The Application of High Dose Food Irradiation

Ingrid De Bruyn
Atomic Energy Corporation of South Africa
South Africa

Abstract

During the 1950's to end 1970's the United States Army developed the basic methodology to produce shelf stable irradiated meat, seafood and poultry products. These products are normally packed without gravy, sauce or brine, as liquid is not required to sterilize the product as in the canning process. This leads to the distinctive "dried cooked" taste normally associated with roasts opposed to the casserole taste usually associated with tinned meats. The meats are cooked, chilled, portioned, vacuum packed and irradiated to the required minimum dose of 25 to 45 kGy (depending on the product) at a temperature of between -20 and -40 °C to ensure absolute sterility even under tropical conditions. The product is packaged in a high quality four layer laminate pouch and will therefore not rust or burst even under adverse weather conditions. The product can be guaranteed for more than two years as long as the integrity of the packaging is maintained.

Historical background

Researchers have been experimenting with the irradiation of foodstuffs for more than 100 years. The first patent to irradiate food was issued in 1909 for the control of Lasiderma beetles in tobacco, by using X-rays. In 1943 researchers at MIT published a paper on "Effect of X-ray irradiation on the bacterial count of ground meat". During the early 1950's isotope sources became available and research started in earnest. These studies gained greater impetus with the "Atoms for Peace Program" which President Eisenhower proposed to the UN in 1953.

The groundbreaking research into irradiation of food at high doses was carried out in the United States of America. Between 1953 and 1962 studies were undertaken by the Army's Laboratories at the Quartermaster Food and Container Institute in Chicago, Illinois, while between 1962 to 1980 research was continued at US Army Natick R&D Command in Natick, Massachusetts[(1), (2), (3)].

In 1963 FDA clearance was obtained to irradiate bacon at high dose. The irradiation of packaging materials to be used as food contact materials, was approved between 1964 and 1967[1]. Unfortunately during 1958 the Food Additives Amendment to the Federal Food, Drug and Cosmetic Act was tabled whereby irradiation was regarded as an additive. The Act specified that food had been adulterated if it had been irradiated intentionally. Such foods can therefore not be sold unless the food is irradiated under prescribed conditions that have been proven to be safe[4].

In 1966 the US Army petitioned the FDA to approve irradiated ham based on the approval of bacon. This petition was finally turned down in 1968 and in the same year the clearance for bacon was revoked[1,2]. This lead to the reduction of most high dose research programs throughout the world[2]. Following the FDA's requirements the protocol for animal feeding studies to determine the wholesomeness of irradiated food was changed considerably[1]. The results of these studies were used as a major source of data for the WHO appointed Study Group which recently published it's findings as: "foods treated with doses greater than 10kGy can be considered safe and nutritionally adequate when produced under established Good Manufacturing Practice."[5].

One of the first commercial applications for shelf stable irradiated food was in 1977 when the Fred Hutchinson Memorial Hospital in Seattle placed an order for pre-cooked irradiation sterilised hospital meals for use by bone marrow transplant patients[6]. Unfortunately in 1988 the Fred Hutchinson Memorial Hospital stopped using radiation sterilised meals, as the source that had been used to sterilise the products became too weak [7]. In 1995 the FDA approved the irradiation of frozen meals at a minimum dose of 44 kGy for use by NASA astronauts[8].

Process parameters

The basic procedure used to irradiate shelf stable products was developed at Natick and can be summarised as follows[7]:

Cook to attain internal temp of 75°C
(inactivation of enzymes)

↓

Slice or portion if needed

↓

Vacuum pack
(multi-layer aluminium foil barrier pouch)

↓

Freeze to -40°C
(cryogenic or mechanical)

↓

Irradiate to minimum dose (25 to 45 kGy)
(Temperature between -40°C and -20°C)

Figure 1. Irradiation process

Microbiological, chemical and temperature parameters

The dose required to produce irradiation sterilised products has to be sufficient to kill off 12 log cycles of Clostridium botulinum, a highly toxic, radiation resistant anaerobic organism[10]. In Table I some of the results are listed which were obtained at Natick to determine the minimum irradiation sterilising dose required to ensure absolute sterility of the products. It must be noted that the nitrite containing products like corned beef, bacon and pork sausage have a lower 12D due to the anti-botulinal effect of nitrite.

