this matter. I feel that it is important not to run into a problem, as has happened in Japan, that people have only discovered a couple of years after something has been introduced that it is there, and now they start kicking up a fuss, because the total public has'nt been informed. I don't think that it is sufficient to inform a buyer at a chain store, but the total public must be properly informed if food of this nature is released.

**Comment by Dr J W L de Villiers** (President: Atomic Energy Board, Pretoria). Once irradiation of food is applied on a large scale, first, second and third grade items which have all been irradiated, will probably be on sale to the public who would then chose for themselves. With regard to the information campaign, the AEB together with ATS have done a very good job of this last year. The irradiation process was introduced on television and all the local media were extensively involved. Most people in South Africa know about this process. We only have to keep on getting through to the public. The problems about quality should be sorted out once the process is operating on a large scale.

**Question:** Is the dosimeter the only means to check the dose applied and is one check sufficient?

**Dr W J de Wet:** According to the general standards on food irradiation each batch should carry a dosimeter. In a continuous plant this would not be necessary in every package. It is sufficient to have two or three dosimeters among 20 or 30 boxes and then to have an irradiation indicator on each box to verify that it has passed through the field. In a batch operation where each batch must be checked for dose received, time monitoring may in some cases be considered as being sufficient. Whether this is acceptable is still open to question.

**Dr P N Swanepoel:** The International Atomic Energy Agency has recently published a book on dosimetry in food irradiation which should set the guidelines in this field in future.

**Question:** Is the ripening of the fruit affected by the irradiation dose, does it slow it down, does it alter it, or does it stop it from ripening?

**Dr H J van der Linde:** Radiation does interfere with the enzymatic process and it does slow down the ripening process. The ripening of mangoes and papayas can present problems — if the fruit is irradiated at a very green stage, it will compare unfavourably with an unirradiated fruit at the proper stage of ripeness, when these are displayed together in a retail outlet. There are many factors besides irradiation which affect the ripening rate. I am therefore wary of referring to the shelf-life extension (which is a rather ambigious term), and would rather define it in terms of transport life, distribution life and display life.

**Comment by Dr L Milne.** There will be various stages of ripeness during a normal packhouse procedure, picking of single trees, picking of trees that have been at different stages of ripeness, simply due to normal farming practice. For any box of mangoes there could be a variability of ripeness. While the irradiation process may slow down the ripening more at one stage than another, this will not necessarily extend the range of ripeness which will occur in any one consignment significantly.

**Dr P S Elias:** When was permission granted for the sale of irradiated papayas in South Africa and who actually made the original submission to the Department? This may be important, for instance for the UK. If someone in the UK wants to market the imported food, whoever it is, he will have to make a submission to the UK authorities to get the clearance. Should the importer do it, or should someone from South Africa ask for clearance to market the product in the UK?

**Dr P N Swanepoel:** The AEB applied to the Minister of Health for the clearance of and permission to market irradiated papayas. They submitted the protocol to the Department together with all the data obtained at the Letaba Pilot Plant and the facilities at the AEB. The necessary information was supplied, e.g. dose, source, source strength as well as toxicological information.

**Dr P S Elias:** In the USA the application to the FDA was submitted by the facility that carried out the irradiation. In the UK it would probably not be the Atomic Energy authority who would make the application to the Department of Health, but it could very well be a private irradiation concern who would apply to the Department of Health for clearance by the committee of a product they wish to irradiate. Or, perhaps the person who would wish to market or import irradiated onions from, say, France, would have to go to the UK authorities.

**Comment by Dr J W L de Villiers.** We have to distinguish between two things. In South Africa we don't import food and the process of irradiation cannot really be done by anyone else but the AEB. It is very obvious that the AEB had to apply for permission at this stage. However, any private concern who wants to erect a plant, will have to satisfy the Department of Health that the plant will be operated in the correct way, and that the products will receive the prescribed dose. One cannot expect the packer, producer or distributor to apply for clearance for that commodity. We have taken the attitude that the AEB has the knowledge of the process and is doing the experiments to get the commodity cleared. It is up to the operator of the facility to convince the health authorities that the operation is done within those bounds.

