FOOD IRRADIATION

Edited by

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ELSEVIER APPLIED SCIENCE
LONDON and NEW YORK

ELSEVIER SCIENCE PUBLISHERS LTD
Crown House, Linton Road, Barking, Essex IG11 8JU, England

Sole Distributor in the USA and Canada
ELSEVIER SCIENCE PUBLISHING CO., INC.
655 Avenue of the Americas, New York, NY 10010, USA

WITH 45 TABLES AND 53 ILLUSTRATIONS

British Library Cataloguing in Publication Data

Food irradiation.
1. Food. Irradiation
I. Thorne, Stuart
664.0288
ISBN 1-85166-651-6

Library of Congress Cataloging-in-Publication Data

Food irradiation/edited by Stuart Thorne
p. cm. — (Elsevier applied food science series)
Includes bibliographical references and index.
ISBN 1-85166-651-6
1. Radiation preservation of food. I. Thorne, Stuart.
II. Series.
TP371.8.F63 1991
664'.0288 dc20 91-13147 CIP

Printed and bound in Great Britain by Hartnolls Ltd

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PREFACE

There is no doubt that irradiation can extend the useful storage life of many foods. This is effected by destruction of micro-organisms and inhibition of biological processes such as sprouting. Although it has been attempted, irradiation sterilisation of foods has not been widely accepted, mainly because the large irradiation doses involved produce unacceptable off-flavours and other changes in the product. Combinations of irradiation with other techniques to endow foods with long storage lives have, however, been shown to be effective. A synergistic effect has been reported for the combined use of irradiation and heat to sterilise foods; the combination being reported to be more effective than either treatment alone. But perhaps the most important application of food irradiation is at lower doses to effect specific changes in foods, reduction in surface flora in strawberries, mushrooms and seafood or inhibition of sprouting in potatoes. It is probably to such operations that we must look for the main long-term future of food irradiation. Extending the storage life of mushrooms, strawberries and similar short-life produce from 1 or 2 days to 1 week or so has huge potential benefits both for industry and for the consumer.

The technology of food irradiation is simple, effective and well-established. The restriction on its large scale application is neither technological nor economic but consumer resistance. Radiation has had a bad press for almost half a century and all processes, whether atomic power generation or food irradiation, are suffused in the common mind with fear and suspicion. The acceptance of food irradiation is hampered by confusion with atomic weapons and the nuclear power station-accidents at Three Mile Island and Chernobyl. Food irradiation, of course, is on a different scale and does not involve large masses of fissionable material. But, nevertheless, it is irrationally tainted by comparison.

This confusion manifests itself not as might have been expected with the possibility of accidents at food irradiation plants but with scare-mongering about the effects of irradiation on food safety. The possibility of accidents is, of course, negligibly small. Unwarranted concerns about the safety of irradiated food falls into four categories. First, that the food might become radioactive. Second, that toxic or carcinogenic products might be produced. Third, that some sort of horrible mutant micro-organisms might result from irradiating foods. And, fourth, the rather curious claim that irradiation should not be permitted because it is difficult to detect! Irradiated food does not become radioactive. Extensive toxicological investigations have revealed little evidence of toxic products. Neither is their any evidence for dangerously mutant organisms. The worst that appears to happen is the loss of some vitamins; a characteristic shared with all other preservation processes.

Irradiation could reasonably be compared with thermal processing. This, too, induces changes in food such as vitamin loss. But, because it has been used since time immemorial, it is accepted. Indeed, some of the changes induced by heating — browning, textural changes, flavour changes — are considered essential to acceptability, but we know comparatively little about their toxicology. And where thermally-induced changes such as caramelisation have been investigated there is often far less certainty about their safety than there is with irradiation-induced changes. There has been far less investigation of the effects of heat on food safety — with the exception of thermal sterilisation — than into the safety of food irradiation. We probably know far less about the effects of heating on foods than about the effects of irradiation. But tradition is a powerful if irrational factor in acceptance. Would, for example, nutmeg or cochineal be accepted if they were proposed as new ingredients, today?

It is, of course, quite proper that we should both continue to use traditional processes and ingredients and insist that the new should be adequately tested. But the problem is convincing the consumer that testing of new processes has been adequate and fair and that the prospect of commercial gain has not blinkered assessment of results. The problem lies with science. No hypothesis can be proved true; it can only be refuted. If our initial hypothesis is that an irradiated food is safe, we can only prove it unsafe. That we have singularly failed to do so means that the probability that the process is safe is very high, but we cannot prove it.

