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NUCLEAR TECHNIQUES TO PROMOTE WORLD FOOD SECURITY

Introduction

World food security was the topic discussed at the World Food Summit, held at FAO's Headquarters in Rome last fall. Several Heads of State feared that securing adequate food for the world's population in the next century could present a difficult aim. By 2030 this would entail doubling food production. Even permitting the unlimited use of inputs: fertilizers, pesticides, irrigation water, to attempt to achieve this, it is doubtful that this aim is attainable without causing irreparable and unacceptable harm to the environment.

Some of the world leaders stressed that use and further sophistication of science and technology in service of agriculture presented the only real hope for feeding the world population towards the middle of the next century.

One of the most powerful scientific tools in agricultural research is nuclear technology, based on the use of ionizing radiation and isotopic tracers.

Many people have difficulty associating nuclear technology with the humble and basic tasks of producing food; yet, these techniques already have added significantly to our ability to increase the productivity of the world's soils, crop plants and livestock as well as contributing to plant and animal health and wholesomeness of food.

What is the nature of the nuclear tools used in food and agriculture?

Nuclear Techniques used in agriculture are of two distinct types but both are based on the special characteristics of radio-isotopes which give off radiation or on isotopes which are heavier than the normal element.

One type of technique makes use of the unique ability of ionizing radiation - x-rays, gamma-rays, electrons and neutrons - to penetrate all types of matter and produce changes within living cells. These changes in cells, induced by radiation can do three things: 1) kill the cell; 2) render it incapable of reproducing itself (sterilize); or 3) cause changes in its genetic make-up, called induced mutations. This is made use of to kill microoganisms in food, prevent sprouting of potatoes and onions, breed better crop plants or sterilize insects for control. Some of this can be accomplished by chemicals, but often the chemicals used leave residues dangerous to health or are themselves dangerous to workers because of their mutagenicity or carcinogenicity. No chemical can compete with radiation in penetrating packaging material or living tissues, flesh, bones and fruits.

The other type of technique uses the radiation given off by isotopes to enable the detection of individual atoms in matter. With this technique we can e.g. follow the travels of fertilizer elements in the soil, into and throughout the plant, or trace the movement of nutrient atoms in the animal and their deposition in milk and meat. This has resulted in enormous advances in crop and livestock research. Very minute traces of pesticides and their residues can be detected in food, in plants and animals and in the environment, enabling the development of measures to reduce harmful effects.

Therefore these nuclear techniques have become highly successful tools in research, development and in processing. Sources of the radiation used are kept in completely shielded containers with no radiation hazard to their users. Electronic accelerators and X-ray machines of course can be turned on and shut off at will like any electronic appliance. The handling of radioactive isotopes requires strict safety measures. Agricultural scientists employing nuclear techniques require special training in handling them

Use of Nuclear Techniques and their Impact

A. Radiation

There are three main types of uses:

1. To sterilize insects for control or eradication
2. To induce mutation for plant improvement
3. To kill or sterilize microbes and pests in food and food ingredients or prevent sprouting quality, to increase shelf-life and wholesomeness

1. <u>Insect Sterilization</u>

This application is used in the so-called Sterile Insect Technique (SIT). The technique is based on an elegant and simple technique, discovered by two American entomologists, Drs. Knipling and Bushland: an insect infestations is eradicated by releasing into the infested area insects, sterilized by radiation in a ratio of 10-15 times the number of the same wild insect species found in the area. Since the flies mate at random, not distinguishing between fertile and sterile flies, it should be obvious that if the sterile flies are 10 times as many as the wild flies, the chance of a fertile mating is reduced to 10%. Therefore the next generation of the wild population is much smaller. If we again release the same number of sterile flies and repeat this over a few generation, we end up with no flies. As I said, this is an elegant and smart theory but the exciting part is that it works in practice.

