Recent Advances in the Preservation of Food by Irradiation

by Karoly Vas

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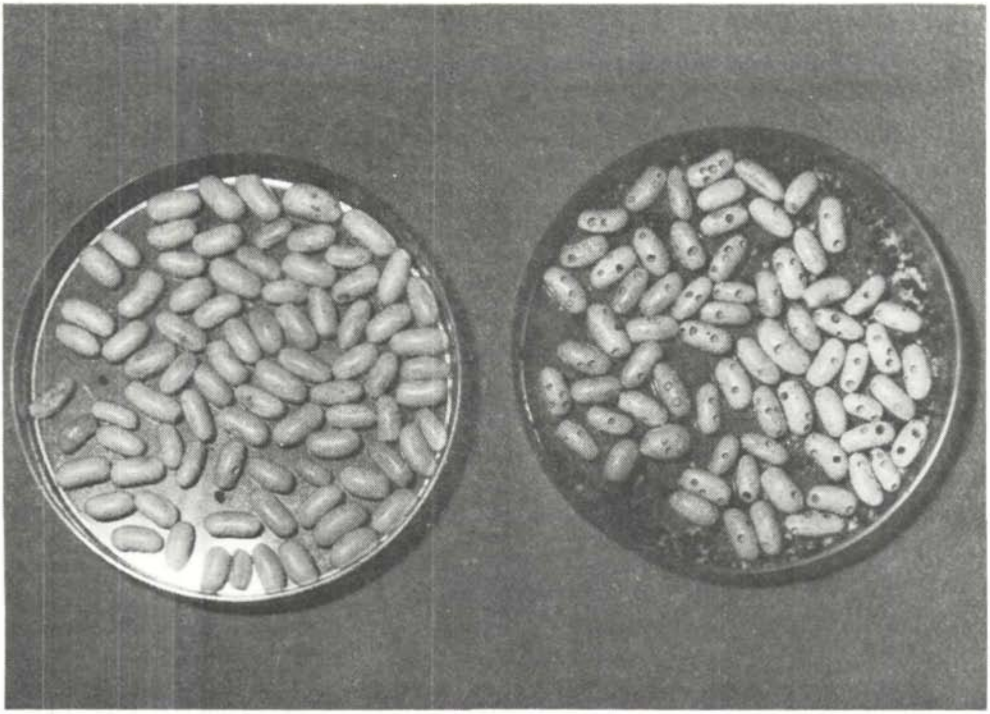
We are living in a world confronted with two interdependent global problems: the problem of energy and the problem of food. Neither can be solved satisfactorily without remedying the other. To carry the argument to the extreme, efficient food production at the global level can be achieved only with the aid of artificially produced energy, and unless mankind has the food necessary for survival, there will be no need for that energy. The IAEA has interest and obligations in both problems. In these fields its activities are directed towards using the atom to produce energy, and to improve the world food situation (in projects carried out jointly with FAO).

There are two ways in which the world food problem can be attacked: (1) by increasing food production, that is, growing more food by utilizing agricultural knowledge and material input, and (2) by preserving more of the food that is already being produced by utilizing food science and technology. While both lines of action should be followed, it is logical that preservation should play a key role not only because it would reduce wastage of existing food that is desperately needed by millions of people, but also prevent the wastage of the energy invested in growing food.