In the mind of the man in the street, science provides proof — 'Scientific proof' is the stuff of newspaper headlines. The problem with the acceptability of irradiated foods is one of communication. The consumer does not understand the scientific method and the scientist is so imbued with it that it is never adequately explained to the layman. Television and newspaper 'science' programmes and articles do not help either; they are usually concerned with inventions and confuse science with technology. Neither does primary or secondary education help, in Britain at least. 'Science' is a mainstay of the National Curriculum, but it is concerned with observation of natural phenomena and with established 'facts' in chemistry, physics and biology; it is not really concerned with the scientific method at all. I do not know what the answer to the communication problem is. Perhaps the media — particularly television — could be persuaded to explain what science is really about. And many protesters want to protest and remain blinkered to reality.

What can be done is to ensure that scientists put their case on the media fairly and properly and explain how they work and what are the limitations of science. Professor Smith appears on television and announces that he is 99.9% certain that irradiated mangosteens are harmless. 'Ah', says the representative of the Consumer Protection Commission, who is paid to object, 'What if I am one of the other 0.1%?'. Professor Smith rarely gets the opportunity to explain that he has not implied that 0.1% of consumers will succumb to the evil effects of irradiated food, but that science never allows him to be absolutely confident. If absolute certainty were a pre-condition of introducing any development then no progress would ever be made.

The essential consideration about any new food process or ingredient is confidence that its use will ensure far more benefit than hazard. It is not adequate to consider the possibility of adverse effects of a preservation process or food ingredient without simultaneously considering the potential benefits in terms of food safety and quality. If, for example, nitrites in some meat products were not permitted, we might reduce the small probability of nitrosamine-induced carcinomas, but we would undoubtedly greatly increase the probability of botulism.

The most curious objection to food irradiation is that it is very difficult to detect. Surely this is grounds not for objection but for commendation. If much research over many years has found only limited methods for detecting irradiation in individual foods using the most esoteric analyses, then surely this is *prima facie* evidence for the safety of the process and its acceptability. The objection really is that it is difficult to detect whether irradiation has been used to make unacceptable food pass safety tests. There have, for example, been reports of seafood imported to Britain being rejected on bacteriological grounds and subsequently being accepted on import after irradiation. This, if true, is unethical and reprehensible. But it does illustrate well the abilities of irradiation and, presumably, the re-imported irradiated food was safe. It could equally be said of thermal processing that it could be used to make unacceptable food acceptable. I am sure that I could devise a process to heat the surface of reject seafood to reduce its surface flora to an acceptable level. No one has ever objected to heating on these grounds.

In spite of the problems of convincing consumers of the safety of food irradiation, it is finding increasing application. The great benefits that it offers will undoubtedly ensure its eventual acceptance.

This volume reflects the current state of food irradiation. Three chapters are concerned with applications of irradiation to food processing; one general and two about important specific applications. The larger part of the book discusses the major problems of irradiation; acceptance and detection. Consumer acceptance varies from country to country, dependent upon attitude to new processes in general and 'atomic' processes in particular. Chapters have, therefore, been included to discuss acceptance and status in the United States, in Europe and in developing countries.

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Chapter 1

AN INTRODUCTION TO THE IRRADIATION PROCESSING OF FOODS

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1 INTRODUCTION

The food industry has used a variety of methods over the years to preserve or extend the shelf life of food. These have included cooking, packaging, smoking, chilling, freezing, dehydrating and using chemical additives. More recently, ionising radiation has been used to extend the storage life of foods.[1]

More research has been focussed on the effects of irradiation on foods than has been directed at any other form of food processing. This research has spanned 40 years and has been carried out in many countries.

The World Health Organisation (WHO) has declared irradiation to be a 'powerful tool against preventable food loss and food borne illness' and the British Government Advisory Committee on Irradiation (ACINF) reported in 1986 that with 'up to an average dose of 10 kGy the technique was effective in food preservation and would not lead to significant changes in the natural radioactivity of foods or prejudice the safety or wholesomeness of foods'. It was unfortunate that the committee reported just days before the explosion at a nuclear power plant in Chernobyl. This event fuelled the consumer's confusion between the undoubtedly dangerous 'radioactivity' and the food preservation technique 'irradiation'.[2]

Food irradiation can be used to: (a) inhibit the sprouting of vegetables; (b) delay the ripening of fruits; (c) kill insect pests in fruit, grains or spices; (d) reduce or eliminate food spoilage organisms; (e) reduce food poisoning bacteria on some meats and sea food products.

