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PRESERVATION OF FOOD

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Of all the applications of radiation processing discussed at this meeting, food irradiation has the greatest growth potential. Research programs in this field have been initiated in more than 50 countries all over the world. Pilot-scale irradiators exist or are under construction in about 30 of these. It is remarkable that a large part of this effort is going on in developing countries. In the Indian Nuclear Research Center at Bombay, for instance, some 70 scientists are working on problems concerned with food irradiation. With respect to one product, developments have gone beyond the research stage: a 300 000 Ci potato irradiation plant with a capacity of irradiating 10 000 t/month has been in operation in Japan since 1973 and potatoes irradiated for the purpose of sprout inhibition are being successfully marketed in Japan.

During the 25 years which have passed since the first studies on food irradiation were done, many - and sometimes exaggerated - claims were made. The new process was sometimes advertised as a "miracle method", and a "revolution in the food market" was predicted. This only antagonized the canning industry and others who had an interest in conventional methods of food preservation My introductory remark about the great potential of this process may therefore be received with scepticism, and I may justly be asked: why, if this process looks so promising, have all the intensive research efforts in many countries resulted in only one large-scale commercial application? How many more years of research will be needed, before irradiated food items will become widely available?

I will try to answer these questions towards the end of this pre sentation. But before coming to this point, I will describe the possible applications of radiation processing in the food field, with some critical remarks about the prospects of commercialization in each case. Time will not permit the presentation of much detail. The proceedings of the international symposium on food irradiation which was held in Bombay in 1972 (1) provide a rich source of information for those who would like to know more.

Irradiation with a sterilizing dose

This process, also called radappertization, has been studied almost exclusively at the U.S. Army's Research and Development

Center at Natick, Massachusetts. Its purpose is the production of foodstuffs which are shelfstable at ambient temperatures and which have better quality characteristics than the corresponding heat-sterilized products. In most products, the rather high radiation doses needed for this purpose (3 - 5 Mrad) produce off-flavors unless irradiation is carried out at low temperature (-30° C or less). Because of the high radiation resistance of autolytic enzymes, enzymatic spoilage occurs in radiation-sterilized foods unless the radiation treatment is supplemented with a mild heat treatment. The whole process thus involves the following steps (a) heating to an internal temperature of 65 - 75° C, (b) packaging under vacuum in a sealed container impermeable to moisture, air, light, and microorganisms, (c) cooling to irradiation temperature (usually -30° C), (d) irradiation (2).

I have participated in some of the quality-evaluation panels at Natick and I can vouch for the good quality of radappertized ham, bacon, pork sausage, beef, corned beef, codfish cakes, shrimp, chicken and lamb. Astronauts ate radappertized ham on Apollo flights to the moon and Soviet cosmonauts joined them when irradiated ham, corned beef, turkey slices and beef steaks were consumed on Apollo-Soyuz missions.

The 4-step process described above must noticeably increase the price of the product. A study carried out by the U.S. Department of Commerce (3) has indicated a cost of about 5 $ per 100 pounds of meat (cooked weight equivalent) for a 5 Mrad dose, assuming a 3 million Ci cobalt-60 source, a throughput of 2000 pounds per hour, 8000 hours per year, and a 30 % efficiency of source utilization. This corresponds to a cost of about 11 cts/kg - without blanching, packaging and refrigeration.

The Natick group does not envision this process as a competition for the established method of marketing refrigerated fresh meat, which accounts for over 70 % of the meat sold in the United States. However, in addition to satisfying special demands of Armed Forces and astronauts, products that can be stored without refrigeration or freezing should be of interest to vacationers, mountain climbers, airline caterers and others who are willing to pay a higher price for higher convenience (4).

Before such products can be marketed, the health authorities have to give their approval. Radappertized bacon was cleared by the U.S. Food and Drug Administration for unlimited human consumption in 1963. However, this decision was revoked in 1968, when FDA reexamined the results of the animal feeding studies (which were conducted in the 1950s) and found that they were not adequate to meet the more stringent testing requirements of today. A feeding study with radappertized beef was commissioned by the Natick Center in 1971 and will be concluded this year. Contracts for testing radappertized ham, pork and chicken are now being negotiated. Three to four years will go by before the results of these tests will be available. Considering the additional time required for petition writing, for FDA clearance and for creating production facilities, it will take at least 8 to

10 years to get an ppreciable number of radappertized foods on the U.S. market.

