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FOOD IRRADIATION: POSSIBLE APPLICATION IN ETHIOPIA FOOD ITEMS.

BY

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Abstract

Food irradiation is the processing of food products by ionizing radiation in order to control food borne pathogens, reduce microbial load and insect infestation, inhibit the germination of root crops and extend the durable life of perishable produce.

The treatment of food with ionizing energy benefits food producers, manufacturers and consumers. It can extend the shelf life of animal or plant products by destroying spoilage organisms. It can destroy pathogenic microorganisms and parasites in frozen, fresh and processed foods, thereby reducing the incidence of food- borne diseases.

This study reviewed global practice of food irradiation, determination dose of Food Irradiation, Ethiopian food items, possible application food irradiation in Ethiopia and its impact on food security for Ethiopia. The hazards posed to consumers as a result of consumption of irradiated food reviewed.

Acronyms

DNA	Deoxyribonucleic Acid
MIT	Massachusetts Institute of Technology
US	United State
IFIP	International Food Irradiation Project
FAO	Food and Agricultural Organization
IAEA	International Atomic Energy Agency
WHO	World Health Organization
KGy	kilo Gray
ICGFI	International Consultative Group on Food Irradiation
SCF	Scientific Committee on Food
EFSA	European Food Safety Authority
FDA	Food and Drug Administration
CDC	Center for Disease Control
USDA	United State Drug Administration
AMA	American Medical Association
ADA	American Dietetic Association
CAST	Council for Agricultural Science and Technology
IFT	Institute of Food Technologists
EU	European Union
WTO	World Trade Organization

SPS Application of Sanitary and Phytosanitary

GMP Good Manufacturing Practice]-

TPT Technical Barriers to Trade

FMHACA Food Medicine and Health Care Administration and Control Authority

UN United Nation

FSIS Food Safety and Inspection Service

USA United State American

PSNP Production Safety Net Programs

JECFI Joint Expert Committee on Food Irradiation

UK United Kingdom

AIDS Acquired Immune Deficiency Sundry me

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Chapter One

Food Irradiation: Possible Application in Ethiopia Food Items.

1. Introduction

The process of treating food with radiant energy is not new. The sun's energy has been used for centuries to preserve meat, fruits, vegetables and fish. Lately, infrared and microwave radiation have been introduced for heating food. Microwave ovens are now common place in both domestic and commercial kitchens. Today, intense radiant energy, known as ionizing energy includes gamma rays produced by radio-isotopes and X-rays and electron beams produced by electron accelerators.

The treatment of food with ionizing energy benefits food producers, manufacturers and consumers. It can extend the shelf life of animal or plant products by destroying spoilage organisms. It can provide an alternative to the chemical fumigants now used to satisfy quarantine requirements for stored grain, fruits and vegetables. It can destroy pathogenic microorganisms and parasites in frozen, fresh and processed foods,thereby reducing the incidence of food- borne diseases. And, since it slows the ripening of some fruits, it can extend their marketable shelf- life or allow them to be harvested closer to maturity, improving quality.

What is Irradiation?

Irradiation is the process by which an object is exposed to radiation (as x-rays or alpha particle) and the application of radiation (x–rays or gamma rays) for therapeutic purposes or for sterilization (as food). Irradiation is a safe and effective technology that can prevent many food borne diseases.

How irradiation works?

Irradiation works by disrupting the biological processes that lead to decay. In their interaction with water and other molecules that make up food and living organisms, radiation energy is absorbed by molecules they contact. The reactions with the DNA cause the death of microorganisms and insects and impair the ability of potato and onions to sprout

Limitations of Irradiation

Irradiation will not inactivate metabolic enzymes naturally present in food, which cause its slow decomposition over time. It can't be used to fix partially spoiled food, as the toxins already produced by microorganisms are not destroyed.