Using this technique it was possible to totally eradicate the enormously devastating pest, the New World Screwworm from the USA and Mexico. To do this large factories had to be built, capable of producing billions of flies which are sterilized by gamma rays. You may recall in 1989 when this pest was found in Libya, posing a potentially disastrous threat, not only to Libya and North Africa, but possibly to all of Africa, the Near East and the northern Mediterranean, including Turkey. Through an emergency programme, costing some 70 million dollars and requiring the air transport of 40 million sterile flies per week from a factory in Mexico to Libya. The number of cases of livestock miasis - the disease caused by the flies - had reached some 12,000 in addition to hundreds of cases of human miasis before the release of the sterile flies which resulted in the total disappearance of the New World Screwworm from the continent.

Unfortunately there is another type of screwworm, the Old World Screwworm which is a major threat to livestock - and to humans- in Africa and Asia. It has become established on the Arabian peninsula and has been found in Iran. In 1996 there was an outbreak in Iraq and this is now being dealt with as an emergency by FAO which is cooperating with IAEA in attempting to use chemical treatments together with SIT to combat this pest. A new factory for mass producing this fly for use in SIT programmes was opened in Malaysia last April.

One cannot exclude the potential danger to parts of Turkey from this pest.

Another important and successful example of the use of SIT concerns the Mediterranean fruitfly. The Medfly is undoubtedly the most damaging insect pest of citrus and stone fruits worldwide, resulting in enormous loss in fruit quality and thus of marketable products as well as the huge costs of treatment with pesticides and the resulting chemical contamination. The Medfly originated in the south Mediterranean area and is a major pest in all the countries bordering on the sea, including Turkey. It was first found in the Americas some 30 years ago. When it invaded Mexico in the mid 70's and threatened its valuable citrus crop, the Mexican Government took immediate steps. With advice from the Joint FAO/IAEA Division the Government built a factory in Southern Mexico capable of producing some 500 million sterile Medflies per week (about 5 tons). Shortly thereafter systematic releases were started in the infested area with sterilized flies in overwhelming numbers. A few years later the Mexico was free of the Medfly.

Medfly factories have been built in Hawaii, Guatemala, Peru, Chile and Argentina. Total eradication has recently been reported from Chile; progress is good both in Guatemala and Argentina. The Hawaiian and the Mexican factories are also being used to combat the fly in California.

The damage inflicted by this pest is certainly no less in southern Europe and around the Mediterranean. Strangely, no large-scale Medfly factories have been built in any of the affected countries. One tries to control the pest by pesticide applications, but there is growing opposition to the use of pesticides due to their secondary effects of wildlife, food supplies and human health. A scheme is now under way to unite all the countries bordering the eastern Mediterranean in an area wide effort at eradicating the Medfly, using the SIT. This includes the Arab countries, the Magreb, as well as Israel and the countries on the northern Mediterranean shores. It has been suggested that a central factory be built on Cyprus for producing billions of flies per week. One thing is certain: The Medfly cannot be eradicated from this area without the participation of Turkey to eradicate it from its southern shores.

A recent breakthrough in mass rearing the Medfly has made the use of SIT much cheaper, many times more effective and completely harmless to marketable fruit. This breakthrough was achieved in the FAO/IAEA laboratory and enables the killing of all female eggs by simply raising the temperature of the solution containing the eggs by some 10 degrees. This means that only male flies need to be reared, resulting in significant savings in rearing costs and that SIT can be used as a means of control without having to aim for total eradication which in some cases is impractical or even unattainable.

The Medfly cannot survive at low temperatures and does not travel over long distances without suitable hosts. This is why the Medfly will not survive north of Naples or move south over the Sahara or east of Amman and Damascus. It is therefore very tempting to consider the total eradication of this pest once and for all from this whole area and I believe the FAO and the IAEA are already drawing up the master plan for such a Pan- Mediterranean Medfly Eradication Project.

2. Food Irradiation

Ionizing radiation has the unique ability to penetrate any type of food packaging and the food itself, specifically killing or sterilizing living and active cells of microbes or in insects while having minimal effect on the food itself.