Some recent findings may shorten this time period. Wierbicky and Heiligman (5) have found that radappertized cured meat requires about 80 % less nitrite/nitrate than does unirradiated meat. This is of interest because of the disconcerting observation that under certain conditions nitrites may react with free amines in food to form carcinogenic nitrosamines. Some toxicologists have advocated a ban on the use of nitrites as food additives. However, nitrite is used not only to produce the characteristic flavor and pink color of cured meats - it also inhibits toxin production by Clostridium botulinum. The hygienic hazard of not using nitrite may therefore be greater than the hazard of possible nitrosamine formation. At any rate, there is general agreement that the use of nitrite should be reduced as much as is possible without increasing the danger of botulism. The recognition that irradiation can help to achieve this goal should go a long way towards overcoming the rather negative attitude held by many administrators in the health ministries with respect to food irradiation.

One rather specialized application of irradiation, which I nevertheless consider as very important, is the sterilization of meals for consumption by patients who require a sterile diet (6). The necessary permissions having been granted in 1969 in the UK and the Netherlands, radappertized meals are being delivered to a growing number of hospitals in both countries. Patients receiving such diets are kept in a sterile environment because they are treated with drugs suppressing the immune response, e.g. patients who have received organ transplants or who suffer from leukemia. As a result of the drug treatment they are extremely susceptible to infections and must be protected from all pathogenic microorganisms. The importance of this application of the radiation process is not directly related to economics. The number of such patients is - fortunately - small and therefore the number of meals to be irradiated is limited. But the recognition that these patients, who are under very close medical observation, respond favorably to the irradiated meals, may be more convincing to some than the results of feeding studies with rats and mice.

Irradiation with a pasteurizing dose

Processes of this kind may have the goal of eliminating specific organisms of public health significance (= radicidation) or of increasing the refrigerated storage time by reducing the numbers of spoilage microorganisms (= radurization). Doses required are roughly in the range of 0.1 to 1 Mrad.

Radicidation is of particular interest with regard to the Salmonella problem. The incidence of infections due to various species of Salmonellae has been increasing in most countries. The news media report frequently about mass outbreaks of salmonellosis, particularly in hospitals, schools. aboard ships and in other situations where large numbers of people are fed from a central kitchen. Proteinaceous foods, such as meat and meat products, dairy products, eggs and egg products have often been identified as the vector of disease. Increasing world trade with food and feedstuffs and the increased role of mass catering have enhanced the risks, so that public health agencies see themselves forced to introduce the strictest standards of hygiene.

As Salmonellae are quite sensitive to radiation, a uniquely suitable process for hygienization is available (7). In contrast to heat, radiation can be successfully used on frozen products and on other heat-sensitive foodstuffs. In contrast to fumigation, e.g. with ethylene oxide, radiation kills not only organisms on the surface of a product but also in its interior. It also avoids residues of ethylene oxide and of interaction products (particularly ethylene chlorohydrine) which are toxicologically suspect. Another important advantage of irradiation is the fact that it can be applied to the packaged product so that reinfection is excluded. This cannot be done with fumigation and only under certain conditions (autoclaving, heat-resistant containers) with heat treatments. Radiation doses being much lower than those required for sterilization, effects of this treatment on sensory properties of most foods of animal origin are negligible.

Studies recently completed in our institute (8) have shown that the dose of 800 krad, which has been recommended for Salmonella control in frozen chicken, did not significantly affect color, odor, texture or flavor of chicken kept at -30^{o} C for periods of up to 2 years.

Considerably lower doses are required for controlling growth and reproduction of such parasites as trichinae (Trichinella spiralis) and tapeworms (Cysticercus bovis and Echinococcus granulosus) (7).