The History of Food Irradiation

1895 Wilhelm Conrad Rontgen discovers X-rays ("bremsstrahlung", from German for radiation produced by deceleration)

1896 Antoine Henri Becquerel discovers natural radioactivity; Mink proposes the therapeutic use

1904 Samuel Prescott describes the bactericide effects Massachusetts Institute of Technology (MIT)

1906 Apple by & Banks: UK patent to use radioactive isotopes to irradiate particulate food in a flowing bed

1918 Gillette: U.S. Patent to use X-rays for the preservation of food

1921 Schwartz describes the elimination of Trichinella from food

1930 Wuest: French patent on food irradiation

1943 MIT becomes active in the field of food preservation for the U.S. Army

1951 U.S. Atomic Energy Commission begins to co-ordinate national research activities

1958 World first commercial food irradiation (spices) at Stuttgart, Germany

1970 Establishment of the International Food Irradiation Project (IFIP), headquarters at the Federal Research Center for Food Preservation, Karlsruhe, Germany

1980FAO/IAEA/WHO Joint Expert Committee on Food Irradiation recommends the clearance generally up to 10 kGy“overall average dose”

1981/1983 End of IFIP after reaching its goals

1983Codex Alimentarius General Standard for Irradiated Foods: any food at a maximum “overall average dose” of 10 kGy

1984 International Consultative Group on Food Irradiation (ICGFI) becomes the successor of IFIP

1998 The European Union’s Scientific Committee on Food (SCF) voted “positive” on eight categories of irradiation applications

1997 FAO/IAEA/WHO Joint Study Group on High-Dose Irradiation recommends lifting any upper dose limit

1999 The European Union issues Directives 1999/2/EC (framework Directive) and 1999/3/EC (implementing Directive) limiting irradiation a positive list whose sole content is one of the eight categories approved by the SCF, but allowing the individual states to give clearances for any food previously approved by the SCF.

2000 Germany leads a veto on a measure to provide a final draft for the positive list.

2003 Codex Alimentarius General Standard for Irradiated Foods: no longer any upper dose limit

2003 The SCF adopts a “revised opinion” that recommends against the cancellation of the upper dose limit.

2004 ICGFI ends

2011 The successor to the SCF European Food Safety Authority(EFSA), reexamines the SCF’s list and makes further recommendations for inclusion

1.1. What is Food Irradiation?

Food irradiation is the treatment of food by gamma rays from a cobalt-60 or cesium-137 source or electrons or X-rays from a machine source. It is analogous to other types of food processing treatments such as heat pasteurization, canning, freezing or dehydration. Irradiated foods are safer to eat and more resistant to spoilage. Irradiation destroys insects, molds, fungi, and pathogens that cause food-borne illness or foods to spoil.

Food irradiation is a technology that improves the safety and extends the shelf life of foods by reducing or eliminating microorganisms and insects. Like pasteurizing milk and canning fruits and vegetables, irradiation can make food safer for the consumer.

Ionizing energy

Food is routinely processed using different wavelengths of radiant or electromagnetic energy. These include infrared waves used in traditional baking and broiling, microwaves used for quick cooking, and sunlight used for drying.

These forms of energy are parts of the electromagnetic energy spectrum which ranges from the low intensity broad waves of radio at one end to the very short high intensity wavelengths of X- rays and gamma rays at the other (figure 1). The latter are used for food irradiation processing.

Gamma rays, X – rays and accelerate electrons are known as ionizing radiation because as they pass through food, they interact with the molecules to form positively and negatively charge ions. These unstable particles change rapidly into highly reactive free radicals which in turn react with each other and with unchanged molecules. The effect of these reactions in the molecules of plant material brings about effects such as the inhibition of sprouting and the retardation of ripening. Large molecules such as deoxyribonucleic acid (DNA) are particularly susceptible to being broken into smaller molecules. This chemical change causes damage to the DNA, which prevents living cells from dividing, thus causing the sterility or death of contamination organism such as parasites, insects, larvae, bacteria, mould spores and viruses. The more simple the organism, the higher the radiation dose needed to kill it.