Dr **P S Elias:** In the UK, materials which have not been cleared by the FDA, would not even be unloaded. This also applies to other EEC members. There may well be a problem with cacao beans. It is a commodity which has been put to the project by one of our members, Ghana, who is a large exporter of cacao beans. This country suffers such losses from infestation and from moulding that it wishes to irradiate its cacao beans before exporting them. Ghana will be forced, purely by the economics of the situation, to do this to reduce the losses which currently amount to 40 to 50 %. We don't grow cacao beans and one cannot, under the present community legislation, make chocolate without using some real cacao powder. As and when irradiated cacao beans arrive in the UK, the committee will have to deal with the situation. If the evidence is reasonable, and they refuse clearance, they will upset a great many people in the Commonwealth and they will do a great deal of harm to our chocolate industry. This is an example of the situation where the developing countries have recognised that they must use this process and the developed countries will have to take a stand.

**Question:** We have heard about the advantages of irradiation, but are there any specific disadvantages?

**Dr W J de** Wet: There are not any disadvantages *per se*. The extra cost is perhaps a disadvantage but certain benefits should be induced by irradiation. There are certainly limitations. A particular limitation is the fact that a maximum irradiation dose exists for a product, above which it becomes unacceptable organoleptically. In such cases one can employ combination treatments. In the case of potatoes, a limitation in the form of a reconditioning period before irradiation must be allowed for, so that any physical damage can heal before treatment. This requires a conditioning period of two weeks at a specific humidity and temperature.

**Question:** Certain forms of preservation, e.g. cured ham or bacon, are not bought because of the longer shelf life but because of the specific taste; canned fruit is often preferred to certain raw fruits. Has any improvement in taste been found as a result of irradiation?

**Dr W J de Wet:** Irradiation is virtually the only mild type of treatment that one can give to fresh produce without seriously affecting the natural qualities, and at the same time extending its keeping quality. I do not think that any preservation method can really improve the taste quality of fresh produce.

**Question:** What expertise is needed to run an irradiation facility e.g. engineers, physicists, microbiologists, etc.?

**Dr H J van der Linde:** A fully automated plant is much more sophisticated than the open-pool pilot plant. It is simple to operate and the maintainance is very low. In fact the plant can form part of an existing food processing line. The Department of Health would probably have to define the requirements of personnel.

**Comment by Dr T A du Plessis** (Atomic Energy Board, Pretoria). The operation of an irradiator can be compared with the manufacturing of, say, aspirin. The Department of Health will never allow a company to manufacture aspirins without a fully qualified professional pharmacist on site. The type of damage that can happen in a sterilisation plant warrants the same type of supervision (if not more! ). People with not only the right training, but with sufficient experience, are needed, especially when things go wrong with the irradiator.

**Comment by Mr C P N Webb.** We fail to remember, it seems, that there are commercial irradiation plants working very successfully in various parts of the world.

**Dr P S Elias:** It is absolutely essential that technical and engineering personnel should always be on duty. I can recall an example where the source got stuck and wouldn't go back into where it should. It took about a week before the engineers managed to get the source out of the housing so that it would be safe to enter the cell. The mechanics of the irradiator can occasionally go wrong, and skilled personnel are necessary in such cases.

Thank you for your lively participation!

# CLOSING REMARKS

**DR J W L DE VILLIERS**
*President: Atomic Energy Board, Pretoria*

It is my pleasant duty to thank everybody who has participated in this Symposium. Unfortunately, I couldn't be here all the time but from what I've heard it is clear that the Symposium was very successful. It gives me great pleasure to thank especially Dr Elias for his contribution to this Symposium. I don't know whether you realise the effort that Dr Elias puts into this whole project, and we should thank him not only for his participation in this Symposium, but also for the excellent work that he is doing for the world community as a whole in getting this process accepted generally by all countries. Without his efforts, there would have been very little chance of success. He has also helped South Africa, specifically in our program e.g. in getting the mango feeding studies (conducted in the USA) accepted by the International Project. The use of irradiation in preserving the fruit and the extention of shelf life might be of some advantage to the devèloping countries, most of them who are situated around the equator in hot climates. Dr Elias has also helped us in obtaining the information to get clearances from the Department of Health in South Africa. Dr Elias's help has been indispensible in getting the project to the stage now when in 1980/81 the Joint Expert Committee will meet to decide whether to clear this process up to 10 kGy. This has been one of the major objectives of the International Project and if successful, this should open the way towards international trade in irradiated products.