The extension of refrigerated storage life of meat, meat products, chicken, fish and shellfish by doses in the 100 - 500 krad range has been studied by numerous authors and the proceedings of the Bombay meeting of 1972 (1) contain several reports on this topic. Meat cuts require some special precautions to prevent discoloration, fat oxidation, and exudation of meat juices (9,10). Depending on product, dose, packaging and other factors the saleable shelf-life can be doubled or tripled.

There is general agreement that this also applies to packaged fish or fish fillets (11,12). We were interested to find out if on-board irradiation of <u>unpackaged</u> iced fish would also increase the storage life. This interest requires perhaps some explanation. German vessels have to travel very far before they reach good fishing grounds in the north-western Atlantic. The return trip from these regions to German ports may take 5 days or more. Because of the limited shelf-life of iced fish, the trawlers must return within about 15 days of the first catch in order to arrive with fish of sufficiently good quality. As this leaves less than 10 days for fishing, the trawlers must often return with incompletely filled holds. Poor utilization of the ships' capacity and an unfavourable ratio of fishing days to unproductive travelling days have caused great economic losses. If a method for extending the shelf-life of iced fish cannot be found, the trend to frozen fish will continue and within a few years fresh ocean fish will no longer be available - although most consumers prefer iced fish to frozen fish.

On the basis of laboratory studies it appeared that on-board irradiation of the freshly-caught fish with a dose of 100 krad would give the desired shelf-life extension (13,14). When this was attempted under practical conditions during several voyages of the research vessel "Anton Dohrn" in 1975, it was found that - in contrast to the situation in the laboratory - shipboard conditions cause immediate reinfection of the unpackaged fish so that the effect of irradiation is abolished and the fish spoils as quickly as it does without irradiation (15). Unfortunately, on-board packaging of whole fish is not considered to be practicable under the conditions prevailing on relatively small trawlers. Many species of fish have rather sharp scales and unless the fish is handled very carefully, cuts in the packaging easily occur, giving access to spoilage microorganisms. Filleting and irradiation of packaged fillets is theoretically a solution - but in practice the trawlers do not have enough space to accomodate filleting and packaging machines in addition to a radiation source. Also, the sales appeal of the whole iced fisch would be lost. The consumer would not see much difference between packaged refrigerated fillets and packaged frozen fillets. Under these conditions it is uncertain that the German fishing industry will continue to be interested in fish irradiation. This should not discourage workers in other countries who are interested in fish irradiation. Where coastal fishing is of greater importance than in Germany the outlook for irradiation on shore may be much better. This applies also to developing countries, where a frozen food chain is generally not an available alternative.

Our efforts concerning irradiation of North-Sea shrimp led to very encouraging results. My collaborator D. Ehlermann has submitted a paper on this topic for presentation during this meeting (16).

Reduction of microbial counts in spices and condiments, products such as dried onion rings and enzyme preparations by irradiation does not quite fit the definition of radurization or radicidation The purpose of the treatment is not primarily or not at all the improvement of the storage life of these products themselves but rather the avoidance of microbial contamination of the foods to which these products are added. Sausages prepared with contaminated spices, for instance, may spoil quickly. Treatment with fumigants is presently the only solution, as heat treatment would destroy or volatilize too much of the characteristic aroma. The chemical treatments have disadvantages, both from the health viewpoint (chemical residues and interaction products) and technologically (off-flavors, danger of recontamination during packaging). The spice industry has therefore shown a particularly keen interest in radiation treatments. A German manufacturer (Gewürzmüller, Stuttgart) was actually the first in the world to market irradiated food products (17). However, the van de Graaff-accelerator bought by this company to irradiate its spices had to be dismantled in 1959 when the new Food Law made food irradiation illegal. Several recent studies have confirmed the superiority of irradiation over other methods for the hygienization of spices (e.g. 18).

Irradiation of enzyme preparations used in food processing is also of considerable interest (19). These enzymes are produced either in microbial cultures or from animal or plant sources, such as calf stomach or the papaya plant. In each case, the raw product contains high microbial counts and constitutes a good medium for growth. Because of the heat-sensitivity of the enzymes mechanical methods such as centrifugation and filtration are the only means of purification. On the other hand, enzymes are very resistent to irradiation and this process provides an ideal solution to presently encountered problems.

