Interview: Dr. Edward S. Josephson

The road to irradiation breakthroughs

Dr. Edward S. Josephson, a pioneer in the development of food irradiation, headed up the U.S. Army Natick Laboratories research program from 1961 until his retirement in 1975. Josephson, a Senior Lecturer at MIT, has written and lectured extensively on the subject and is recognized worldwide as an authority on the technology. He was interviewed on Nov. 20 by Marjorie Mazel Hecht, managing editor of Fusion *magazine.*

Q: You are one of the U.S. pioneers of food irradiation, going back 25 years or more. What started your interest in the technology?

Josephson: I got interested because the Army was interested when I was with the Army laboratory in Natick, Massachusetts. I heard wonderful stories from the philosophical father of food irradiation in the United States, Dr. Ralph G. H. Siu. He got food irradiation started in a really serious way in the U.S. government. He's a scientist, a philosopher, an author of a number of books; he's the father of food irradiation.

Q: What did he do to get the technology started?

Josephson: He convinced the Defense Department that this was a process that should be looked into for potential military feeding systems, and he also had the vision to see the much broader implications for civilians worldwide. I used to hear about this from him. Food irradiation was not under my purview in those days, and I was very much impressed by what I heard and what I could see about its potential. One day the scientific director at the Natick Laboratories called me in and said he was going to put me in charge of the food irradiation program. So that's how I got into it.

Q: When was this?

Josephson: This was back in 1961. On Feb. 1, 1961, I took charge of the food irradiation program at the Army's Natick Laboratories. At that time, Dr. Siu was in Washington in the Office of the Quartermaster General, so he was an echelon above me. He gave me a free rein to do what had to be done, what I thought best. He also made sure that we had the funds—that was most important, of course—and the personnel to do what had to be done.

Dr. Siu also saw to it that a top-notch facility with which to do this work would be constructed. So when we started off, we had the facilities, the funding, and the personnel.

Q: What kind of a research program did you design?

Josephson: We designed a program to work on the foods that were most important to the military. Our aim was to get the technology completed, the processing completed, and the safety for consumption assured, in order to petition the Food and Drug Administration for permission to use these products. I was concerned with the technology of the foods and the processing—in other words, the acceptability of the foods, the nutritional quality and the microbiological safety of the foods. We also made funds available to the Army's Surgeon-General to do the toxicological testing of these foods.

We had to assure ourselves that we would not induce radioactivity in the foods, above the background level; this meant that we had to carefully check out using an electron beam accelerator as a source of the radiation, to determine the conditions under which an accelerator could be used safely without making the foods radioactive above background. We also had to look into the health physics aspect, so that the radiation facilities we used would not be harmful to the people in the laboratory.

Also, since our lab was right across the street from private homes, we had to assure that these people would not be subject to any hazards. This was back in 1961. I think if anybody tried to put a facility like ours close to a populated area today, they might have some trouble with the environmentalists. But in all the years that we operated, there was not a single accident that would have jeopardized the safety and health of anyone. We were also located on the shore of a lake, and we had to make sure that no radioactivity would get into the lake and make the lake unusable to the people who had homes there.

These were just some of the aspects of the technology that we had to work out. We were pioneers. Our radiation source of cobalt-60 for food processing at that time was the world's largest source.

Q: What was it in curies?
Josephson: It was at that time about a million and a half curies of cobalt-60 when it was loaded in 1961.

Q: So the Natick lab began in 1961 and continued for about 20 years.
Josephson: Yes, it operated there for just about 20 years, although I retired at the end of 1975, and Dr. Ari Brynjolfsson took over when I retired. In those 20 years, we had only one episode where the cobalt-60 source malfunctioned: It jammed on its elevator. The cobalt-60 is in the bottom of a pool of water. When food is to be irradiated, the cobalt-60 is raised on an elevator, and the food comes on a conveyor and is exposed to the radiation. When you're through with the radiation process, you lower the elevator, and the cobalt-60 source rests at the bottom of the pool. Somehow the elevator got jammed, and it took several days to work from the roof and straighten it out and then lower it to the bottom of the pool. That was the only episode in about 20 years, and at no time was there any danger to the environment or to the people working in the area. . . .