Table 1
Minimal irradiation sterilising (12D) doses in kGy[9]

Food	Irrad. Temp	Method of establishing 12 D dose[a]	
	(°C)	Extreme value[b]	Spearman-Karber[c]
Beef	- 30 ± 10	41.2	43.3
Chicken	- 30 ± 10	42.7	44.3
Ham	- 30 ± 10	31.4	38.1
Pork	- 30 ± 10	43.7	39.2
Codfish cake	- 30 ± 10	31.7	32.4
Corned beef	- 30 ± 10	26.9	24.4
Pork sausage	- 30 ± 10	25.5	26.5
Bacon	5 to 25	-	25.2

Source: RB Rowley, Natick labs

a Based on recoverable botulinal cells and an assumed one most resistant strain/can

b Based on an assumed exponential spore death rate with an initial shoulder

c Based on an assumed exponential spore death without an initial shoulder

During the planning of an inoculation pack study to determine 12D doses, the envisaged processing parameters should be adhered to strictly as changes in temperature during irradiation[11] as well as the chemical formulation of the meat product[12], [13] have a significant effect on the 12D value.

Packaging requirements

Originally tinplate cans were used for the packaging of shelf stable foods, however with the development of flexible pouches this is now the preferred material. The requirements for the packaging material were[14]

1 must be easily heat-sealed

2 must withstand the processing at -40°C without delaminating, cracking, or losing seal strength

3 must withstand shipment and handling hazards

4 must provide an oxygen and moisture barrier

5 must be inert to the food in the pouch

6 must protect the food from microbial or other contamination

Because of potential changes in the material caused by irradiation, the safety of any material has to be tested before use. Migration of chemicals in the packaging is affected and harmful volatile decomposition compounds can migrate directly into the food. FDA therefore requires that food irradiation packaging materials must conform to regulations (21 CFR 179.45) and be based on appropriate testing [4]. The material used by Natick is a three-layer composite consisting of: nylon 6 film on the outside, aluminium foil in the middle and polyethylene terephthalate-polyethylene film on the inside[14].

Advantages and quality of irradiated foods

Irradiation leads to a high quality product, which cannot easily be distinguished from a similarly processed equivalent. Because of the process the products can be served in bulk as whole beef or pork roasts, or in individually portioned servings. These products have a typically "dry cooked" flavour which cannot be produced by any other sterilisation process. The process reduces or eliminates the need for chemical preservatives. The product normally has a higher nutritional value than heat sterilised food because there is less destruction of vitamins and essential amino acids[9],[15].

Irradiation tenderises the meat by degrading connective tissue therefore lower quality meats can be used, however meat must be trimmed of bone, excess fat and gristle. Irradiated meats are slightly drier than meat products produced by other processes, but this can be solved by the addition of sodium chloride and phosphates prior to cooking which ensures a tender, juicy end product[3].

The South African experience

Introduction

During the late 1970's the South African Defence Force requested the Atomic Energy Corporation of South Africa (AEC) to develop shelf stable meats products for use under special conditions. The radappertisation techniques developed by the USA Defence Force laboratories at Natick[7] were therefore optimised for South African conditions.

In all cases meat with low internal muscle fat is used and bone, gristle and excess fat is trimmed off the meat before cooking. Vacuum packaging is done in a four laminate flexible pouch consisting of Nylon/Foil/ Polyester/LLDPE.

The freezing is mechanical and the product freezes down to -40°C in about 8 h. During irradiation the product is maintained at low temperature by placing dry ice on top of the product in the irradiation totes.

The dose used throughout is a minimum of 45 kGy as that dose was found to be equivalent to a 12D dose for the "worst case" product i.e. Roast beef without any preservatives or phosphates. Inoculation pack studies were carried out using Clostridium sporogenes to establish the 12D dose[16]. Nitrite containing products like bacon can be irradiated at a minimum of 26 kGy, which provides 12D safety due to the added anti-botulinal effects of the nitrite[17]. However, for practical reasons it was decided not to irradiate different products at different minimum doses.