Radiation costs for treatment with a pasteurizing dose should be somewhere in the range of 1 - 10 cts/kg, depending on dose and throughput. This is not a high cost compared to the benefits of improved hygienic quality and reduced spoilage losses.

Numerous animal feeding studies have been carried out with radiation-pasteurized fish and chicken. On the basis of such studies the Canadian Food and Drug Directorate has permitted test marketing of poultry (700 krad max.) and cod and haddock fillets (150 krad max.) in 1973. In the Soviet Union, the sale of experimental batches of poultry (600 krad) and culinary prepared meat (800 krad) was permitted in 1966 und 1967, respectively. Permission for the irradiation of limited batches (10 t) of spices and condiments (800 - 1000 krad) has been granted repeatedly in the Netherlands since 1971.

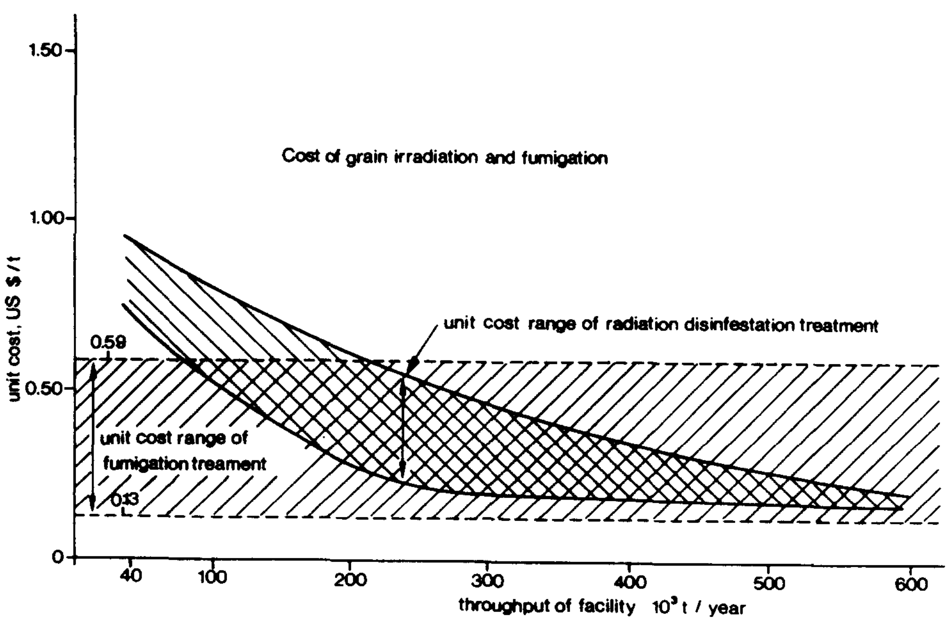
Several extensive feeding studies with irradiated ocean fish are presently being carried out under the auspices of the International Project in the Field of Food Irradiation (IFIP), about which I will say more later on. Provided that the results of these tests continue to show no adverse effects, this should open the way to worldwide clearances for fish irradiation. Abovementioned feeding studies on radiation-sterilized beef, chicken etc., should - again provided that the results continue to be negative - facilitate the clearance of the same products irradiated at a lower dose. The testing of spices and enzymes in animal feeding studies presents considerable difficulties. As these products are added to foods in low concentrations I think it would be reasonable to forsake animal feeding studies in this case and to base clearances on the results of chemical analysis. The Dutch health authorities have followed this line when they permitted the marketing of irradiated spices and condiments.

Insect disinfestation, quarantine control

Doses below 100 krad may be used to disinfest grain and other cereal products, pulses, fresh fruits, dried fruits, dried fish etc. The egg phase of the life cycle of insects is the most sensitive to irradiation, followed by the larval, pupal and adult stage in that order. Most insects are sterilized at doses of 5 to 20 krad. Some adult moth species are more resistant and will survive even 100 krad. However, the few progeny they produce under these conditions are sterile (20).

