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Protecting the Military Food Supply: Applications of *in situ* Decontamination Technologies

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Executive Summary

Food safety is a subject of critical importance to U.S. citizens and the military. While the U.S. food supply is generally considered to be one of the safest in the world, foodborne illness continues to be a source of concern. Each year, millions of Americans become ill from foodborne infections and up to 5,000 people die.

The United States Department of Agriculture (USDA) estimates that diseases caused by seven major foodborne pathogens could result in medical costs and productivity losses of between $6.6 billion and $37.1 billion annually. Furthermore, recalls of contaminated food—such as the massive recalls of thousands of pounds of ground beef contaminated with *Escherichia coli* 0157:H7 have resulted in severe economic losses to the affected industry. There is currently no effective means to eliminate all foodborne illness.

Scientists, regulators and lawmakers, working to determine how best to combat foodborne illness, are encouraging the use of new technologies that can enhance the safety of the nation's food supply. Many food safety experts believe that irradiation can be a safe and effective tool in helping to control foodborne pathogens and should be incorporated as part of a comprehensive program to enhance food safety. These same technologies can be employed at various points in the supply chain to protect the food products served to our troops. Irradiation, which involves exposing food briefly to radiant energy (such as gamma rays, high-energy electrons or X-rays), can reduce or eliminate microorganisms that cause foodborne disease that may be inadvertently, or intentionally, introduced into the food supply. Other benefits of food irradiation include extending the shelf life of certain foods, and controlling insect infestation in grain products, fruits and vegetables. The technology has been used routinely for more than 30 years to sterilize medical, dental and household products.

Concerns on the part of food processors, retailers and others about consumer acceptance of irradiated foods have limited their efforts to introduce irradiated products. Education will play a crucial role in promoting the acceptance of irradiated foods. Studies have shown that consumers are willing to buy irradiated food if the purpose of irradiation is clearly understood. They are also willing to pay a premium for a safer product.

Food treated by irradiation is generally as nutritious as, or better than, the same food treated by conventional processes such as cooking, drying or freezing. Irradiation has no significant effect on macronutrients, such as proteins, lipids and carbohydrates. Micronutrients, especially certain vitamins, may be reduced by irradiation, but generally these same vitamins are similarly reduced by the other commonly used food processing methods or by simple storage. Scientific studies have shown that irradiation of many foods according to a validated protocol does not significantly change food taste, texture or appearance. There are many good examples of the excellent sensory quality of radiation processed foods, including the NASA menu items, which have been consumed by astronauts for many years.

Several extensive reviews of toxicological data by regulatory and health organizations, including the U.S. Food and Drug Administration, Health Canada, the Codex Alimentarius Commission, and the European Commission's Scientific Committee in Food have determined that food irradiated at doses below 10 kiloGray (kGy) is safe. In fact, food is safer after being irradiated because the process destroys harmful bacteria that may be present. Food irradiation is endorsed by national and international food and public health organizations, such as the American Medical

Association, the American Dietetic Association, the American Council on Diet and Health, the U.S. Public Health Service, the Mayo Clinic, the Center for Disease Control and Prevention and the World Health Organization.

Irradiated foods do not become radioactive. As the energy passes through the food, it only kills the bacteria, leaving no residue. Irradiation facilities are subject to strict federal and state regulations. In North America, in over four decades of transporting the types of radioactive isotopes used for irradiation, there has never been an accident resulting in the escape of radioactive materials into the environment.

The Food and Drug Administration has approved the irradiation of meatand poultry and allows its use for a variety of other foods, including fresh fruits and vegetables, and spices. More recently, the FDA has approved the irradiation of fresh spinach and iceberg lettuce for pathogen control and extension of shelf life. Today food irradiation is approved in nearly 50 countries worldwide.