The South African Bureau of Standards (SABS) requires that the total production be incubated at 38°C for 10 days and not just a percentage as is done in the canning industry. They are still slightly wary of this "new" technology and are strictly monitoring the production. After completion of the incubation, sampling is done by the SABS and microbiological and sensory evaluation of the product is carried out. A Certificate of Compliance is then issued before the product may be sold.

Meat products

A number of meat dishes were successfully developed: Roast beef with gravy, Roast chicken with gravy, Beef steak with tomato and onion, Bacon, Beef curry, Beef stroganoff, Bobotie, Roast pork with gravy, Chicken curry, Chicken and tomato and Country sausage. The meat products are of high quality and have a good taste and texture profile, although optimisation of some of the sauces is still required[(7)].

Studies have shown that starch based thickeners used with the meat products are seriously affected by the freezing[(18)]. A pea protein based thickener has been used to create a stable sauce, but the protein imparts an unacceptable taste and it can therefore not be used at present. This work is still underway and final results are therefore not available.

Vegetables

Experimentation was carried out with various vegetables. Initial studies were carried out by cooking the vegetables, which were then frozen and irradiated further. It was found that the products became very soft and mushy after processing. Subsequently the products were only blanched and then packed, frozen and irradiated. After irradiation the products were initially marginally acceptable but after a three month period the product again became very soft and mushy.

In summary it is possible to produce some shelf stable vegetables but on the whole they are not that appetising in appearance and taste and are fairly expensive due to the process. It is therefore possible to buy canned vegetables of equivalent or better quality at roughly a third of the price. However vegetable dishes could possibly be investigated since being value added products the price is not such a problem.

Starches

Initial work with starches showed that they became very soft and mushy after processing and it was therefore decided to only partially cook them for later studies. However par-boiling did not solve the problems.

In summary except for the kidney beans none of the starches tested were acceptable because of the damage to the starch compounds by the freezing and irradiation and the subsequent moisture loss. All of the products were edible but not palatable and the cost of the process and packaging is again a major stumbling block in contrast with the meat where the raw product is already a much higher priced commodity and can therefore absorb the process costs.

Details of the South African research into shelf stable food products can be found in Appendix B of IAEA-TECDOC-843[(7)].

Sales of irradiated meat products in South Africa

Military sales

During 1989 general clearance was obtained from the Department of Health to supply shelf stable irradiated food to the South African Defence Force (SADF)

Between 1989 and 1995 approximately 1.8 million portions were sold to the SADF. Due to the restructuring in the South African Government and therefore the SADF no contracts are currently in existence. The SADF has absorbed members from the three different freedom fighting groups and it's numbers have therefore increased from approx. 60 000 to approx. 120 000 troops. This has gone hand in hand with massive cuts in the defence budget, which allows for few "luxuries" such as irradiated shelf stable foods.

General George Meiring, Chief of SA National Defence Force, has written a letter in which he confirms the military use of the food. He states: "Many of our special forces used them (irradiated meat products) for long periods as their sole protein intake, and not a single negative health report is on record. We have found the meat packs to be consistently of the highest quality and with their guaranteed shelf life (without refrigeration) of 3 years, they were invaluable for military and emergency operations."[19]