I would also like to mention that besides the Atomic Energy Board, the Department of Agricultural Technical Services (ATS) is also heavily involved in food irradiation in South Africa. In this regard I would like to thank Dr Immelman (Secretary for ATS), as well as Dr Stydom (Chief Director, Horticulture, of ATS) for their interest and support. We have had excellent cooperation with ATS, as well as with other Departments such as the Department of Agricultural Economics and Marketing and the Department of Commerce and Consumer Affairs, who all serve on an Advisory Committee on this subject.

As far as the South African irradiation program is concerned, we have only really touched the surface and I believe that this Symposium is just an introduction to things that will happen in this country, and perhaps in future we will have even larger and better symposia than this one. Our program has just started, so to speak, to bear fruit.

I would also like to thank the Nelspruit, Stellenbosch and Roodeplaat Institutes for their collaboration, support and the efforts put into this program. The Atomic Energy Board also has committees who are involved in this; in view of the new committee proposed earlier by Dr van der Linde, I would like to suggest that these committees be limited in number.

Last but not least, I would like to mention Dr Boyazoglu, the representative of South Africa on the Board of Management of the International Project. Thank you very much for your effort on our behalf.

And, of course, the Department of Health. They have been very helpful without taking any chances at all.

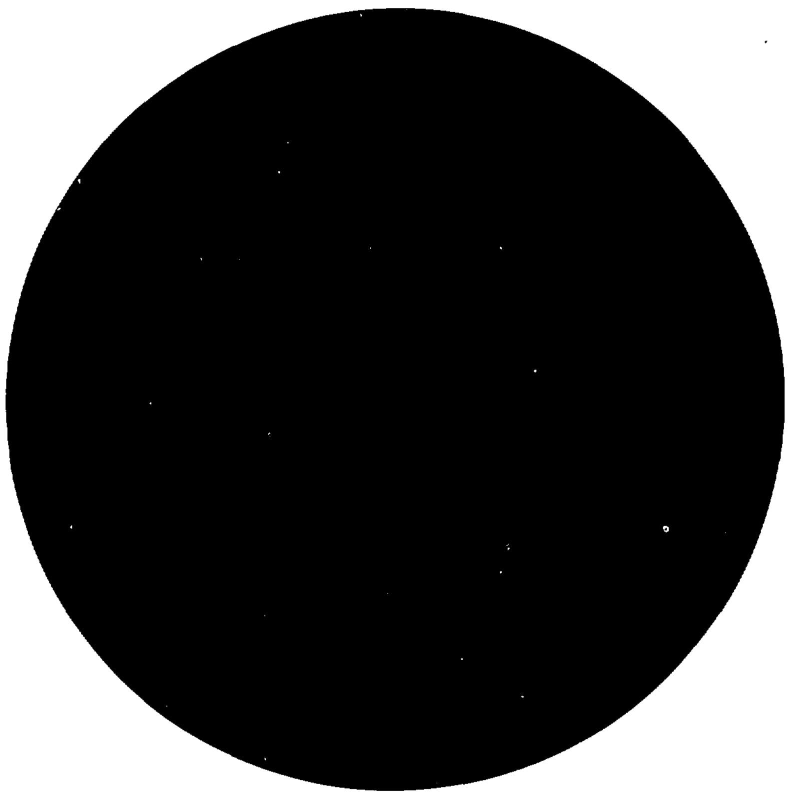
In our marketing of fresh irradiated produce, we have learned a lot about quality aspects. I would like to emphasise that we have just started this marketing and evaluation campaign, and the questions that we are so concerned about today will probably disappear once the process has reached a commercial scale. There is, of course, the question of labelling. Our label is of some value, at least at this stage, for the testing of consumer response. I am reminded of an incident concerning a company on the west coast of America, which was involved in the canning of salmon. The salmon was pink, as is normally the case with salmon in cans. Another company produced salmon which was not pink, and they experienced problems in selling their product. So they labelled the cans: "This is the only salmon that doesn't turn pink in the tin". This sort of practice has to be prevented in South Africa. The claim of "our product has not been irradiated" should never be permitted. The Department of Health can perhaps prevent such advertising. Two supermarket organisations have given us a lot of support and I would like to thank them for their interest and cooperation. I would also like to thank Mr Lunt of the Letaba Cooperative for his collaboration with the Atomic Energy Board in introducing this process to the agricultural industry.