Ionizing energy that passes through food creates biochemical changes but leaves no residual radioactivity. Just as radiotherapy does not make cancer patients radioactive irradiation does not make food radioactive. This is because the energy levels used are too low to induce nuclear activation.

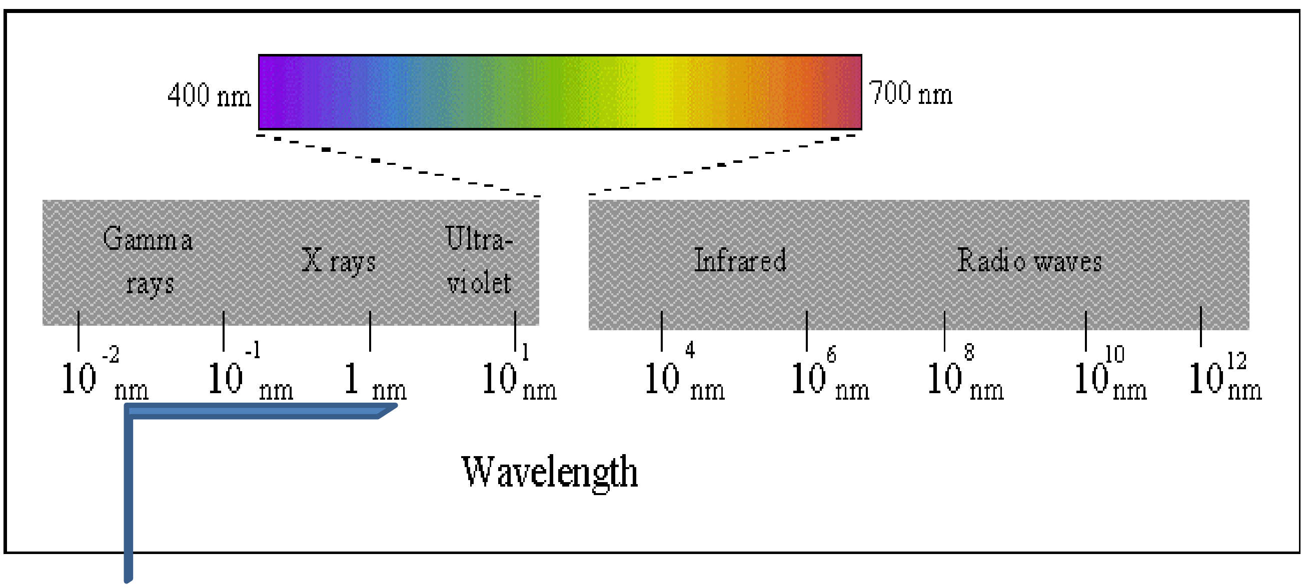

Figure1. Food irradiation

Food irradiation is a promising new food safety technology that can eliminate disease-causing bacteria and microorganisms from foods.

Food irradiation is a process in which food products are exposed to a controlled amount of radiant energy to kill harmful bacteria, to control insects and parasites, reduce spoilage, and inhibit ripening and sprouting. It is also calledcold pasteurization as it kills harmful bacteria without heat.

This treatment is used to preserve food, reduce the risk of food borne illness, prevention the spread of invasive pests, and delay or eliminate sprouting or ripening.

The fundamental difference between food irradiation and pasteurizationis the source of the energy used to destroy the microbes. While Conventional pasteurization relies on heat; irradiation relies on the energy of ionizing radiation

Irradiation is also used for non-food applications, such as medical devices.

The FDA has approved irradiation of meat and poultry and allows its use for a variety of other foods, including fresh fruits, vegetables and spices.

The agency determined that the process is safe and effective in decreasing or eliminating harmful bacteria. Irradiation also reduces spoilage bacteria, insects and parasites and in certain fruits and vegetables it inhibits sprouting and delays ripening.

The effects of irradiation on the food and on animals and people eating irradiated food have been studied extensively for more than 40 years.