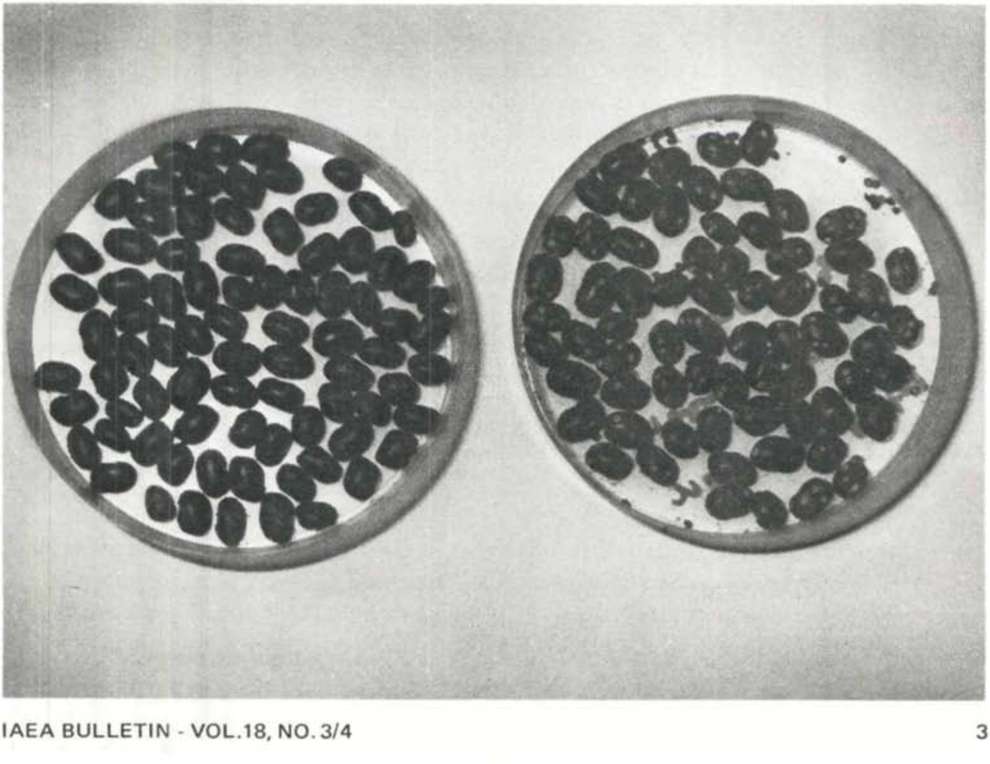
The preservation of food is, therefore, a vital technology, and studies of both traditional food preservation methods and new techniques should be actively pursued. The irradiation of food, usually by gamma rays from a cobalt-60 source, offers advantages over traditional methods. Irradiation not only can delay the processes that lead to the onset of undesirable physiological changes (sprouting, over-ripening), microbial spoilage (rot, mould formation) and damage caused by insects, but also can kill disease-causing organisms that will infect the food if it is left untreated. It is rather surprising to find that after 25 years of extensive studies, practical introduction of food preservation by irradiation has only recently been started in one Member State of the IAEA. The main obstacles are of a psychological nature, but a number of other problems also remains to be solved. Nevertheless, it is clear that many questions have already been settled and significant progress has been made. Some of these developments will be briefly enumerated below. However, it should be noted right at the onset that, like the conventional methods, irradiation also has its limitations and cannot be considered a cure-all for all food problems under all conditions.

TECHNOLOGICAL AND ECONOMIC FEASIBILITY

As with all new food processing methods, food irradiation too has to undergo a three-way test of suitability before it can be introduced on a commercial scale. First, it has to be shown that the new process is technologically feasible, for example, that it yields products



Infestation of white kidney beans (top) and cow peas (bottom) by the weevil *Zabrotes subfasciculatus* can be virtually eliminated by low-dose irradiation. Photo: IAEA/Holzinger



of acceptable or superior quality under practical conditions, or that it can save products from spoilage for a longer time, preferably also under more adverse conditions. Second, the new process has to be economically feasible (its costs should not exceed its benefits). Third, it has to be proven that the new product is wholesome and safe for human consumption.

As far as work on the first two preconditions is concerned, *recent* developments can be highlighted as follows:

Technological feasiblity: Work on radiation sterilization (radappertization) of **meat** (beef, pork, ham, chicken) is in progress in the USA (Natick Development Center) with positive results. Meat slices of excellent quality, packaged in special plastic pouches, can now be produced by a combined irradiation process (4–7 Mrad, see *Bulletin* Vol.15, No.1). The product has a shelf life of several years even at ambient temperatures. Radappertized meat is especially advantageous for supermarkets, vacationers, campers, airline caterers, as well as for the armed forces. The final results of this multi-million dollar project will become fully available in the next few years. Radappertization has been shown to reduce the nitrite + nitrate requirements of cured ham by about 80%, thereby reducing the cancer hazard associated with the nitrosamine content of hams produced by adding nitrate to the meat during curing.

Bulgarian work on radappertization of **protein preparations** of vegetable and animal origin show that irradiation (1.5–2 Mrad) is capable of producing practically sterile meat extenders.