Until recently, a variety of chemical fumigants have been used to disinfest fruits and grain or to prevent sprouting. Now a number of these fumigants have been found to be harmful, carcinogenic or mutagenic. As a result, many countries have banned nearly all of them, creating great concern in the food industry. Ionizing radiation will effectively disinfest fruits, vegetables and grains without any harmful effect. Even more important is that the products can be packaged before treatment, thus preventing reinfestation as long as the package is intact. Now that the GATT accords on sanitary and phytosanitary measures in international trade have taken effect, it is essential that quarantine regulations be met. It is becoming widely recognized that radiation treatment may present not only the most effective means but also the safest way of meeting quarantine regulations and thus facilitating international trade.

It is also becoming widely known that food borne pathogens are on the increase and are causing widespread serious illnesses. WHO says that diarrhea caused by food borne pathogens is the most common cause of child death in the developing world. It is almost impossible to buy chicken in the market which is free of Salmonella or other pathogens. While Salmonella is killed with proper cooking, secondary contamination of e.g. vegetables, continues to cause outbreaks. WHO has recognized that the only effective method of treating chicken for Salmonella is irradiation treatment and indeed recommends to travellers that if possible they should buy irradiated chicken to prevent infection. The recent ban by the EU on import of chicken from the USA arises from their treatment of chicken with what the EU considers excessive levels of chlorination to control Salmonella. Clearly a low level and harmless radiation treatment of chicken could easily resolve this issue, if such treatment was permitted on both sides of the Atlantic.

The advantages of food irradiation are many and its potential uses manifold. Yet, it has been difficult to introduce food irradiation into the food industry. There is surprising fear of the use of radiation in the minds of consumers and consumer unions. For those who know how radiation treatment works and how the results of decades of extensive research into the wholesomeness of irradiated food, it is difficult to understand the basis for this fear. The reason seems to be a general fear of anything "atomic", a belief that irradiated food becomes radioactive - which is never the case - and the association of ionizing radiation with atomic bombs and power plant accidents (Chernobyl).

I recall that in 1965 Turkey built an irrradiation plant for disinfestation of grain. The facility was ready and about to start, when a campaign was initiated against it. It was said that there was no proof that irradiation of food was harmless, that there could be something in food treated with ionizing radiation which could in some way be detrimental to human health and that the Turkish people were to be used as Guinea pigs to test the wholesomeness of irradiated grain. As a result this project was abandoned. If it had been built it would have been the first commercial food irradiation facility in the world.

Regardless of the grounds for this unfounded fear, consumers' attitudes must be taken seriously and the consumers and their associations should be given factual information about the true nature of food irradiation and the benefits food irradiation can have for improving and securing food supplies

3. Mutation Breeding

Plant cells are sensitive to ionizing radiation. A high dose can kill or stunt the cells; appropriate dose levels can break chromosomes and affect the DNA in the nucleus, giving rise to permanent genetic changes, by inducing so-called mutations. Certain chemical treatments can also induce mutations. All present day life forms of plants and animals, including man, are the result of nature's selection of "natural" mutations which have arisen as a result of cosm: radiation, various chemicals and environmental factors. The use of ionizing radiation or mutagenic chemicals only speeds up the induction of mutations, thereby accelerating evolution. Mutations can cause plants to become shorter, mature early or late, having more resistance to pests and diseases or to give higher yield or better quality food. Most induced mutations are harmful; only a few are beneficial and the task of the plant breeder is to select from the mutations induced those which will improve the performance of the crop and breed a new variety.

The results of the application of radiation in plant breeding have been quite dramatic: To date, over 2000 varieties of nearly all species of crop and ornamental plants of induced mutant origin have been officially named and released to growers throughout the world. Induced mutations have resulted in improvement of practically all important agronomic characters and have resulted in improved varieties in all important crop species, especially in the major cereals. In some countries the induced mutants have come to represent major areas of cultivation, e.g. wheat and rice in China, cotton in Pakistan, rice in the USA, durum wheat in Italy and barley in Europe. These mutant crops are grown on millions of hectares throughout the world and their value to growers, consumers and national economies is measured in billions of dollars.