1.2. Are Irradiated Foods Safe?

Yes. Irradiated foods are safe. Irradiation makes meat and poultry safer by reducing the numbers of harmful bacteria and parasites.

Nutrient losses caused by irradiation are less than or about the same as losses caused by cooking and freezing.

Public health agencies worldwide have evaluated the safety of food irradiation over the last fifty years and found it to be safe. In 37 countries more than 40 food products are irradiated. In some European countries, irradiation has been in use for decades and in the United Stated, the Food and Drug Administration regulates food irradiation.

In addition, food irradiation has received official endorsement from the American Medical Association (AMA), the World Health Organization (WHO) and the International Atomic Energy Agency (IAEA).

1.3. Are Irradiated Foods Still Nutritious?

Yes. Irradiation, like all known methods of processing food, can lower the content of some nutrients, such as vitamins, but storing food at room temperature for a few hours after harvesting does the same thing.

At low doses of radiation, nutrient losses are either not measurable or, if they can be measured, are not significant.

At the higher doses used to extend shelf-life or control harmful bacteria, nutritional losses are less than, or about the same as, those caused by other kinds of food processing. It can certainly be said that irradiated foods are wholesome and nutritious.

1.4. Does Irradiation destroy all Bacteria?

No. Irradiation is equivalent to pasteurization for solid foods, but it is not the same as sterilization. Food irradiation can be an important tool in the war against illness and death from food borne diseases. But it is not a substitute for comprehensive food safety programs throughout the food distribution system.

In addition, food irradiation is not a substitute for good food-handling practices in the home: irradiated foods need to be stored, handled and cooked in the same way as UN irradiated foods.

How does the irradiation process destroy bacteria?

a. Radiation breaks the DNA or damages other critical molecules in bacteria, either killing them or preventing them from reproducing.

b. Irradiation is a process that employs ionizing energy. Radiation energy ionizes a very small number of the molecules within the food product and any bacteria within the food product. When a molecule is ionized, it effectively breaks. If a DNA molecule of a bacterium is ionized, it is damaged or destroyed, preventing the bacteria from being able to reproduce. If a water molecule within a bacterium cell is ionized, it can form peroxide and act as a disinfectant within the bacterium itself. These molecular level changes destroy the bacteria by preventing their reproduction. Only a very small fraction of the molecules within a living organism, such as a bacterium, need to be damaged to have this effect. Because only a small fraction of food product molecules are ionized, minimal adverse effects, such as changes in taste, occur.

1.5. Will Irradiation Increase the Cost Food?

Yes.Any processing will add to the cost of food. In most cases, however, food prices may not necessarily rise just because a product has been treated. Many variables affect food costs, and one of them is cost of processing canning, refrigeration, freezing ,fumigation ,pasteurization and irradiation adds cost to the product.

These treatments will also bring benefits to consumers in terms of availability and quantity, storage life, convenience and improved hygiene of the food. Reduced losses will bring revenue to producers and traders, thus in turn, compensating treatment costs.

The major factors influencing the economics of food irradiation using cobalt-60 include irradiation design parameters are applied dose, handling conditions (dry versus perishable products), capital costs consisting of the irradiation, spare parts for linear accelerators, packing density of products, radiation source, dose uniformity and through put, warehouse capacity and operating costs **.**such as: -salaries, utilities, replenishments of cobalt-60, maintenance, etc.

1.6. Does the irradiation process make food radioactive?

No. The irradiation process involves passing of food through a radiation field allowing the food to absorb desired radiation energy. The food itself never comes in contact with the radioactive material. Gamma rays, X-rays and electrons prescribed for radiation processing of food do not induce any radioactivity in food.

What is the difference between the terms “Irradiated” and “Radioactive” food?

Radiation processed foods are those that have been exposed to radiation as prescribe about to bring about the desire effect in food.

Radioactive foods, on the other hand are those that become contaminated with radionuclides. This type of contamination never occurs during food irradiation.

1.7.How can Irradiated Food be identified in the Market?