Challenges

The importance of the U.S. food supply was recently highlighted when the agricultural system was identified as a critical infrastructure. Despite the vulnerability of the food supply, there are limited examples of intentional contamination of food. A recent study of food defense breaches concluded that 391 fatalities and 4,355 injuries have resulted from intentional contamination. The most successful of these attacks occurred in 1984, when a cult in The Dalles, Oregon, contaminated restaurant salad bars with *Salmonella typhphimurium*. The attack, which made 751 people ill, appears to be the only publicly confirmed case of food terrorism in the United States. Several other instances of deliberate contamination have occurred, though they have been relatively minor, often affecting fewer than ten individuals. There have been two recent documented attempts to specifically poison military food supplies. In January 2003, several "Islamic militants" were arrested for plotting to poison food at a British military base, though no such attack ever took place. In October 2006, approximately 400 Iraqi police officers succumbed to food poisoning. There were few if any fatalities and it remains unclear if they were intentionally poisoned or simply were served spoiled food.

There is no doubt that contamination of the food served to U.S. troops overseas is a real possibility that could seriously decrease their combat readiness, both physically and psychologically.

However, when thinking about food defense, we must be cognizant of the cost-benefit ratio of increased capabilities. Thus, when considering methods of increasing our food defense capabilities, we should be particularly aware of both the cost and the additional benefits of these methods. Fortunately, many of the techniques that can be used to defend the military food supply have additional benefits for food safety, delivery, and storage.

Fresh fruits and vegetables, which are extremely desirable to eat as well as a significant source of nutrients, are continually supplied to all ships, submarines and ground forces during deployment. The ability to continually supply these items is limited by the time the fresh fruits and vegetables can be kept fresh. Even when refrigerated, many spoil due to bacteria and mold that are present on the foodstuffs. In addition, nearly all fresh fruits and vegetables will spoil as a result of internal enzymes that work to ripen the fruit.

Irradiation technologies can extend the shelf life of fresh fruits and vegetables significantly. As an example strawberries that will normally wilt or become moldy in 3 to 5 days when properly refrigerated can be kept fresh up to 24 days following irradiation (Captain Queeg would not have had to worry about the frozen strawberries).

The cost of the irradiation is offset by potential economic gains. For instance in FY05 the Naval Supply Systems Command spent $26 million dollars on fresh fruits and vegetables with more than 10% lost due to spoilage. Irradiation could significantly reduce loss.

How Food Irradiation Works

Food irradiation is a process in which food products are exposed to a controlled amount of radiant energy to kill harmful bacteria such as *E. coli* 0157:H7, Campylobacter, Listeria and Salmonella. The process can also control insects and parasites, reduce spoilage and inhibit ripening and sprouting.

Food is packed in containers and moved by conveyer belt into a shielded room. There the food is exposed briefly to a radiant energy source; the amount of energy depends on the type and amount of food. Energy waves passing through the food generate reactive ions, free radicals and excited molecules. These in turn chemically attack essential biomolecules, such as nucleic acids (DNA, RNA), membrane lipids, proteins, and carbohydrates of bacteria or other pathogens, and insects causing damage to them. As a result, these organisms die or are unable to reproduce, limiting the damage to the food. The food is left virtually unchanged. Similar technology is used to sterilize medical devices so they can be used in surgery or implanted without risk of infection.

The dose of irradiation is usually measured in a unit called the Gray (Gy). This is a measure of the amount of energy (Joules) transferred to a specific weight of food or other substance being irradiated (1 Gy = 1 Joule/kg). Parasites and insect pests, which have large amounts of DNA, are rapidly killed by extremely low doses of irradiation, with D-values (value causing a 10-fold reduction of an organism) of 0.1 kGy or less. It takes more irradiation to kill bacteria, because they have less DNA, with D-values in the range of 0.3 to 0.7 kGy. Bacterial spores are more difficult to kill, with D-values on the order of 2.8 kGy. Viruses are the smallest pathogens that have nucleic acid, and they are in general resistant to irradiation at doses approved for foods. They may have D-values of 10 kGy or higher. To measure the dose of irradiation of a product, a photographic film is exposed to the irradiation at the same time. The film fogs at a rate that is proportional to the irradiation level.