Q: How would you sum up your accomplishments?
Josephson: We took products that originally were marginal at best—from both a taste point of view and from a nutritional point of view—and we worked out a food irradiation sterilization technology of excluding oxygen from the process and also of applying heat to inactivate the enzymes that would have made the food get soft and mushy upon storage at nonrefrigerated temperatures. From this, we were able to develop food products that match or come close to matching nonirradiated, foods, even after two years' storage without refrigeration.

Q: Were you working with produce as well as meats?
Josephson: Before I took over the program, the Army was involved in irradiating all foods. But when I came in, there had been a realignment of the program where the Atomic Energy Commission concerned itself with the low-dose applications to fruits and vegetables and cereals, and we were concerned with the *high-dose* applications that were based mostly on meat, poultry, and seafood.

I felt we had, by far, the more difficult task, because we were using very, very high doses—maybe 10 or 100 or even 1,000 times higher doses than the low-dose program that was then carried out by the Atomic Energy Commission. We dealt with the high dose to get products that could keep without refrigeration for long periods of time, and yet maintain the texture, the nutritional quality, the flavor, and the color, and so forth, of foods that had not been irradiated.

The only other way you could keep these foods for long periods of time was either to freeze-dry them or heat-sterilize them. Of course, you cannot freeze-dry whole turkeys, or whole roasts of beef, lamb, pork, or ham, etc. We were concerned with developing a process that did not require refrigeration, so freezing was out. We would be comparing our process with heat-sterilization or drying. The drying was applicable only to thin slices or powdery material and was ungodly expensive, so freeze-drying couldn't compete. Therefore, our major basis of comparison was with heat-sterilized canned foods.

One of the first things we did was to create the right kind of packaging for the irradiation-processed food. The can was developed for sterilization at high temperatures, and since we developed a process of radiation sterilization at low temperatures—between −40° and −20° Celsius—we had to check into the packaging, do a thorough job. We looked at metal cans, at the liners of the cans, at the sealing compounds, at the solder that's used in cans, at the structure of the can to maintain a high vacuum in the frozen state. We had to develop the best packaging systems, and we arrived at flexible packages. We worked out three layers of laminates: a plastic liner that the food contacted, an aluminum foil middle layer, and a plastic layer on the outside, with sealing materials to hold the three layers together.

We had to make sure that these materials would not impart molecular fragments to the food as a result of the radiation; that they would maintain their integrity. They could not get brittle or develop pinholes—in other words, they had to maintain their flexibility even at low temperatures. So we developed a whole line of packaging materials and got them approved by the FDA. We later developed even more materials that were ready to go to FDA, but our lawyers at Natick said, why submit petitions if you don't have any foods cleared to put in them?

So we pioneered in packaging. I don't think any other laboratory had even done anything with packaging, and I would consider our packaging as a big success story.

Q: I think that you also pioneered in the foods to put into the packaging.
Josephson: Yes. In our technology for developing the high-dose irradiated foods, we were able to conserve the nutritional quality of these foods so that in many cases there is less destruction of nutrients than with thermal processing; in no case was there any more destruction of nutrients than with thermal processing. We were also able to work out the conditions of inactivating enzymes so that the foods would not get mushy—as I said earlier—or become bitter, as a result of enzymatically catalyzed breakdown of food constituents in the packages stored for at least two years at room temperature. That was a big accomplishment.

We were also able to prove that the foods would not be hazardous to the consumer. Specifically, at Natick, we were able to identify the products formed as a result of irradiation and show that they were not unique to irradiation. You would find practically every one of these products in other foods that were not irradiated.

Q: That's of course one of the big screaming points of the environmentalists, that radiation creates "unique radiolytic products" in the food.

Josephson: That's right. There are no "URPs." And based on our work with radiolytic products, the FDA has now been willing to accept the *chemiclearance principle*. That is, if you did a complete toxicological evaluation with animal feeding studies over a long period of time on one food; and if you showed that you knew the composition of a food to begin with and the conditions of irradiation (such as the temperature of irradiation, the radiation dose, and the exclusion or nonexclusion of oxygen), then you could predict what the radiolytic products would be. And since the radiolytic products that we isolated and measured in the case of beef were deemed nontoxic by a panel of experts, the FDA said that if we gave them the deemed nontoxic by a panel of experts, the FDA said that if we gave them the radiolytic product data for ham, pork, chicken, fish—all foods of animal origin—and one big toxicological study, then we could clear the whole family of meats and poultry. That's what the chemiclearance principle is; instead of clearing foods item by item, a whole family could be cleared at one time.