In most areas of the world, and particularly in warm, humid climates, grain cannot be stored without insect control. This is now achieved with chemicals, which are relatively cheap and quite effective. However, the growing concerns about chemical residues in the environment may strengthen the interest in physical methods of insect control, such as irradiation.

Summarizing the results of 5 cost evaluation studies which had been carried out between 1961 and 1972, Baĺazs-Sprincz (21) has produced the following graph, which indicates that the unit cost of fumigation of grain is independent of the quantities treated, while the cost of irradiation decreases with increasing throughput of the irradiator. According to these data irradiation should certainly be competitive with fumigation at annual throughputs of 200 000 t or more. It should be noted that, in contrast to irradiation, most chemical treatments leave residues which give continued protection against insect attack for weeks or months. Insect-proof silos are therefore more essential for radiation-disinfested grains than for chemically treated grains. However, this difference between irradiation and fumigation will be eliminated as persistent chemicals are more and more ruled out for health reasons.



Packaged flour and other packaged products cannot be adequately disinfested by fumigation while irradiation appears uniquely suitable for this purpose. Availability of this method would not eliminate the need for careful production methods: filth regulations make sure that products containing more than a minimal number of dead insects are kept off the market.

In spite of presently practiced fumigation with methyl bromide, dried dates exported from countries such as Iraq are frequently condemmned because of insect contamination. Intensive studies are therefore being carried out in Iraq with the aim of establishing the optimal conditions for radiation disinfestation of dates (22, 23).

In order to prevent the spreading of plant pests the movement of certain plants from country to country - or even within one country - is prohibited. Sometimes the plants can be disinfested by fumigation. However, there are situations where fumigation is not sufficiently effective because the organisms are located inside the fruit. This is for instance the case with mango seed weevils. Mangoes may therefore not be shipped from Hawaii to other parts of the United States. Irradiation could solve this problem and large new markets could thus be opened for mango producers (24).

Concerning the legal situation: irradiation of grain (30 krad) has been permitted in the Soviet Union since 1959. In the United States, wheat and wheat flour may be irradiated since 1963 (50 krad max), in Canada since 1969 (75 krad max). The Soviet Union has also permitted treatment of dried fruits (100 krad; 1966) and of dry food concentrates (70 krad; 1966). As far as is known no practical use is being made of these permissions in any of these countries.

Animal feeding studies with irradiated strawberries, papayas, mangoes and certain other fruits have been completed or are now being carried out. It may therefore be expected that clearances for disinfestation treatment of some fruits will be forthcoming in the near future.

Sprout inhibition, delayed ripening

All radiation treatments discussed so far are intended to affect microorganisms or parasites and not the food itself. In contrast, treatments to be considered in this section are intended to influence physiological properties of living plant tissue. The first permission granted for any food irradiation process concerned sprout inhibition of potatoes with a dose of 10 krad (Soviet Union, 1958). Since then the process has been approved in about a dozen other countries. A commercial potato irradiation plant ("Newfield Products") was put into operation in Canada in 1965. It was a financial failure and closed down within a year.

Construction costs of the Japanese potato irradiation plant mentioned earlier were 1.3 million U.S. $. Operating and maintenance costs, including repayment and interest on the invested capital, were 230 000 U.S. $ in 1973/74 when 15 000 t of potatoes were irradiated (15 $/t) and 245 000 $ in 1974/75 when 13 000 t were irradiated (19 $/t) (25). During the '75/76 season 30 000 t were to be irradiated, with expected costs closer to 9 $/t. Sprouting of potatoes can also be prevented by using chemicals such as CIPC (Chloroisopropylphenylcarbamate). This costs about 1 $/t. Capital investments are not needed - other than for a solid storage building into which the chemical can be blown as an aerosol. Depending on temperature and ventilation conditions, the CIPC gradually evaporates off, and for long-time storage the treatment may have to be repeated several times. If we assume that 3 chemical treatments are needed to prevent sprouting during 9 months of storage, this process is still cheaper than irradiation.