Irradiation has been hailed as a safer alternative to other methods of preservation such as the use of chemical additives. Other claims are that the process is completely safe and that consumers will benefit from reduced wastage, greater convenience and better quality food. Conversely, there is a body of opinion that claims a variety of adverse effects of irradiation, such as: (a) unique chemical changes; (b) loss of vitamins; (c) off-flavours and aromas; (d) a limited range of applicability; (e) the necessity for use of additives to offset undesirable effects; (f) adverse health effects in animals and humans fed on irradiated foods.[1]

The failure of food irradiation to gain wider acceptance is not difficult to fathom. Negative public attitudes towards virtually everything associated with radiation are found all over the world. In millions of people's minds radiation is associated with war on a scale the earth has never previously seen, with accidents that pose health threats lasting for generations and with nuclear wastes that will still be dangerous 10 000 years from now. Even recognising that radiation is an invaluable aid in diagnosing and treating disease, sterilising medical devices and pharmaceutical products and producing many kinds of manufactured goods, vast numbers of people are genuinely afraid of anything that would appear to increase the risk of exposure to irradiation.[3]

Supporters of irradiation say it will revolutionise the way we eat; food would stay edible for longer, prepared meals could sit on the larder shelf for months before being heated by microwaves for an instant hot dinner. Its detractors say it could result in unidentified toxins remaining in seemingly 'fresh' food and that abuse of irradiation to disguise decay could result in food poisoning and even death.[1] Before food irradiation can be universally accepted, it must be ensured that it brings real benefits to consumers, that there are few risks to the public or to those who work in the food industry, and that an effective system enforcing these regulations is established to prevent abuse.[1]

2 HISTORICAL BACKGROUND

Roentgen discovered X-rays in 1895 and Becquerel discovered radioactivity the following year. In 1896, it was suggested that ionising radiation could be used to kill micro-organisms in food, but it was not until 1921 that a practical use for food irradiation was established and Schwartz obtained a US Patent on the use of X-rays to kill the parasite *Trichinella spiralis* in meat — a cause of worm infection in humans. In 1930, Wust obtained a French Patent for the preservation of foods by irradiation.

In 1948, work on food irradiation started at the Low Temperature Research Station at Cambridge, England. Considerable scientific research was performed during the 1950s and early 1960s elsewhere in the United Kingdom. In the mid-1950s the US Army Quartermasters Corps became interested in food irradiation and sponsored research as part of President Eisenhower's 'Atoms for Peace' policy. Throughout the 1960s and 1970s research into the wholesomeness of irradiated foods and into the technological aspects of food irradiation became even more widespread.[6]

In 1970, 19 countries launched the International Food Irradiation Project (IFIP) financing research into combined processing using irradiation in conjunction with other preservatives. The project was completed in 1982, and replaced in 1984 by formation of the International Consultative Group for Food Irradiation (ICGFI), established by the Food and Agriculture Organisation (FAO), the International Atomic Energy Authority (IAEA) and the World Health Organisation (WHO) and comprising 26 member states of these three United Nations organisations. The ICGFI's brief was to undertake and sponsor research. Joint FAO/IAEA/WHO Expert Committees on the Wholesomeness of Irradiated Foods (JECFI) concluded in 1980 that irradiation of any commodity up to an average dose of 10 kGy neither presented any toxicological hazard, nor introduced any special nutritional or microbiological problems.[7] In 1983, the Codex Alimentarius Commission adopted a revised 'General Standard for Irradiated Foods' and a revised 'Recommended International Code of Practice for the Operation of Radiation Facilities Used for the Treatment of Foods' which incorporated the main conclusions of the 1980 JECFI.[6]

3 GENERAL ASPECTS OF IRRADIATION

3.1 Technique

In deciding to allow irradiation, governments have undoubtedly been influenced by the need to combat the growing incidence of food poisoning. In this context it should be regarded as an additional method of food sterilisation. There are two methods of irradiation used for food sterilisation:

(i) *Gamma Rays.* Electromagnetic radiations produced during the decay of certain radio-isotopes, e.g. Cobalt-60 (a cobalt isotope produced by irradiating cobalt metal in a nuclear reactor) or Caesium-137 (present as a fission product in the fuel elements used in nuclear reactors).

Cobalt-60 is usually used. This is a nuclear process and must comply with the regulations governing Radioactive Substances, Ionising Radiations (Sealed Sources). Gamma rays are very penetrating and can be used for irradiating products in their final shipping cartons.