I think that the Natick Laboratories should take full credit for developing the chemiclearance principle that now the FDA, the international community, the World Health Organization, and so forth, have accepted. That is, I think, our most significant accomplishment.

The other significant accomplishment, of course, is the long-term animal feeding studies that were conducted over the years. Even though many of them done during the 1950s and 1960s may not have met the criteria for proof of safety established in the late 1960s or '70s or '80s, I think that we paved the way by showing that there is nothing harmful that we could detect—or that anybody else could detect.

We also worked out the technology for the use of the electron accelerators. We developed this to be a reliable workhorse in the laboratory.

Q: What kind of an accelerator did you have?

Josephson: We had an electron linear accelerator that was manufacturated by Varian Associates in Palo Alto, Calif. The machine was built in 1956-57 and was originally destined to go into the Army quartermaster's facility in Stockton, Calif., but it was later determined that it should go to Natick. The facility at Natick was not completed until 1962, so that by the time we got this unused accelerator at Natick, it was already obsolete. The machine had to be turned on, warmed up, and tuned, and we had a lot of trouble getting it to work

Irradiation: More food and better food

The commercialization of food irradiation will not only begin to "conserve" food by extending shelf-life and saving the 25% of U.S. meat and produce that now is wasted because of insect and rodent infestation or spoilage; it will also give us better quality food.

Today, salmonella contaminates an estimated 55% of our chicken, and the United States has one of the highest rates of trichina in pork (for this reason a number of European nations embargo U.S. pork products). Both problems could be eliminated by processing poultry and pork with low-level irradiation. In fact, the National Pork Producers Council has passed a resolution to "rid the pork industry of the trichinae organism" and backs food irradiation as the way to do it. Chopped meat, where bacteria cause sliminess and a putrid odor, or frozen beef and frozen shrimp, which have a high salmonella contamination rate, could also be treated with low-level irradiation to eradicate the pathogenic bacteria. A 1976 U.S. government report estimated that there were 2 million cases of salmonellosis yearly; the Atlanta Centers for Disease Control now puts the cost of this to the economy at $1.2 billion per year. Recently, the Canadian government estimated that salmonella led to between 10 and 15 million cases of gastroenteritis per year, and the Canadians are now test-marketing irradiated chicken to eliminate the problem. Atomic Energy of Canada, Ltd. estimates that 250 irradiation facilities could eliminate salmonella in poultry at a cost of merely 2¢ per pound.

Although the Food and Drug Administration's proposed new regulation would permit 100 kilorads of irradiation for fruits and vegetables and for pork—only one-tenth of the accepted international standard—the benefits of this low-level irradiation will be tremendous, especially if the FDA also permits irradiation of fresh poultry and fish. It would extend the refrigerator shelf-life of meat, poultry, and fish, for example, by four to eight days; it would reduce salmonella by 99.9%; it would destroy triproperly because of its complexity and its obsolete design. It was like doing the Indianapolis 500 with a Model-T Ford.

But because it was a piece of capital equipment, we had to show that we got our money's worth out of it; we couldn't just junk it and get another one. So we brought in Dr. Ari Brynjolfsson as a visiting scientist from Denmark in 1962 to try to get the machine operable, to make it work. He decided that the only way to get it to work was to rebuild the machine but to keep the outside shell, so that we could always say we didn't throw the machine away! And he trained a staff of young eager-beavers and went back to Denmark. Then he joined us permanently two years later. He made that machine work, and toward the end, it became a real workhorse. When that cobalt-60 source jammed for a week on the elevator, the accelerator was the major source of radiation.

Q: Did you do all of your experiments both with cobalt and with the accelerator?