One way of lowering costs would be to use the irradiator for treating other foods during the months when no potatoes are to be irradiated, e.g. for sprout inhibition of onions. Clearances for irradiation of unlimited amounts of onions have been granted in 7 countries between 1965 and 1973. A generally accepted chemical method for sprout inhibition in onions is not available. A Dutch working group has designed an onion irradiation facility for which unit costs of 11 U.S. $/t are foreseen (26). A private investor is prepared to build this facility as soon as some countries which are the main importers of Dutch onions (such as West-Germany) have approved the process. The Dutch government has cleared gamma-irradiated onions (5 krad) in 1975.

In some tropical countries, yams are an important constituent of the diet. As Adesuyi has shown in Nigeria, sprouting, the main cause of the large storage losses which annually occur, can be prevented by a radiation dose of 5 to 10 krad, while various chemical treatments were not found to be effective (27). Here in Puerto Rico, Rivera et al. (28) have observed that a dose of 7.5 krad prolongs the storage life of yams at ambient temperatures by 4 months, with no appreciable effect on chemical composition.

Radiation doses in the range of 10 to 100 krad cause delayed ripening in many fruits such as bananas, mangos, guavas, sapodillas (28), thus providing increased storage life. Higher radiation doses tend to cause accelerated ripening or various types of tissue damage. Beneficial effects of low-dose radiation observed in fruits are often a combination of effects on the fruit's physiology and spoilage flora. Continued research is likely to show that low doses of irradiation applied together with hotwater dipping and/or skin-coating and/or controlled atmosphere storage will give better results than radiation alone or the other treatments alone.

Improvement of food quality

There are some indications that irradiation can be used to shorten the cooking time of some dried vegetables, to improve rehydration capacity of dried fruits, to improve the digestibility of soybeans, to increase the juice yield from fruits and berries, to have a favorable effect on the ageing of some alcoholic beverages or to be a tool for the production of modified starches (29). Whether any of these observations can lead to practically useful processes remains to be seen.

Food-related items

Rather large quantities of feeds for laboratory animals are routinely sterilized by irradiation (30). As the users of such feeds become aware of the advantages of radappertization over heat-sterilization and as more radiation sources become available, the volume of this application will certainly grow. This is of interest for two reasons. Firstly, radiation processing of such materials during periods of the year when no foods are to be irradiated will help food irradiation plants to operate more economically. Secondly, the observation that, year after year, laboratory animals are thriving on irradiated diets should help to convince the sceptics that irradiated foods are safe to eat.

Sterilization of food packaging materials and containers is another process that can help food irradiation facilities to better utilize their capacity. The Dutch food irradiation plant at Wageningen, for instance, is processing milk cartons round-the-clock when spices, or other foods cleared for irradiation in the Netherlands, are not available for treatment.

Why the slow commercialization?

Although some 17 countries have given complete or partial clearance for one or another irradiated food product, only the Japanese potato irradiator and - on a much smaller scale - the irradiation facility at Wageningen are producing irradiated foods commercially. This is sometimes cited as evidence that industry is not at all interested in food irradiation and that all further efforts in this field are a waste of money.

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 are removed. What good is a clearance for onion irradiation in the Netherlands or for potato irradiation in France if export to none of the neighboring countries is possible?

Also, irradiated products approved until now are not the most suitable ones from an economic viewpoint. This is particularly true for wheat and potatoes. These are bulk commodities with a low unit price. Even a small price increase to cover radiation costs will be significant in this case. Particularly when cheaper chemical processes are available. On top of this, both these commodities are seasonal. An irradiator specifically built for potato processing is idle 9 to 10 months of the year - while the cobalt-60 is disintegrating at a rate of 12 % per year. Compare this with the situation of a plant where spices are packaged or where enzymes are produced. Production continues year-round and irradiators could be utilized efficiently. Irradiation costs would thus be low in relation to the high price of these products. For similar reasons the economic outlook should be good for irradiation of meat and meat products (including game and fowl) - be it for Salmonella destruction or for extension of refrigerated shelf life. Some of the tropical fruits which are harvested all year and for which rather high prices are paid on export markets should be in the same class. These are the products that could bring the breakthrough for commercialization. But none of these have received unlimited clearance in any country.