Our sponsors have done us proud, and I would like to extend my grateful appreciation to them: Bull Brand Foods (Pty) Ltd; Distillers Corporation (SA) Ltd; Mr A Du Venage, Glenwood Farms; Farm Fare (Pty) Ltd; Intercontinental Beer Sales; Letaba Cooperative Ltd; Lilroy Prepak (Pty) Ltd; Meat Board; Mr G A Solomon, Haakdoornboom; Tongaat Mushrooms (Tvl) (Pty) Ltd; and Total SA (Pty) Ltd.

We also owe a word of thanks to Dr de Wet and his staff who have put in a tremendous effort in organising this Symposium. The assistance of the External Relations Division of the Atomic Energy Board also deserves our appreciation.

Finally, let me thank you all for your attendance and participation, not only the authors, but also those who took part in the discussions and hence contributed to the success of the Symposium. Let me express the wish that this process will eventually be used to the benefit of mankind, not only in South Africa, but also in other parts of the world.

Thank you very much!



# LIST OF CLEARANCES

## GENERAL SURVEY OF IRRADIATED FOOD PRODUCTS CLEARED FOR HUMAN CONSUMPTION IN DIFFERENT COUNTRIES

**(Grouped according to country)** **August 1979**

| COUNTRY (Organisation) | PRODUCT | PURPOSE OF IRRADIATION | TYPE AND SOURCE OF RADIATION | | | DOSE (kGy) | DATE OF APPROVAL |
|---|---|---|---|---|---|---|---|
| | | | $^{60}$Co | $^{137}$Cs | electrons | | |
| BULGARIA | potatoes* | sprout inhibition | + | | | | 1971 |
| | potatoes* | sprout inhibition | + | | | 0,1 | 30 April 1972 |
| | onions* | sprout inhibition | + | | | 0,1 | 30 April 1972 |
| | garlic* | sprout inhibition | + | | | 0,1 | 30 April 1972 |
| | grain* | sprout inhibition | + | | | 0,3 | 30 April 1972 |
| | dry food concentrates* | insect disinfestation | + | | | 1,0 | 30 April 1972 |
| | dried fruits* | insect disinfestation | + | | | 1,0 | 30 April 1972 |
| | fresh fruits* (tomatoes, peaches, apricots, cherries, raspberries, grapes) | radurisation | + | | | 2,5 | 30 April 1972 |
| CANADA | potatoes | sprout inhibition | + | | | 0,1 max<br>0,15 max | 9 November 1960<br>14 June 1963 |
| | onions | sprout inhibition | + | | | 0,15 max | 25 March 1965 |
| | wheat, flour, whole wheat flour | insect disinfestation | + | | | 0,75 max | 25 February 1969 |
| | poultry● | radicidation (Salmonella) | + | | | 7,0 max | 20 June 1973 |
| | cod & haddock fillets● | radurisation | + | | | 1,5 max | 2 October 1973 |
| CHILE | potatoes* ● | sprout inhibition | + | | | | 31 October 1974 |
| CZECHOSLOVAKIA | potatoes* | sprout inhibition | + | | | 0,1 max | 26 November 1976 |
| | onions* | sprout inhibition | + | | | 0,08 max | 26 November 1976 |