Josephson: We also used a cesium irradiator. Dr. Brynjolfsson felt that as long as we are working with the sources without bias toward any one, we owed it to the taxpayers to explore all three major sources—electrons, cobalt, cesium. We also fixed the accelerator to have the electrons hit a heavy target and create x-rays or what's called Bremsstrahlung radiation.

We also worked out the technology of dosimetry; we had to develop dosimeter systems that could be used in a practical way, not just the highly theoretical calorimeters that measure temperature rise as a function of absorbed radiation. The dosimetry group developed new systems suitable for use in commercial production, for high-dose food irradiation—another area we pioneered.

Q: By the end of the Natick program in 1981, then, you had actually established that the technology was safe at much higher doses than the 100 kilorads now being considered by the FDA.

Josephson: Yes, we established the safety of the technology at much higher doses than anybody else in the world had considered. We were the only laboratory working seriously at *sterilizing* doses for food. Even today, people say, "Oh, it's not practical." I was just in Israel, and one of the retired scientists from the Atomic Energy Commission came to see me at my hotel, and he sort of pushed it aside. He didn't think there would be any practical use for high-dose food irradiation. When I told him that he was mistaken, he said, well maybe not in the next 25 years. And I said, you are very, very much mistaken, because we have indications from the grocery-line people in the big packing houses and supermarkets that they would love to see shelf-stable meats and seafood items in large containers—not those flimsy little sardine cans or small cans of salmon or tuna fish. They would like to

china (at only 30 kilorads) and other pathogenic bacteria.

The benefits even at this low level extend to other products. Sprouting in potatoes, onions, and garlic will be inhibited; insect eggs won't hatch in grains, cereals, or flour; bananas won't brown so fast; strawberries will last three to four weeks before getting moldy; citrus fruits can be disinfested after harvest and shipped interstate without live insects or insect eggs; and so on.

Sterilized foods

At higher levels of radiation, of course, the benefits are even greater. The number of vegetative bacteria, molds, and fungi can be reduced by a factor of 100,000 (10^6) with a dose of 100 to 1,000 kilorads, depending on the food product. A similar reduction in the number of dried or frozen vegetative bacteria, fungi, and spores can be obtained with a dose of 200 to 2,000 kilorads; and the number of viruses can be reduced by 10^6 at doses of 1,000 to 4,000 kilorads.

At sterilizing doses, usually in the range of from 2,500 to 4,500 kilorads, no viruses, parasites, or pathogens remain in the food, and when properly packaged, radiation-sterilized foods can be *stored indefinitely at room temperature* without a loss of wholesomeness or taste. One of the measures for a sterilizing dose is that which will reduce the number of spores of *Clostridium botulinum* from 1,000,000,000,000 to 1. All the astronauts eat radiation-sterilized food when they are in space, because it tastes good, stores easily, and is guaranteed to be pure. Hospital patients with immune system deficiencies and other conditions would similarly benefit from radiation-sterilized meals.

Although the scientific experts have determined that foods irradiated at up to 5,800 kilorads are safe and wholesome, the only items that the FDA now permits to be irradiated above 100 kilorads are spices, onion powder, and garlic powder, for which there is a limit of 1 megarad (1,000 kilorads). This dose is enough to reduce the level of bacteria by 3 or 4 orders of magnitude, whi proposed dose of 3,000 kilorads would ensure that the spices would be "commercially sterile." To give you an idea of the problem, the common herb tea chamomile ordinarily contains a level of bacteria of 10,000 per gram.

see whole roasts, whole birds, turkeys, chickens, and so forth, on the shelves rather than in the refrigerators or frozen food chests. I have letters from producers, processors, and supermarket executives, endorsing the high-dose program.

One of my colleagues, Dr. Eugen Wierbecki, and I made a survey in 1972. We packed our bags with samples and criss-crossed the United States several times to get a cross-section of the meat industry, the seafood industry—and when I say seafood I'm including the shrimp producers down in the Gulf area. We went from coast to coast and north to south, from the Canadian border to the Mexican border. And we left a letter with the chief executive asking them whether they thought the technology was worthwhile, whether they could use the irradiated products, and were interested in them. In every instance but one, they said "absolutely, yes."

Q: I don't think there's any question now that the industry is interested, and that the safety has been established. Why is the FDA taking so long to approve?
Josephson: It's on the labeling issue. In the mid-1960s, the FDA asked for suggestions on what the label should have to identify the irradiation process.