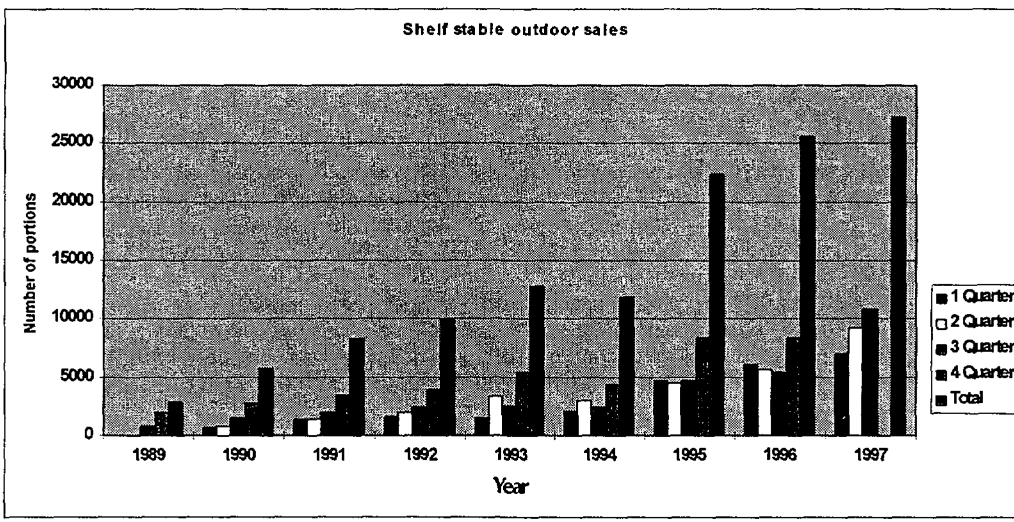

Figure 2: Sales of shelf-stable meat products to outdoor enthusiasts in South Africa

Outdoor sales

During 1992 AEC obtained special approval from the South African Department of Health to sell to outdoor enthusiasts subject to certain conditions. Prior to this clearance, outdoor enthusiasts could only buy directly from the AEC. Sales are allowed through selected hiking/outdoor shops that act as agents. Sales to corporate clients are also allowed by obtaining approval from the Department of Health to sell to that specific client as long as it is used in-house and not resold.

Shelf stable meats have been used by:

- 1st South African Mount Everest expedition
- Cape to Rio international yachtsmen,
- Hiking and outdoor enthusiasts in South Africa
- 4 x 4 Clubs and Safari's in South Africa and the rest of Africa
- Other outdoor adventures such as river rafting, pony trekking etc.

Typical comments by some of these users:

"I like it, it can be compacted very small after use and the packaging can be used as a plate in itself... As a quick and easy food, THE BEST I HAVE FOUND YET." - Charlotte du Toit, Camping for Africa (A hiking shop owner), Johannesburg. South Africa.

"Such a wonderful application in difficult cooking situations - yachting especially. Open cooking is dangerous aboard a yacht - this solves that problem. Great "KITCHENEERING!". This is my second irradiated Cape to Rio!" Robin Stamper, Cape to Rio Yachtsman.

Consumer response

A commercial firm of market analysts conducted a marketing survey on the attitude of consumers towards irradiated shelf stable foods. The people attending the session were selected at random from the general population. When asked initially whether they would buy irradiated foods, 15% said they were likely to and 65% said that they were unlikely to.

After the consumers were exposed to visual information, 54% said they were likely to buy the food and 29% said they were unlikely to. After audiovisual information and tasting of the food, 76% said they would likely buy the product and 5% said they would probably not buy the food. These results confirm those obtained by various researchers in the United States[(20), (21), (22)].

Conclusions

High quality shelf stable meat products can be produced using high dose irradiation. The process parameters have been well defined and coupled to Good Manufacturing Practices lead to safe, healthy products. These products are well received by the general public without undue negative reaction to the irradiation process.

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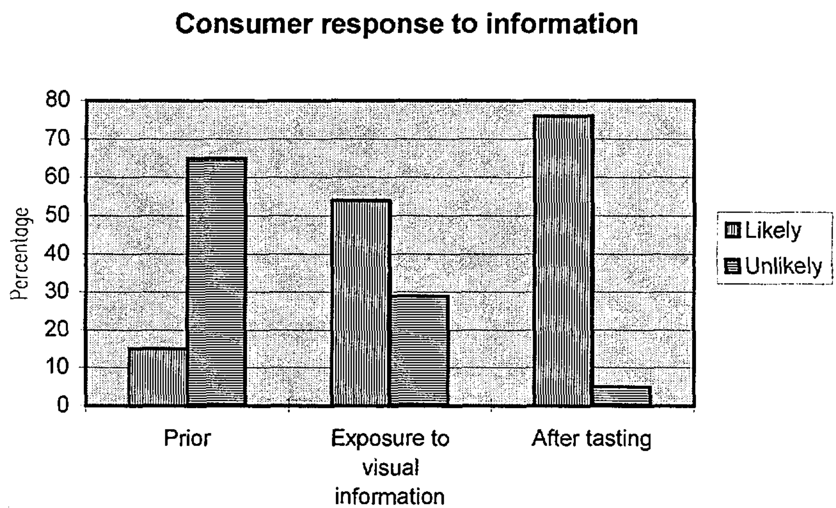

Figure 3: Consumer response to information and tasting of irradiated foods

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