| | mushrooms* | growth inhibition | + | | | 2,0 max | 26 November 1976 |
| DENMARK | potatoes | sprout inhibition | | | 10 MeV | 0,15 max | 27 February 1970 |
| FRANCE | potatoes★ | sprout inhibition | + | | | 0,075 – 0,15 | 8 November 1972 |
| | onions★ | sprout inhibition | + | + | | 0,075 – 0,15 | 9 August 1977 |
| | garlic★ | sprout inhibition | + | + | | 0,075 – 0,15 | 9 August 1977 |
| | shallot★ | sprout inhibition | + | + | | 0,075 – 0,15 | 9 August 1977 |
| FEDERAL REPUBLIC OF GERMANY | deep-frozen meals*★ | radappertisation | + | | | 25 – 45 | 24 March 1972 |
| | potatoes* | sprout inhibition | + | | | 0,15 max | 26 September 1974 |
| HUNGARY | potatoes● | sprout inhibition | + | | | 0,1 | 23 December 1969 |
| | potatoes● | sprout inhibition | + | | | 0,15 max | 10 January 1972 |
| | potatoes● | sprout inhibition | + | | | 0,15 max | 5 March 1973 |
| | onions● | sprout inhibition | + | | | | 5 March 1973 |
| | onions● | sprout inhibition | + | | | 0,06 | 6 August 1975 |
| | onions* | sprout inhibition | + | | | 0,06 | 6 September 1976 |
| | strawberries● | radurisation | + | | | 5,0 | 5 March 1973 |
| | mixed spices* (blackpepper, cumin, paprika, dried garlic: for use in sausages) | radicidation | + | | | 5,0 | 2 April 1974 |
| | mixed dry ingredients for canned hashed meats* (wheat flour, Na caseinate, onions and garlic powder, paprika) | radiation decontamination | + | | | 5,0 | 20 November 1976 |
| ISRAEL | potatoes | sprout inhibition | + | | | 0,15 max | 5 July 1967 |
| | onions | sprout inhibition | + | | | 0,1 max | 25 July 1968 |
| ITALY | potatoes | sprout inhibition | + | | | 0,075 – 0,15 | 30 August 1973 |
| | onions | sprout inhibition | + | | | 0,075 – 0,15 | 30 August 1973 |
| | garlic | sprout inhibition | + | | | 0,075 – 0,15 | 30 August 1973 |
| JAPAN | potatoes | sprout inhibition | + | | | 0,15 max | 30 August 1972 |
| NETHERLANDS | asparagus* | radurisation | + | | | 2,0 max | 7 May 1969 |
| | cocoa-beans* | insect disinfestation | + | | 4 MeV | 0,7 max | 7 May 1969 |
| | strawberries● | radurisation | + | | 4 MeV | 2,5 max | 7 May 1969 |
| | mushrooms | growth inhibition | + | | 4 MeV | 2,5 max | 23 October 1969 |
| | deep-frozen meals★ | radappertisation | + | | | 25 min | 27 November 1969 |
| | potatoes | sprout inhibition | + | | 4 MeV | 0,15 max | 23 March 1970 |
| | peeled potatoes● | radurisation | + | | | 0,5 | 12 May 1976 |
| | shrimps* | radurisation | + | | 4 MeV | 0,5 – 1,0 | 13 November 1970 |
| | shrimps● | radurisation | + | | | 1,0 | 15 June 1976 |
| | onions* | sprout inhibition | + | | | 0,15 max | 5 February 1971 |
| | onions | sprout inhibition | + | | | 0,05 max | 9 June 1975 |