Q: In the 1960s?
Josephson: Yes, in the mid-1960s. And we put our heads together, the whole team at Natick, including our legal department, and came up with the words "ionizing energy." We felt that this was scientifically sound, and not misleading. Well, FDA rejected that. It had its own mind really made up and wanted the word "gamma radiation," or "electron radiation," or "ionizing radiation." This is now legally, by regulation—not by law, but by regulation—what is required.

Now when the proposed new FDA regulation was ready to be printed up in 1981, evidently some people in the industry got to [Health and Human Services Secretary] Margaret Heckler and told her that they were opposed to any stigmatizing labels, such as having the word "radiation" in it. But the FDA was insisting that it have such a label. So there was a difference of opinion between the Secretary of Health and Human Services and the FDA.

In 1980, a Joint Expert Committee of the Food and Agriculture Organization and the World Health Organization was convened in Geneva. The statement in their report was that there was no valid *scientific reason* for a label to identify the irradiation process; the process, being safe, should be treated like any other process. They used the words "scientific reason," because it's a political reason, not a scientific reason, that has tied up the proposed approval by FDA.

In 1982, a panel convened by the International Atomic Energy Agency in Vienna to consider consumer aspects, wrestled with the labeling problem. I was the chairman of that panel. We subdivided into three subcommittees to look at different aspects of concern to consumers, and one of the subpanels focused on the label issue. The chairperson of that subpanel was a consumer representative. And on her subpanel was a young gentleman who occupied a similar position with the consumer organizations in France. And we had another woman from Bulgaria, a grandmother; and a woman from the Netherlands with teenage children; and the head of the food irradiation program for Israel on that subpanel.

I was surprised that this subpanel on labeling, chaired by Marilyn Young, recommended against an identifying label on the retail package. I asked them to list the pros and cons in the report, just to make a statement, because I said, this is a very, very important issue. And then, in the plenary session, I asked each member, "Do you support this without reservations?" I gave every opportunity to the panelists to reconsider themselves or renege, because I was flabbergasted. The only one from that subpanel who wanted an identifying label was the Israeli. It turned out that in Israel in 1969 and 1970, they ran several consumer tests in supermarkets and greengrocers, and for years after that, people kept coming back and asking, "When can we get some more of that special food?" So the Israeli panelist felt that the label would *sell* the product. He was kind of talked out of that by others saying, "When was this test run? 1969-70? Before Three Mile Island?" and so forth.

In any event, there was an impasse between Mrs. Heckler's office and FDA, and when I went to see somebody in Mrs. Heckler's office in November 1983, I was told that the labeling issue was holding everything up. I told them that I would send them the report that my panel prepared, which IAEA has printed and distributed. I sent it, and within a couple of months, the proposed regulation of February 1984 came out with the FDA saying, "We don't propose a label. If you think there should be one, write in and tell us." So the FDA, having been overruled, was inviting people to overrule Mrs. Heckler. And this is when 4,000 letters came in to the FDA.

Q: These letters were mainly from the antinuclear movement and their associated environmentalist-consumer groups?
Josephson: Yes, and Dr. Sanford Miller of the FDA said, "Four thousand letters! Why, this is a tremendous outpouring!" And I said to Dr. Miller, "In a country of 240 million, what is 4,000? I could walk up and down the streets of my neighborhood with a petition and get 4,000 signatures for a traffic light or for somebody to get nominating papers to run for dogcatcher!"

Q: As part of this education process, I'd like you to answer briefly some of the objections that the environmentalists always raise. First, the bugaboo of "dangerous genetic mutations."
Josephson: We have not seen any evidence of these, and we have recycled salmonella about 36 generations. We got about a twofold-to-threefold increase in resistance, but no mutations. Since you're only going to irradiate *once*, there'll be no problems with bacterial mutations. We haven't seen that in 30 years of research. . . .

Q: Another point the environmentalists raise is that aflatoxin will be produced more abundantly on irradiated foods than on nonirradiated foods.
Josephson: That's not true, and I don't think anybody's ever confirmed it. Actually, at least at high-dose radiation, you *destroy* aflatoxin. There was a paper on that done out of my department under the toxicology group at MIT.