Modern field and horticultural crops are becoming ever more refined and higher yielding. In the efforts ahead to double food production in the next 30 years, we are unlikely to find the necessary qualities in existing plant germ plasm collections. The plant breeder will have to depend on the generation of additional genetic variability which can be induced by mutagenic agents, particularly ionizing radiation. There are many ways to combine mutation breeding techniques with modern biotechnology, molecular biology and genetics, cell and tissue culture. Combination of these techniques has already opened up new possibilities for crop breeding. The application of these and yet to be discovered new technologies were said by many of the world leaders at the summit to present the only real hope of producing enough food for mankind after the middle of the next century.

B. Isotopes

1. Soil Fertility

A radioactive or stable isotope of a fertilizer element allows tracing of the fertilizer after it enters the soil, is taken up by a plant root and distributed to various plant parts. Using this technique, a scientist can determine how best to apply fertilizers, how deep to place it in the soil, how close to the roots, at what time before or after planting and in what chemical form the fertilizer gives the best results. Many such studies were carried out within the joint FAO/IAEA programme throughout the world some 20-30 years ago. They led to new and improved ways of fertilizer applications. The new methods have long since been incorporated into recommended fertilizer application practices in many countries and for a number of crops, e.g. all the major cereals, legumes and some tree crops. Documented savings to farmers and consumers from more effective use of fertilizers are enormous and may now amount to billions of dollars, in addition to minimizing the effect of chemical fertilizers on the environment, especially by run-off into waterways.

Similarly, the use of isotopic tracers for studying nitrogen fixation by bacteria in symbiotic relation with legumes (e.g. peas, beans and clovers), it has been possible to develop more efficient ways of employing this symbiotic relationship to replace expensive nitrogen fertilizers. Isotopic techniques are by far the most exact methods of measuring nitrogen fixation rates.

2. Agrochemicals

There is increasing concern for the impact agricultural practices can have on the environment, especially the harmful effects which may result from careless use of agrochemicals, such as fertilizers and pesticides. An isotopically labelled ingredient in the effective component of such agrochemicals will reveal the presence of the chemical or its residues long after their application when they may appear in plants and animals, water and soil, food or human beings.

For this reason, one attempts with isotopic techniques, to assess the impact of various agrochemicals on the environment, on the non-target fauna and flora as well as in food and water.

However, radioisotopes can only be used under experimental and closed-system surroundings since the release of long-lived isotopes emitting harmful radiation is not desirable. Therefore most of these applications in nature rely on non-radioactive or stable isotopes which can be identified and traced on the basis if their atomic weight. FAO, together with IAEA, is establishing at their agricultural and biotechnology laboratory at Seibersdorf in Austria, an international reference and training facility for pesticide and food quality control which will assist its Member Nations in controlling the wholesomeness of food in international trade. The need for such a facility has become very evident after the establishment of the WTO and the increasingly free flow of food in international commerce.

3. Disease Diagnosis, Molecular Biology and Genetics

Isotopic markers are widely used in a variety of basic scientific disciplines which form the basis for much work undertaken in support of food and agriculture. It can be safely stated that without the use of isotopic markers there would be no modern biotechnology, no molecular biology and genetics or the myriad spinoffs off these technologies such as modern disease diagnostic techniques. DNA, the basic chemical of life on earth, containing the genetic code, consists of two strands which separate in cell division during reproduction. Molecular biology and genetics are based on the ability to identify one strand of DNA from the other. This is done by labelling one of the strands, in most cases by a radioactive isotope (^{32}P).