| COUNTRY (Organisation) | PRODUCT | PURPOSE OF IRRADIATION | TYPE AND SOURCE OF RADIATION | | | DOSE (kGy) | DATE OF APPROVAL |
|---|---|---|---|---|---|---|---|
| | | | $^{60}Co$ | $^{137}Cs$ | electrons | | |
| NETHERLANDS (continued) | poultry, eviscerated (in plastic bags) | radurisation | + | | | 3,0 max | 31 December 1971 |
| | chicken | radurisation radicidation | + | | | 3,0 max | 10 May 1976 |
| | fresh, tinned & liquid foodstuffs★ | radappertisation | + | | | 25 min | 8 March 1972 |
| | spices & condiments* | radicidation | + | | 4 MeV | 8 – 10 | 13 September 1971 |
| | spices■ | radicidation | + | | 4 MeV | 10 | 4 October 1974 |
| | spices■ | radicidation | + | | 3 MeV | 10 | 26 June 1975 |
| | spices■ | radicidation | + | | | 10 | 4 April 1978 |
| | vegetable filling*● | radicidation | + | | | 0,75 | 4 October 1974 |
| | powdered batter mix● | radicidation | + | | | 1,5 | 4 October 1974 |
| | endive● (prepared, cut) | radurisation | + | | | 1,0 | 14 January 1975 |
| | fresh vegetables● (prepared, cut, soup greens) | radurisation | + | | | 1,0 | 6 September 1977 |
| | fillets of haddock, coal-fish, whiting● | radurisation | + | | | 1,0 | 6 September 1976 |
| | fillets of cod & plaice● | radurisation | + | | | 1,0 | 7 September 1976 |
| | frozen frog legs■ | radicidation | + | | | 5,0 | 25 September 1978 |
| | rice and ground rice products■ | disinfestation | + | | | 1,0 | 13 March 1979 |
| PHILIPPINES | potatoes■ | sprout inhibition | + | | | 0,15 max | 13 September 1972 |
| SOUTH AFRICA | potatoes | sprout inhibition delayed greening | + | | | 0,12 – 0,24 | 19 January 1977 |
| | onions | sprout inhibition | + | | | 0,05 – 0,15 | 25 August 1978 |
| | garlic | sprout inhibition | + | | | 0,1 – 0,20 | 25 August 1978 |
| | chicken | radurisation radicidation | + | | | 2 – 7 | 25 August 1978 |
| | papaya | radurisation | + | | | 0,5 – 1,5 | 25 August 1978 |
| | mango | radurisation | + | | | 0,5 – 1,5 | 25 August 1978 |
| | strawberries | radurisation | + | | | 1 – 4 | 25 August 1978 |
| | dried bananas§ | insect disinfestation | + | | | 0,5 max | 28 July 1977 |
| | avocados§ | delayed ripening | + | | | 0,1 max | 28 July 1977 |
| SPAIN | potatoes | sprout inhibition | + | | | 0,05 – 0,15 | 4 November 1969 |
| | onions | sprout inhibition | + | | | 0,08 max | 1971 |
| THAILAND | onions | sprout inhibition | + | | | 0,1 max | 20 March 1973 |
| UNION OF SOVIET SOCIALIST REPUBLICS | potatoes | sprout inhibition | + | | | 0,1 | 14 March 1958 |
| | potatoes | sprout inhibition | | | 1 MeV | 0,3 | 17 July 1973 |
| | grain | insect disinfestation | + | | | 0,3 | 1959 |
| | fresh fruits & vegetables* | radurisation | + | | | 2 – 4 | 11 July 1964 |
| | semi-prepared raw beef, pork & rabbit products (in plastic bags)* | radurisation | + | | | 6 – 8 | 11 July 1964 |
| | dried fruits | insect disinfestation | + | | | 1,0 | 15 February 1966 |
| | dry food concentrates (buckwheat mush, gruel, rice pudding) | insect disinfestation | + | | | 0,7 | 6 June 1966 |
| | poultry, eviscerated (in plastic bags)* | radurisation | + | | | 6,0 | 4 July 1966 |
| | culinary prepared meat products (fried meat, entrecote) (in plastic bags)* | radurisation | + | | | 8,0 | 1 February 1967 |
| | onions* | sprout inhibition | + | | | 0,06 | 25 February 1967 |
| | onions | sprout inhibition | + | | | 0,06 | 17 July 1973 |
| UNITED KINGDOM | any food for consumption by patients who require a sterile diet as an essential factor in their treatment | radappertisation | | | | | 1 December 1969 |
| UNITED STATES OF AMERICA | wheat and wheat flour | insect disinfestation | + | | | 0,2 – 0,5 | 21 August 1963 |
| | (changed on 4 March 1966 | | + | | | 0,2 – 0,5 | 2 October 1964 |
| | from wheat and wheat product) | | | | 5 MeV | 0,2 – 0,5 | 26 February 1966 |
| | white potatoes | sprout inhibition | + | | | 0,05 – 0,1 | 30 June 1964 |
| | | | | + | | 0,05 – 0,1 | 2 October 1964 |
| | | | + | + | | 0,05 – 0,15 | 1 November 1965 |
| URUGUAY | potatoes | sprout inhibition | + | | | | 23 June 1970 |