Three different irradiation technologies exist: gamma rays, electron beams and X-rays. Gamma rays use the radiation given off by a radioactive substance (Cobalt-60 or Cesium-137), which can penetrate foods to a depth of several feet. These particular substances do not give off any neutrons, which mean that they do not make anything around them radioactive. Irradiation of food takes place in a chamber with thick walls that keep any rays from escaping. This technology has been used routinely for more than 30 years to sterilize medical, dental and household products, and it is also used for radiation treatment of cancer.

Electron beams are streams of high energy electrons, propelled out of an electron gun. This electron gun apparatus is a larger version of the device in the back of a TV tube that propels electrons into the TV screen at the front of the tube, making it light up. This electron beam generator can be simply switched on or off. No radioactivity is involved. The electrons can penetrate food only to a depth of three centimeters, or a little over an inch, so the food to be treated must be no thicker than that to be treated all the way through. Two opposing beams can treat food that is twice as thick. Electron beam medical sterilizers have been in use for at least 15 years.

X-ray irradiation is the newest technology, and is still being developed. The X-ray machine is a more powerful version of the machines used in many hospitals and dental offices to take X-ray pictures. To produce the X-rays, a beam of electrons is directed at a thin plate of gold or other metal, producing a stream of X-rays coming out the other side. Like gamma rays, X-rays can pass through thick foods, and require heavy shielding for safety. Similar to electron beam irradiation, no radioactive substances are involved. Systems can be constructed such that they can provide both electron beam capability as well as X-ray capability, expanding the utility and decreasing the cost compared to two separate systems.

Benefits of Food Irradiation

Pathogen Reduction. According to numerous studies conducted worldwide over more than 50 years, irradiation, within approved dosages (typically 1-10 kGy), has been shown to destroy at least 99.9 percent of common foodborne organisms, including pathogens such as Salmonella (various species), *Campylobacter jejuni*, *Escherichia coli* 0157:H7 and *Listeria monocytogenes*, which are associated with meat and poultry. It is also effective against Vibrio species associated with seafood and against parasites, such as *Toxoplasma gondii* (found in many animal species) and *Trichinella spiralis* (found in pork).

Fig 1. Nearly all types of fresh or packaged foods can be decontaminated by irradiation.

The radiation doses used to treat meat and poultry typically achieve 10,000 to 1,000,000-fold reductions of the bacterial load, and are comparable to heat pasteurization. It is therefore referred to as cold pasteurization. Officials from the Food and Drug Administration (FDA) and others emphasize that irradiation does not replace proper food handling; irradiated food must still be properly refrigerated and cooked prior to consumption. Because of irradiation's effectiveness in controlling common foodborne pathogens and in treating packaged food (thereby minimizing the possibility of cross-contamination prior to use), federal regulatory agencies and the Food Chemicals Codex at the National Academies Institute of Medicine view irradiation as an effective critical control point in a Hazard Analysis and Critical Control Points (HACCP) system. Appropriate radiation doses are well-known, and compliance can be monitored by accurately measuring the absorbed radiation dosage.

Spoilage Reduction. Low doses of radiation (typically up to 1 kGy) can prolong the shelf life of many fruits and vegetables by reducing spoilage bacteria and mold, and by inhibiting sprouting and maturation. As a result, products can be harvested when fully ripened and can be transported and displayed for longer periods while maintaining desirable sensory qualities longer than non-irradiated products. For example, according to the Council for Agricultural Science and Technology, irradiating strawberries extends their refrigerated shelf-life to up to three weeks without decay or shrinkage, versus three to five days for untreated berries.

Irradiation can also be used as an alternative to chemical sprout inhibitors for tubers, bulbs, and root crops. These chemical inhibitors are considered by some to be harmful, and many countries have prohibited their use. The softening and browning associated with the ripening of certain fruits and vegetables, such as bananas, mangoes, and mushrooms, can be delayed with irradiation.