(ii) *Electron Accelerators* produce high-energy electron beams and accelerate them to very high speeds, producing millions of kGys in fractions of a second. This process is a non-nuclear method but the degree of irradiation penetration is no more than a few centimetres.[4]

Food is irradiated in an irradiation unit — a high energy source situated in a room possessing thick concrete walls. The energy source is either a machine source of electrons or a radioactive element e.g. Cobalt-60.[5] The Cobalt-60 is contained in a series of stainless steel tubes which are mounted in a frame to produce a uniform field of emitted radiation. When not in use, the source is lowered into a concrete enclosed pit or a deep pool of water within the cell.[4]

Food must be fresh and of good quality before irradiation. It can be packaged and frozen or chilled as appropriate. Once food has been transported to the irradiation unit, it is loaded on to a conveyor belt which passes into the irradiation unit, carrying the food. At no time will there be contact between the food and the energy source.[5] The food remains within the unit for a predetermined time; the speed of the conveyor determines the exposure time of the product within the cell, and hence the dose delivered to the product. Control of this, combined with accurate methods of measuring the absorbed dose in the product, forms the basis of quality assurance procedures.[4] It then leaves the unit, can be handled immediately, and distributed to the wholesaler and retailer in the normal way. (The food is not radioactive.)[5] There are 11 gamma plants in the United Kingdom handling this type of work. Isotron PLC operates five of these and is the only independent processor.[4]

3.2 Cost

Both the gamma ray method and electron accelerators are costly processes to install. For example, to run a gamma ray installation the cost of the Cobalt-60, which has a half-life of 5·3 years, would be approximately £400 000. The plant to house the operation would involve a capital cost of approximately £1·25 million and the associated machinery involved would require a further investment of £0·75 million. The total capital cost would therefore be nearly £2·5 million. The capital cost involved in the installation of an electron accelerator would be in the region of £2 million, so there is little to choose between the two processes in capital costs.[4]

3.3 Dose

Different doses of radiation can be applied to foods to achieve different aims (Table 1). Low doses can be used to inhibit sprouting of vegetables, to delay ripening of fruit and vegetables and (as an alternative to chemicals such as ethylene oxide or ethylene dibromide) to achieve insect disinfestation.

TABLE 1
IRRADIATION DOSES RECOMMENDED FOR VARIOUS PURPOSES

Process	*Approximate dose range (kGy)*
Inhibition of sprouting	0·05–0·15
Delay ripening of various fruits	0·20–0·50
Insect disinfestation	0·20–1·00
Elimination of various parasites	0·03–6·00
Shelf life extension by reduction of microbial load	0·50–5·00
Elimination of non-sporing pathogens	3·00–10·0
Bacterial sterilisation	up to 50·0

Higher doses can be used to reduce the food's microbial load in a way analogous to thermal pasteurisation (for shelf life extension and elimination of some pathogens) and to kill parasites in meat. Doses higher than 10 kGy are usually needed to achieve bacteriological sterilisation. The food industry in the United Kingdom has expressed an interest in using irradiation up to a maximum overall average dose of 10 kGy for the treatment of food intended for general sale.[6]

3.4 Applications

Radiation produces chemical changes in the food and these in turn induce biological changes. The following effects can be produced:

A. *Radurisation* low doses, usually below 1 kGy: (a) Sprouting of vegetables such as potatoes and onions can be inhibited to extend their storage life. (b) Ripening of fruits can be delayed to increase storage life. (c) Insect pests in grains such as wheat and rice, or in spices and some fruits can be killed. This might replace current methods involving gas storage or fumigation treatments that are hazardous to workers, and could reduce losses of foodstuffs.

B. *Radicidation* medium doses, between 1 kGy and 10 kGy: The number of food spoilage micro-organisms such as yeasts, moulds and bacteria could be reduced to extend the life of foods or reduce the risk of food poisoning. This might be important in the case of *Salmonella* in chicken or fish, etc.

C. *Radappertisation* high doses above 10 kGy: These extremely large doses — higher than the proposed 10 kGy limit — can sterilise food completely by killing all bacteria and viruses. This would be used mainly for meat products allowing them to be kept almost indefinitely if adequately packaged.[1]

Food irradiation processing causes virtually no increase in temperature in the treated products and is therefore often termed a 'cold' process. It has been used for some 20 years for the sterilisation of disposable medical supplies, as well as pharmaceuticals that are ingested or injected and pro ducts such as sutures or implants which remain in the body. Of such products, 30% are presently sterilised by irradiation in about 150 plants and used commercially throughout the world. Another application for the benefit of humans is the radiation sterilisation of meals for inclusion in diets of patients lacking the usual immunological defences.

Post-harvest storage losses may in certain regions of the world be as high as 40%. Reduction of such losses by irradiation could contribute significantly to food availability, thereby meeting the world's growing need for food. It is sounder policy to conserve what is produced rather than to produce more to compensate for subsequent losses. Prolongation of storage life can facilitate a wider distribution of foodstuffs by enabling exports to those countries where transportation time previously made such distribution impossible. Wider distribution not only has an impact on export potential, but also provides a more varied and nutritionally superior diet to populations.[8]

The current awareness of food poisoning might convince the public that there is a place for irradiation in the armoury of techniques available to make food safer. It has been suggested that food irradiation might be used to 'cover up' poor hygiene during food production and manufacture. This argument could equally be applied to thermal processing. It is