Irradiated foods cannot be recognized by sight, smell, taste, or feel. The only sure way for consumers to know if a food has been processed by irradiation is for the product to carry a label that clearly announces the treatment in words, a symbol, or both. Labeling practices can be expected to vary from country to country, but countries that elect to follow the guidelines developed by the Codex Alimentarius Commission will label all foods that have been irradiated and, in addition, possibly other products those have no themselves been irradiated, but of which one or more components were irradiated before incorporation into the final product. The choice of wording, or symbol, is up to the individual country. However, the symbol shown in **Fig. 2** is gaining increasing acceptance as a means of informing the public that a food product has been treated with ionizing radiation.

Fig. 2 Symbol indicating that a food product has been treated with ionizing radiate

1.8. What are the Benefits of Food Irradiation?

Food irradiation offers a number of benefits:

a. To extend the shelf life of many fresh foods. This may be done through preventing sprouting, deactivating mould and killing spoilage bacteria.

b. To improve world food supplies. There could be less food waste through reduction of post-harvest losses. The United Nations estimates that over 25 percent of the world’s harvest is lost to spoilage and waste. Irradiation could allow many food items that now spoil quickly to be shipped to other countries, or to be grown, irradiated and stored in other countries.

c. To replaces fumigants and other pesticides.The resulting reduction of chemical residues in food.

d. To improve food safety. This is destroying the microorganisms that cause food borne illness and parasites that cause diseases. Consumers who have a high risk for food borne illness, such as the elderly, the very young, and those with compromised immune systems, would especially benefit from irradiated food.

1.9.Factors affecting Food Irradiation

The factors that need to be considered and controlled during food irradiation include: Safety and wholesomeness of the foods, Resistance of food to ionizing energy, Resistance of microorganisms to ionizing energy, Resistance of enzymes to ionizing energy and Cost

1.9.1. Safety and Wholesomeness of Irradiated Foods

The issues of safety and wholesomeness of irradiated foods revolve around criteria of the following four principles:

a. Radiological. Ensuring that foods do not become radioactive during irradiation

b. Toxicological safety. Ensuring that production of toxic and possibly carcinogenic substances does not occur

c. Microbiological safety. Ensuring the efficacy of the radiation process with respect to the ability of the prescribed absorbed dose to kill disease-causing microorganisms that could be in the food

d. Nutritional adequacy .Ensuring that undue losses of nutrients do not occur as a consequence of treatment of food with ionizing energy.

1.9.2. Resistance of Foods to Ionizing Energy.

Not all foods are amenable to preservation by treatment with ionizing energy. The same can be said for thermal processing, freezing and dehydration as methods of food preservation.

The quality of some foods may be adversely affected by irradiation, depending on the dose, temperature and conditions during irradiation. For example, color, flavor or textural changes may result after exposure of food components to ionizing energy.

1.9.3. Resistance of Microorganisms to Ionizing Energy

As in the case of thermal processing (pasteurization, commercial sterilization), microorganisms vary in their resistance to the killing effects of ionizing energy. Analogous to thermal processing where Clostridium botulism is the most heat resistant pathogen, Clostridium botulism spores are the most radiation resistant forms of pathogenic bacteria.

a. Is it true that Irradiation can mask food spoilage?

Irradiation cannot be effectively used to mask or cover up food spoilage since the microorganisms can be easily killed but the spoilage odors, off-flavors and color changes caused by the spoilage microorganisms cannot be changed or eliminated by ionizing radiation. Thus, claims that ionizing radiation can be used to mask signs of poor quality in food are untrue.

b. What about microbiological safety?

There has been concern about the creation of "super bugs" or mutants that are more dangerous but this is not a significant issue at the doses of ionizing radiation used in food processing.