Insect and Microorganism Control. Irradiation is also an effective means to decontaminate certain food products. Spices, herbs and dry vegetable seasonings, which are among the most commonly irradiated food products in the United States, are frequently dried in the open air and become severely contaminated by air and soil borne microorganisms and insects. Food processors often fumigate these commodities with ethylene oxide to reduce or eliminate pathogens and sometimes treat with methyl bromide to reduce insects. An alternative to the use of chemical products would be to use irradiation. Low doses of irradiation (up to 1 kGy) are effective against insects. Irradiation can be used as a pest control treatment on quarantined fruits and vegetables to prevent the importation of harmful pests, such as the Mediterranean fruit fly. To minimize this risk, the United States Department of Agriculture (USDA)'s Animal and Plant Health Inspection Service's (APHIS) quarantine procedures require the use of fumigation or heat (hot water or hot air) or cold treatment of fruit that is not ripe.

Irradiation treatment is an effective alternative for many types of fresh produce because it can be used on riper fruit and on fruit that cannot tolerate heat treatment. Moreover, a number of past quarantine treatments have recently been prohibited, an example being fumigation with ethylene dibromide. In 1997, APHIS issued a final rule allowing the use of irradiation as a quarantine treatment for papayas, carambola and litchi coming from Hawaii to the U.S. mainland. In May 2000, APHIS proposed a rule to allow irradiation for use in killing fruit flies and mango seed weevils on fruits and vegetables imported into the United States. This rule is expected to further expand the use of irradiation in pest control. Irradiation the only phytosanitary (produce-cleansing) treatment that has been approved (as of 2006) by the USDA Animal and Plant Health Inspection Service (APHIS) on a generic basis—regardless of commodity—with specific minimum doses for various insect pests.

Higher doses of irradiation can also be used to greatly reduce the non-pathogenic microorganism and bacterial spore load of dried spices, herbs and dry vegetable seasonings. In the U.S., these products can be irradiated up to levels of 30 kGy for this purpose. In multi-ingredient foods, spoilage prevention and microorganism control is achieved more easily when spices are pre-treated by irradiation

L-3 Applied Technologies Solution

L-3 Applied Technologies Inc., (ATI) offers a selection of high-power electron beam and X-ray systems capable of producing the irradiation fields required to effectively reduce the bioburden found on raw, fresh and frozen foods.

The ExactBeam™ Solution for Food Safety Applications

Treatment of food products by electron beams and x-rays is a proven method to guarantee the safety of our food supply. Cold pasteurization will destroy pathogens in meats and vegetables extend shelf-life and inhibit sprouting on root crops as well as disinfest fruits and vegetables of destructive pests. The cold pasteurization process does not otherwise affect the nutritional quality, taste or texture of the food. The FDA, USDA, CDC and many international agencies have declared electron beam and x-ray processing of foods to be safe and effective.

The **ExactBeam™** System combines electricity and microwaves in a linear accelerator to generate a high-energy electron beam (E-beam) or X-rays. The beam is fanned sequentially and rapidly across the food being cold pasteurized. Our process ensures the destruction of harmful microorganisms and insects.

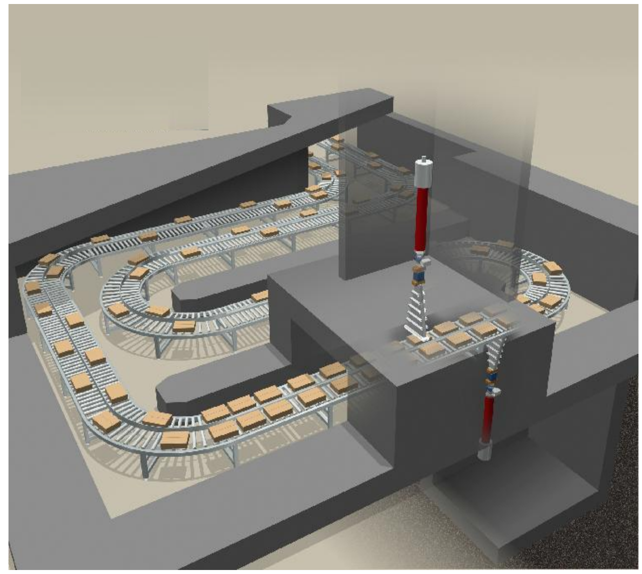

Fig 2. Illustration of an installed **ExactBeam™** system.