| COUNTRY (Organisation) | PRODUCT | PURPOSE OF IRRADIATION | TYPE AND SOURCE OF RADIATION | | | DOSE (kGy) | DATE OF APPROVAL |
|---|---|---|---|---|---|---|---|
| | | | $^{60}$Co | $^{137}$Cs | **electrons** | | |
| WORLD HEALTH ORGANISATION (FAO/IAEA/WHO Expert Committee) | potatoes ■ | sprout inhibition | + | + | | 0,15 max | 12 April 1969 |
| | **potatoes** | sprout inhibition | + | + | 10 MeV max | 0,03 – 0,15 | 7 September 1976 |
| | onions § | sprout inhibition | + | + | 10 MeV max | 0,02 – 0,15 | 7 September 1976 |
| | **papaya** | insect disinfestation | + | + | 10 MeV max | 0,5 – 1,0 | 7 September 1976 |
| | **strawberries** | radurisation | + | + | 10 MeV max | 1 – 3 | 7 September 1976 |
| | wheat & ground wheat products ■ | insect disinfestation | + | + | 10 MeV max | 0,75 max | 12 April 1969 |
| | **wheat & ground wheat products** | insect disinfestation | + | + | 10 MeV | 0,15 – 1,0 | 7 September 1976 |
| | rice § | insect disinfestation | + | + | 10 MeV max | 0,1 – 1,0 | 7 September 1976 |
| | **chicken** | radurisation radicidation | + | + | 10 MeV max | 2 – 7 | 7 September 1976 |
| | cod & redfish § | radurisation radicidation | + | + | 10 MeV max | 2 – 2,2 | 7 September 1976 |

- * experimental batches
- ■ temporary acceptance
- ★ hospital patients
- ● test marketing
- § provisional

**bold**: unlimited clearance (unconditional acceptance: WHO)

Kindly supplied by Dr J C van Kooij
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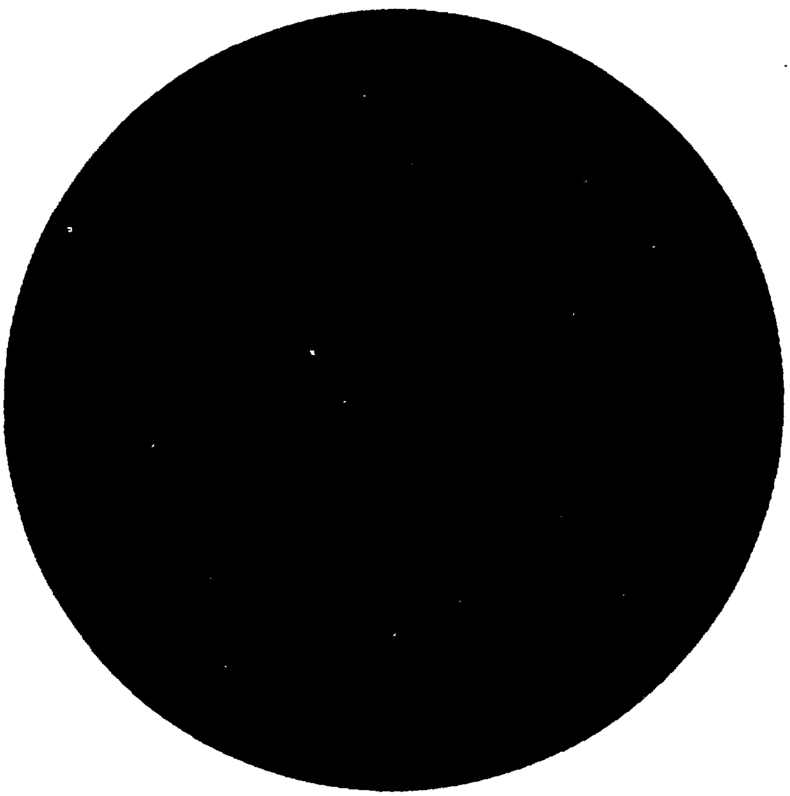

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