1.9.4. Resistance of Enzymes to Ionizing Energy

The majority of food enzymes are more resistant to ionizing energy than spores of Clostridium botulism. From this noted that enzymes cannot be easily inactivated by treatment with ionizing radiation. Ionizing energy could never be used for blanching vegetables. One of the concerns expressed by groups opposed to food irradiation is that enzymes in food are destroyed by exposure to ionizing energy. If vegetables were to be preserved with ionizing energy, they would first have to be blanched with heat followed by treatment with ionizing energy to inactivate the microorganisms of concern.

1.9.5.Costs

After the issues of safety and wholesomeness have been satisfied, economic factors must be considered in evaluating the feasibility of an application of food irradiation. Food irradiation may be economically viable if it results in substantial increases in storage life and therefore marketing time and decreases in post-harvest or catching losses. This may be the case in terms of treatments of fresh fish or some fresh fruits. In cases where the process does not offer advantages (such as nutrition retention, technological advantages, economic advantages) it would not be economically viable.

1.10. Advantages of Food Irradiation

a.Immune deficiency benefits. Those who suffer from a disease that depresses the immune system, which can occur through med or the disease itself, can become ill from the most general food contaminants. With food irradiation, you have something that will remove those contaminants

b. It kills dangerous organisms. The best food handling measures in the world aren't a guarantee that all of the dangerous organisms will be avoided and/or removed.Food irradiation obliterates ninety percent of these organisms

c.A proactive measure against insects. As most of us know, moths and similar insects love grains. Storing them in your home certainly isn't going to deter them. Food irradiation makes the products less appealing to the insects. This in turn makes it less likely that the insects will leave eggs in the grains, which can cause a variety of health problems.

1.11. Disadvantage of food irradiatio

a. No Promises. One of the problems with food irradiation is that there is no definitive way of killing all of the organisms that can come into contact with our foods. Some organisms are in fact resistant to the mild radiation that utilized. b.Animals. Studies going back several decades come to the same conclusion over and over again. Irradiated foods can cause health problems with a variety of animals. Rare cancers, chromosome abnormalities and even premature deathscanoccur.

c. Colors and Textures.Both vitamins and minerals are at risk through irradiation. Worse yet, the textures and flavors can also be altered through this process. For many people, these changes are unpleasant. The smell of beef after irradiation is one exam

Chapter Two

2. Global practice of food irradiation

The treatment of food with ionizing radiation has been in practice for nearly a century since the first irradiation process patents were filed in 1905. Regular use of the technology in food processing started in 1963 when the United State Food and Drug Administration (FDA) approved the sale of irradiated wheat and wheat flour. Today irradiation treatment is used on a wide variety of food products and is regulated in the United States by the FDA under a Department of Health and Human Services regulation. Irradiation of food has three main applications: extension of shelf life, elimination of insects and the destruction of bacteria and other pathogens that cause food borne illness

Irradiation technology involves exposing food to ionizing radiation. The radiation is generated from gamma rays emitted by cobalt-60 or cesium-137, or from x-rays or electron beams.

The FDA has approved the use of irradiation for wheat and wheat powder, spices, enzyme preparations, vegetables, pork, fruits, poultry, beef, lamb, and goat meat.In 2000, the FDA also approved the use of irradiation to control salmonella in fresh eggs.

2.1. Emerging Food Irradiation Applications

Irradiation is an effective form of food preservation that extends the shelf life of the food and reduces the spoilage of food. The process also benefits the consumer by reducing the risk of illnesses caused by food borne diseases.

Food irradiation may be achieved using:-Since worldwide food borne diseases are increasing and attempts to reduce them have been unsuccessful, the World Health Organization considers food irradiation important toward ensuring food safety and reducing food losses**.**

Irradiation can be a useful control measure in the production of several types of raw or minimally processed foods such as: - poultry, meat, meat products, fish, seafood, fruits and vegetables.

Low-dose and medium-dose irradiation applications are currently being investigated with food products, but the use of irradiation in combination with other processes, and high-dose food irradiations are beginning to emerge.