Work of this nature has led to the many breakthroughs which have occurred in both basic an applied biotechnology. One such application has led to the development of chemicals which are used for the most efficient disease diagnostic method known, called ELISA (enzyme linked immuno sorbent agent). This diagnostic method supports a large programme supported by FAO and IAEA in making available diagnostic kits to veterinarians, enabling them to make reliable and quick diagnosis. The large and successful campaign to eradicate Rinderpest from Africa relies on the use of FAO/IAEA supplied ELISA kits. Many other techniques used in the fight against animal diseases rely on isotopic labels: DNA probes, monochlonal antibodies. A related immunoassay technique is based on radiation and is called radioimmunoassay. In FAO/IAEA programmes this technique is primarily used to study the level of the reproductive hormone progesterone. Such studies have given results which have led to shortening of the time interval between calves, thereby increasing markedly both meat and milk production and the grazing pressure on land.

The use of isotopic markers in animal nutrition similarly has led to improved animal feeding practices and better utilization of locally available feeds and agricultural wastes. Using *in vitro* systems (artificial rumen) one can use full strength radioisotopes to conduct detailed studies on the complex mechanism of digestion in the rumen.

The Role of Nuclear Techniques to Meet Food Security Challenges of the Future

FAO has published two papers on this subject: one on agriculture towards 2000 and the other on agriculture towards 2010. The first one really told us not to worry: increase the use of inputs, fertilizers, pesticides, irrigation water, employ higher yielding varieties and break new land and forests for crops. The second one was more sober. Yet it said, yes, enough food can be produced, provided there are sufficient inputs. Some experts have said that these predictions are unrealistic; it really can't be done that way.

The World Food Summit attempted to analyze these issues and look further into the future - all the way to 2015! By then the assembled world leaders hoped that the number of hungry people on earth could be halved, from the present count of 800 million to 400 million. One thing a number of Heads of Government and Ministers of Agriculture were sure of: Without scientific breakthroughs and development of new technology, without breaking through the yield barrier and more sustainable use of natural resources, there would be no hope of securing adequate food supplies for all towards the middle of the next century.

One must realize that, from the time of radiation treatment of a seed to the release of a marketable, improved variety, there may be a 12-15 year interval, so that desicions on actions taken today may not be translated into reality until the year 2010 to 2015. In other words: there is no time to lose to make decisions for the future.

The overriding concern for future developments is the rapid population increase, one million more mouths to feed every 4 days and most of them in already food-deficient countries.

Another, equal concern is for the 800 million souls living with us on this earth who do not get adequate food and the 200 million children who are undernourished or malnourished and either do not survive or are left with lasting physical deficiencies.

A simple calculation shows that around 2030 there may be some 9 billion people on earth, and to feed them all we must double food production. And this must be done in face of growing environmental concerns and demands for sustainable development. Doubling food production would be difficult enough even if we were allowed to dump ever increasing amounts of fertilizers and pesticides on crops, have unrestricted access to water and plenty of fertile, virgin soils which could be brought under cultivation.

Unfortunately, none of this is available. On the contrary: Soils are eroding at 22 billion tons per year, half of that directly attributable to man's use of the soil. Half of the earth's soil resources may have disappeared in a hundred years. Over the last 30 years, cultivated land per person has shrunk some 32%. These trends must be reversed lest our food production capability is not going to deteriorate further in the future.

Whatever measures will be taken, one thing is certain: We must rely on science and technology to uncover new methods and new materials, new systems and new crop varieties that will give us a chance. As reviewed above nuclear techniques provide accurate, sensitive, fast and effective tools in research and development. They seem to become more relevant in agricultural research with every year. They are based on some of the most fundamental characteristics of our physical universe, the very nature of atoms and nuclei; it is difficult to imagine technology more firmly based on fundamental natural phenomena.

The problems of food and agriculture must be resolved to meet man's most basic and essential needs: the very survival of the individual and the human species is at stake. The application of nuclear technology therefore must be problem driven; not simply a demonstration of elegant technology. Nuclear techniques in food and agriculture should not be used aside from and in isolation from the overall effort to increase and secure food supplies. It is for this reason that the International Atomic Energy Agency applies nuclear technology in food and agriculture in a joint programme with the Food and Agriculture Organization of the United Nations. It is an example which should be followed by national and regional atomic energy establishments.