Recent experiments in the Federal Republic of Germany confirm the usefulness of radiation treatment of **enzyme** preparations. It eliminates or substantially reduces the bacterial content without appreciably changing the enzymatic activity.

Research on the irradiation of **fish** and **fishery products** is being carried out in several laboratories, especially in South East Asia (Bangladesh, India, Indonesia, Republic of Korea, Pakistan, the Philippines). The aim is to prolong the useful shelf-life of fresh and processed (dried, salted-dried, cooked) fish, mainly mackerel. The storage life of iced, fresh fish can be extended by a factor of between 2 and 5 by moderate doses of ionizing radiation (0.15–0.25 Mrad).

Salmonella control in **frozen chicken** (0.8 Mrad) has been found feasible in recent experiments carried out in the Federal Republic of Germany. This would improve the hygienic quality of the products considerably.

Recent experiments on **spices** (Egypt, Hungary, Poland) confirm earlier findings showing that these products, which are normally severely contaminated with micro-organisms, can be sanitized by irradiation (0.3–2 Mrad) without losses in aroma or colour. This process would greatly improve the hygiene of several foods since, at present, spices are an important source of microbial contamination in spiced foods, leading to early spoilage or to health hazards.

French work on radiation sanitation (0.3 Mrad) of **starch** preparations led to the designing of a pilot plant with a large throughput capacity. Irradiated (0.5–1.5 Mrad) starches with modified technological properties have been investigated in the USSR and Egypt.

Brazilian and Egyptian reports show the suitability of radiation disinfestation (0.01–0.075 Mrad) of **beans**, a staple food of considerable importance in meeting the protein requirements of the population. Irradiation against insect damage in **cereals, lentils** and **coffee** is also effective.

Mexican pilot-scale experiments with **maize** disinfestation by radiation indicate that the process is technically feasible.

Work carried out in Iraq on radiation disinfestation (0.05 Mrad) of **dates** gave encouraging results.

In Hungary it was found that velocity and extent of rehydration of **dried vegetables** can be improved by treating the vegetables with doses of between 1 and 3 Mrad. This decreases the cooking time requirements, thereby reducing the energy consumption in the households and in industrial cooking.

The most successful practical application achieved to date in the radiation control of physiological processes in fresh vegetables is sprout-inhibition in **potatoes.** An agricultural co-operative on the island of Hokkaido, Japan, has successfully operated a commercial-sized potato irradiator (throughput capacity: 0.2 Mrad m^3h^{-1}) since 1973, treating 15 000, 18 000 and 30 000 tons of potatoes in three successive seasons with doses around 0.01 Mrad. Reports on favourable results of large-scale consumer tests (with several tens of tons) of potatoes come from Chile, the Federal Republic of Germany, Hungary, Italy and Uruguay. Radiation-treated (0.005 Mrad) **onions** showed reduced internal sprouting and, consequently, increased suitability for long-distance shipment (*e.g.* between Thailand and the Netherlands). Irradiated onions also give higher yields of onion flakes (Hungary).

Mango irradiation (0.075 Mrad) in South Africa retarded maturation, thereby making it possible to transport the fruit over longer distances, for example to European markets, and simultaneously eliminated plant quarantine problems by killing the mango weevil, even at the centre of the fruit where no insecticide can possibly reach.

Bulgarian work carried out in the German Democratic Republic confirms the suitability of radiation preservation (1.2 Mrad) of **fruit** (apple) **juice concentrates.**