Future development

Future progress thus depends primarily on the clearance of more irradiated products in more countries. Until now the granting of such clearances has been based on the satisfactory demonstration of wholesomeness by long-term animal feeding experiments (31). How involved, how expensive such studies have become may be illustrated by the fact that the completion of the U.S. Army's program for testing the wholesomeness of radappertized beef alone has required about 5 years and 5 million $ (32). It involved 1500 dogs, 27000 rats and 20000 mice.

In an effort to pool their resources for carrying out such costly testing programs, 23 countries have joined the International Program in the Field of Food Irradiation (IFIP) which has its headquarters in our Research Center at Karlsruhe. The attitude of the World Health Organization and of national health authorities towards clearance petitions for irradiated foods will be much influenced by the results produced under this program. As it stands now IFIP will terminate in 1979. Unless its work will have brought about a fundamental change in the evaluation of the wholesomeness of irradiated foods by that time, participating countries are likely to loose all interest in food irradiation. In view of the very large sums that have been spent on wholesomeness testing of irradiated foods over a period of some 20 years, it is the general feeling that "this cannot go on forever".

The U.S. Food and Drug Administration, and in its wake other national health agencies, have declared food irradiation as a food additive - but a different food additive with each foodstuff. Clearances for chemical food additives are based on feeding studies in which these chemicals are fed to animals together with a standard laboratory diet. When food additive X is to be used on oranges or raisins, nobody would think of demanding separate feeding studies with oranges and raisins containing X. It is sufficient to feed X with a standard rat or mouse diet. Not so with irradiation. Although scores of animals have been fed successfully with irradiated standard diets, clearance for irradiated oranges requires long-term feeding studies with irradiated oranges. Not enough. The "rules" state that the irradiation conditions for the test diet should be as nearly as possible identical to those likely to prevail in the treatment of that food in commercial practice. Taken literally this means that clearance for irradiated packaged fish fillets cannot be granted if the feeding studies were done on unpackaged whole fish. It also means that clearance for fish irradiated at 100 krad cannot be granted if the feeding studies were done with fish irradiated at 5 Mrad. According to present practice it is necessary to do feeding studies on irradiated rice before irradiated rice can be cleared - although irradiated wheat has been tested in extenso; feeding studies on mangoes have to be done although irradiated papayas and several other fruits have been tested for years. And so on.

This is absurd. Perhaps this approach was necessary twenty years ago when little was known about the effect of irradiation on foods. But it is not necessary now. The scientific literature on radiation effects has grown exponentially in these twenty years and we know more about radiation induced changes than about the effects of heating, smoking and curing. We can estimate the amounts of radiolysis products in irradiated foods and we find that, with a radiation dose of 500 krad for instance, no product is formed at a concentration of over 1 mg/100 g or 10 ppm (33). Actually, the only product found at this level is CO_2. Compounds of any potential toxicological significance are probably closer to one tenth or one hundreth of this level.

Under these circumstances it is senseless to go on with the old "item-by-item" feeding studies, petitions and clearances. If it is senseless it is also a waste of public funds. The time has come to recognize that irradiation is a process rather than a food additive - a physical process comparable to heating. I am not saying that no further research is required. Research is being done on heated foods although they have been consumed for thousands of years. Nor do I say that irradiation of all foods at any dose level should be permitted. I do suggest that enough animal feeding studies, enough teratogenicity, mutagenicity, cancerogenicity testing, enough microbiological studies and enough chemical analyses have been carried out to classify all foods irradiated with a dose of 500 krad or less as "generally recognized as safe" (GRAS). When the work now going on under the auspices of IFIP and of the Natick Laboratories has progressed with satisfactory results for another 3 or 4 years it should be possible to lift the dose limit to 5 Mrad. If this actually happens I have no doubt that the process will be widely accepted by food industries. If on the other hand the old "item-by-item" testing and petition requirements are still in force at the end of this decade, food irradiation will be a dead issue.

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