Q: What interests me about this particular objection is that I know in products like "natural" peanuts that have been produced without pesticides, there is a very high percentage of aflatoxin; it is actually more dangerous to eat this so-called natural food!
Josephson: That's right. With a high enough dose you'll destroy the aflatoxin; so that is not a problem.

Q: Another thing that I hear so frequently from these people is that one USDA report on chicken showed that there were fewer offspring produced among the fruit fly that had been fed this chicken.
Josephson: That has nothing to do with the issue. We don't do fertility studies or fecundity studies with fruit flies. This is done with dogs, rats, and mice; and they showed *no* impairment in reproductive capabilities. So the fruit fly has been involved in genetic studies for about 80 years, but never for reproduction and showed no genetic changes when fed irradiated chicken.

Q: Another favorite allegation of the environmentalists is that irradiation will destroy all of the vitamins in food.
Josephson: There is no merit to this point. I have written several review articles showing the contrary. They just don't read my articles, or the articles of other people. In fact, we are conservative, and say that radiation is "no more destructive" of the vitamins or any other nutrients than the conventional processes that are now used commercially. Now, that's a conservative statement, because in many instances, it is *less* destructive.

Q: I would like to ask you some questions about the developing-sector use of this technology. I know that you have been a consultant to Chile, India, China, and Israel on food irradiation. What do you think the promise is for countries where there is right now malnutrition, and certainly not enough food?
Josephson: I'm not one to say that irradiation is going to solve all their problems, because it is more than just enough food. It's government policies, land ownership, investment, putting resources where they should be, building an infrastructure of roads and warehouses and so forth. However, irradiation can certainly make a substantial contribution to conservation of food, so there would be less spoilage and therefore more available to the people who need it.

Q: Have you done any estimates of how much more food? In some of these countries I know 50% to 60% of the food spoils.
Josephson: It varies from country to country, from season to season, and from food to food. I've seen numbers anywhere from 25% to 60% of the crops that are lost through spoilage. Irradiation could help alleviate, ease those losses; but again, you have to have good roads to get the products from one place to another. It's got to be a national policy. For example, when I worked out in India a process for preserving bananas, thinking that bananas could go from the place where they're produced to places where they're going to be consumed, my Indian colleague said, "Oh, no, we've proposed to ship bananas by sea, by surface, to the port of Odessa." I said, "For this, I'm helping you?" Who needs that? Now, that was a national policy, to earn currency, or to trade for something that the Russians might have to offer.

I'm saying that I don't want to make it appear that radiation is the answer, but radiation certainly can help ease the problem of insufficient food. And where the distribution chain is very primitive, by being able to keep the food longer, you can overcome some of the deficiencies of maldistribution.

Q: Have you done any economic studies, to show comparisons of how this particular process will be cheaper?
Josephson: There have been a number of studies done, going back to the very beginning days—studies by Arthur D. Little and the National Academy of Sciences, then continued by the U.S. Department of Commerce and by the Operations Research Office of Johns Hopkins University. Time after time after time, whenever these studies are done, it has been shown that, in commercial production, the costs of food irradiation, the costs for this processing, will be competitive with the other major food preservation methods.

Q: Does that take into account the longer shelf-life that the food will have?
Josephson: Yes, because in some of these preserving methods you need to freeze or use refrigeration, and the longer you keep the product frozen, the more costly it becomes because of energy demands. So if it's going to cost so much a week to keep something frozen and you're going to keep it a year, you have to multiply the cost by 52. With irradiation at a high dose, you just don't need any refrigeration, after you have irradiated at −40°.

The longer you store the product, compared to a shelf-stable product, the better the numbers become on the side of irradiation. For example, take the costs of irradiation-sterilized bacon, assuming a throughput
year in a facility. If we used a certain type of accelerator, it was about 3/4 of a cent a pound; using a gamma ray source, it came out to about 2¢ to 3¢ a pound. Then if you added the cost of bringing the product down to −40° for irradiation, you have a cost of 4¢ to 6¢ a pound on the product. To compare with a product that sells for $2 or $3 a pound, 4¢ to 6¢ is a a very small amount.