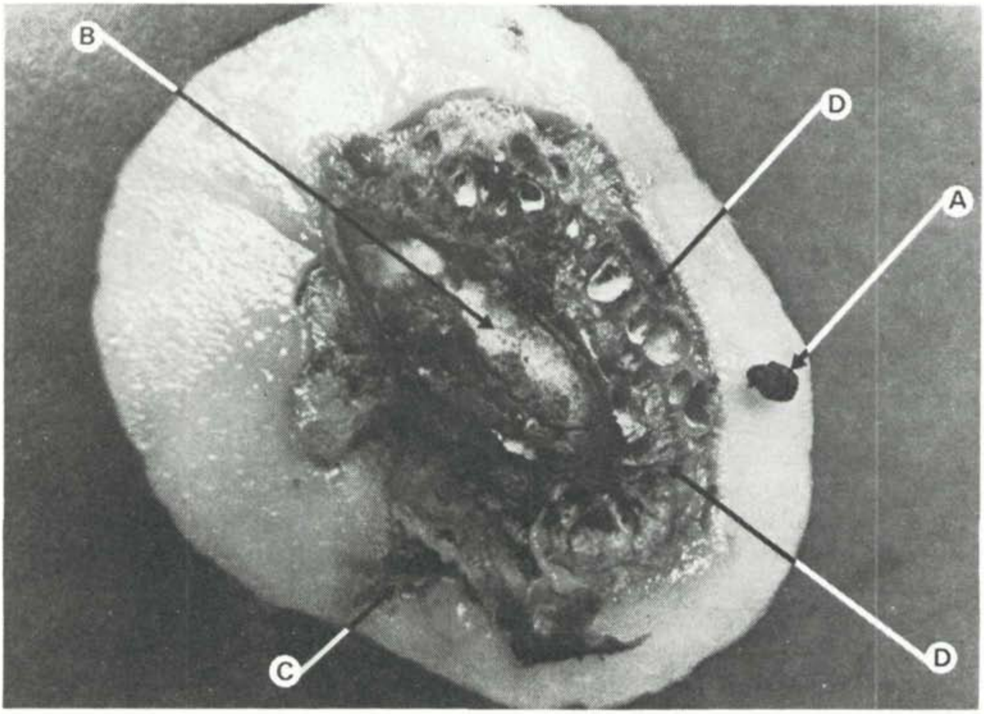
Experiments in Nigeria and in Puerto Rico show that the sprouting of **yams** can be prevented by irradiation (0.005—0.1 Mrad).

Research in Hungary demonstrated that the juice yield of **grapes** can be increased considerably by irradiation (0.2—0.4 Mrad) prior to pressing.

According to reports from the Netherlands, **cartons for milk** are being routinely irradiated to achieve commercial sterility.

Radiation sterilization of **animal food** (mainly for laboratory animals) is an established practice in several countries (Australia, Austria, Canada, France, Israel, Japan, the Netherlands, UK). A yearly total of some 700 tons of irradiated (2.5 Mrad) laboratory animal diet is sold, enough to feed 180 000 rats or 900 000 mice per annum on a totally irradiated diet. This, actually, constitutes a huge wholesomeness experiment involving — over the last few years — a total of several millions of laboratory animals, which continue to grow excellently on the irradiated feed. It has been reported that in some countries (for example, Israel) irradiation of feed for chickens is being planned in the near future.

On the question of **economic feasibility** of food irradiation, a background paper for a 1974 advisory group meeting of the IAEA made a comparative study of data published between 1961 and 1972. The analysis of data on the economics of the radiation



Cross-section through a Kent mango shows damage caused by the weevil and secondary infection in the insect's exit hole. A — mango weevil; B — seed; C — weevil's exit hole; D — fungal disease.
Photo: Nuclear Active, South African Atomic Energy Board.

treatment of potatoes, onions, mushrooms, grains, meat and fish showed that one of the main factors of profitability is the size of the operation, specifically, the annual throughput capacity of the plant. For every product, there is a threshold value above which the process becomes competitive with traditional techniques of preservation, even the cheapest one.

A number of new economic calculations have been prepared lately in various countries. Calculations on the cost of irradiation of certain products were published recently in Canada. Cost-benefit analysis of these data shows that with several items irradiation is economically feasible. The costs of the treatment frequently constitute only a few percent of the value of the commodity. The value of the material that can be saved by the treatment may many times be more than the cost of the process.

A general evaluation of the economics of food preservation by irradiation in Brazil showed that large benefits could accrue from the commercialization of sprout inhibition of potatoes and onions, and disinfestation of rice, beans, corn, corn flour, wheat, wheat flour and coffee.

Recent calculations from Uruguay indicate that establishment of a food irradiator to treat 25 000 tons of potatoes, 5000 tons of onions and 500 tons of garlic per year would be profitable.

Cross-section of onions stored in a chilled room. The irradiated onion (left) shows no sign of sprouting, while the untreated onion has begun to sprout.

Calculations performed in the USSR concerning the economics of radiation prevention of sprouting in potatoes, to be used for producing dehydrated potatoes, showed that the radiation treatment would cost considerably less than the usual chemical treatment and would have an amortization period corresponding to the one that is usual in the food industry.