Unique to **ExactBeam™** is our patented **SureTrack®** process control software. **SureTrack®** oversees all parts of the system to insure accurate, safe and uniform dose delivery. In the event of a system interrupt (fault) the **SureTrack®** system can restart the process, return and deliver the E-beam at precisely the "spot" where the product was last dosed. This patented triple-interrupt capability maximizes product throughput.

- The **SureTrack®** System is easy to operate and provides built-in checks to assure process integrity and product safety.
- The operator interacts with **SureTrack®** via a touch screen display.

- **SureTrack®** checks operator-provided data about the impending lot to ensure its validity and schedules the lot for processing.
- **SureTrack®** uploads pre-determined processing set points for all critical parameters including, but not limited to, the electron beam scan height, process conveyor speed and whether processing is to be single or double sided to the E-beam and Material Handling PLC's.
- **SureTrack®** checks that all system parameters are set correctly and in turn, that the System is operating within these specifications.
- **SureTrack®** tracks the location of all products that are being processed. Dosimeter placement within a lot is critical; this is controlled and monitored by **SureTrack®** as well.
- The **SureTrack®** system also includes reporting and data base modules that provide the necessary documentation for product release as well as an historical record of all lots processed through the ***ExactBeam™*** system.

Why L-3 Applied Technologies, Inc., ?

- L-3 ATI has pioneered the use of high energy and high power electrical and microwave technologies for a variety of industrial applications including cold pasteurization of foods.
- L-3 ATI is an ISO 9001:2008 registered company focused on delivering quality, dependable, reliable systems and services satisfying the requirements of contract sterilizers and food processors.
- L-3 ATI's ***ExactBeam™*** systems are successfully operating and processing food in the following organization: Hawaii Pride (HI), Sadex (IA), Son-Son (Vietnam), SME (Saudi Arabia), Texas A&M University (TX) and are considered to be the configuration of choice.

L-3 ATI Provides A Turnkey Solution Including:

- ✓ Integrated facility design
- ✓ A/E and construction support
- ✓ E-beam or X-ray configurations
- ✓ 24/7 customer support **Proven Reliability**
- ✓ 7000 hours per year operation
- ✓ Documented up-time >95% **Proven Safety**

- ✓ Radiation-safe design
- ✓ SIL 4 rated safety system **Precision dose delivery**
- ✓ Patented process table design
- ✓ Patented process interrupt recovery

The *ExactBeam*™ system consists of the following major subsystems:

•Radiation Shield designed "for general population" exposure limits
•Linear Accelerator(s)
•E-beam or X-ray output
•Material Handling System including High Speed Conveyor
•Rotation, Closing and Process Conveyors
•Information and Control System incorporating SureTrack®
•SIL 4 (IEC 61508) Safety System

Compared to other irradiation systems the *ExactBeam*™ system provides the fastest throughput and processing time as well as:

- ✓ Precise dose delivery
- ✓ Highest quality
- ✓ Safe and environmentally friendly

Summary

1. Irradiation is an effective way to enhance the safety of the nation's food supply. It can help prevent foodborne illness, control insect infestation and extend product shelf life.

2. Irradiated foods are safe, wholesome and nutritious. Irradiation is endorsed by federal regulatory agencies and numerous national and international health organizations.

3. The Food and Drug Administration (FDA) has approved the irradiation of meat and poultry, and recently fresh spinach and iceberg lettuce, and allows its use for a variety of other foods, including fresh fruits and vegetables and spices.