It is well known that technological and economic feasibility can only be studied in larger-scale experiments. These, in turn, can only be performed with radiation sources larger than those found in the laboratory. Pilot plant irradiators must be capable of handling from a few hundred to several thousand kilograms of material within a short period of time. A list of such facilities has been compiled and published in the *Bulletin* recently (Vol.17, Nr.6, 1975).

Recent Dutch calculations, based on successful multi-ton experiments, showed the economic feasibility of onion irradiation in a plant of a yearly throughput capacity of 20 000 tons at a dose of 0.004 Mrad. Reports from India and Thailand also gave encouraging data.

Thus, it appears that progress has and is being made in clarifying the technological and economic feasibility of food irradiation. What is urgently needed now is intensive international collaboration in this field. In spite of various national and regional efforts (EURISOTOP, EURATOM, EEC), the problem of technological and economic feasibility of irradiated food has still not been clarified on a *large-enough scale* and in the necessary detail. In order to speed up progress in the practical introduction of food preservation by irradiation, an international project on the technology and economics of food irradiation is deemed necessary.

SAFETY FOR HUMAN CONSUMPTION

The safety for human consumption (wholesomeness) of irradiated foods is one of the most important aspects in need of further studies and final clarification before the process can be introduced on an international scale. Accordingly, studies of unprecedented depth and volume are underway to settle the question of wholesomeness, both at the national and the international level. The largest wholesomeness study is now being carried out in the USA, organized by the Natick Development Center. The magnitude of these efforts can conveniently be characterized by the annual budget for studies on beef radappertization, which is around US $2 million. More than half of this amount is earmarked for wholesomeness studies. Recently, the number of meat foods to be examined has been expanded to cover pork, ham and chicken, and the annual budget has been increased to more than US $5 million. The results obtained to date with radappertized beef failed to show any harmful effect.

Although smaller in financial size (about US $0.3 million per year), the studies directed by the International Project in the Field of Food Irradiation (IFIP, Karlsruhe) are of no less importance. This autonomous project, launched by the IAEA, FAO and OECD(NEA) and financed by 23 countries, originally aimed at performing confirmatory studies on wheat and wheat products, and potatoes. These studies were requested by the 1969 Joint FAO/IAEA/WHO Expert Committee on Wholesomeness of Irradiated Food.

The scope of the studies of IFIP was extended to include fish, spices, rice and mangoes for wholesomeness testing, as well as research on the methodology of wholesomeness testing of irradiated food, including a search for quicker ways to establish safety and devising cheaper methods which place high reliance on the extrapolation of results from animal to man.

The fact that all these studies are being carried out under contract in independent laboratories in various countries is expected, and intended, to ensure that the results are completely objective.

These data will be submitted to an international Expert Committee to be convened jointly by the FAO, IAEA and WHO in September 1976 in Geneva for evaluation and recommendations. A preliminary WHO Consultation in 1974 found the toxicity data generally satisfactory. The same was found for the microbiological aspects of the wholesomeness of food irradiation at a consultation convened by the FAO/IAEA in 1974 in Vienna.

As a result of intensive wholesomeness studies in a number of countries, approvals for several irradiated food commodities were granted recently. At present, 25 commodities have received restricted or unrestricted clearance in one or more of 18 countries having legislation on food irradiation. General (unrestricted) clearance for onions was granted in the USSR in 1973 and in the Netherlands in 1975. Approval in principle was given in

1973 in Canada to test market irradiated (0.7 Mrad) chicken for salmonella control, and similar clearance was granted for irradiated (0.15 Mrad) cod and haddock fillets. In 1976, the Netherlands granted full approval for irradiated chicken.

OUTLOOK

It is expected that several other irradiated foods will receive general clearance for human consumption in the near future. This should stimulate the implementation of the process into the food industry. The rising concern regarding the increase in chemical residues in man's environment, and especially in food (*e.g.* thousands of tons per annum of pesticides and fumigants in internationally marketed grain), should further increase the interest in this new alternative.

An additional development could be the rise in cost of these chemicals caused by the increase in the price of petrochemicals. Furthermore, the world-wide shortage in energy automatically directs attention to irradiation as an energy-saving method of food preservation.