2.2. Legal and Regulatory aspects of Food Irradiation

a. FDA Approval

Food irradiation is regulated as a food additive (rather than as a process, like pasteurization or canning) by the FDA under the terms of the 1958 Food Additive Amendment to the Food Drug and Cosmetic Act.This law prohibits the use of a new food additive until its sponsor has established its safety and until the FDA has issued a regulation specifying conditions of safe use.

The law specifically includes “any source of radiation” in its definition of “food additive.” This legal definition created some problems in early studies of the safety of irradiation because it require that toxicological studies be carried out on individual irradiated foods such as cod, red fish, chicken, beef, papaya, and mangoes.Irradiated foods that have been approved for production and consumption by the FDA are listed in Table 1:

Table 1: Irradiated Foods Approved by the FDA

Food items	Purpose	Max.dose	Approval
Spices and dried vegetable seasonings	Insect and microbial control	10 kGy	1983
Pork	Control of Trichinella	1kGy	1985
Fresh fruit and vegetables	Insect disinfestations and growth control	1kGy	1986
Poultry meat	Inactivation of pathogens, e.g. Salmonella	3kGy	1990
Ground beef and	Inactivation of pathogens, e.g.,	7kGy	1997

other non-intact red meat	**E. coli O157:H7**		
Shell eggs	**Inactivation of Salmonella**	**3kGy**	**2000**
Sprouting seeds	**Inactivation of pathogens, e.g., Salmonella**	**8kGy**	**2000**
Mollusks	**inactivation of pathogens, e.g., Vibrio**	**2kGy**	**2005**

b. USDA Approvals

The USDA has jurisdiction over approval of quality control programs of processing of meat, poultry and eggs, as well as of quarantine treatments of fresh fruits and vegetables that may harbor exotic pests.The maximum dose for any irradiated food must still follow the FDA-specified guidelines. The USDA may, however, require minimum absorbed doses to meet specific objective for example, a minimum of 0.40 kGy to control any insects in fresh produce.Table 2 shows the foods of irradiation approved by the USDA.

Table 2: Irradiated Foods Approved by the USDA

Food Item	Purpose	approval
Fresh and frozen poultry Meat and meat products	**Inactivation of pathogens**	**1992**
Ground meat and other non-intact meat products	**Inactivation of pathogens**	**2000**
Fresh fruits and vegetables	**quarantine control**	**2006**

2.3. What is the Legal Status of Food Irradiation around the World?

About 60 countries have approved specific applications of irradiation and irradiated foods are actually produced for commercial purposes in some 30 countries. Both the number of countries that have approved irradiation for food processing as well as the numbers of approved products/applications is increasing.

Recently, the trend has been to approve irradiation of classes of food (e.g., fruits, vegetables, meat and poultry, seafood, roots and tubers, cereals and certain pod-bearing plants, spices and seasonings) rather than individual food items, per the recommendations of the International Consultative Group on Food Irradiation (ICGFI).

2.3.1. Control of Food Irradiation

International perspectives

The Joint Expert Committee on Food Irradiation (JECFI) convened by the Food and Agricultural Organization (FAO), the International Atomic Energy Agency (IAEA) and the World Health Organization (WHO) are of particular importance in the development of food irradiation in the international arena.

JECFI is a group of scientists working on the wholesomeness of irradiated foods and gives decisive interventions on the safety of food irradiation.

These declarations resulted in the development and eventual adoption of the Codex general standard for irradiated foods stipulating both the general and technological requirements for the process and its associated recommended code of practice for the operation of radiation facilities used for the treatment of Foods to provide guidelines to ensure radiation processing of food products is implemented safely and correctly.

Codex has also developed a set of guidelines for irradiated food labeling.

The Codex general standard for the labeling of pre-packaged foods contains provisions for labeling of irradiated foods that a food which has been treated with ionizing radiation shall carry a written statement indicating such treatment in close proximity to the name of the food.

2.3.2. Labeling & Regulatory

Which foods can be irradiated?

Many foods can be irradiated effectively including meat, poultry, grains, shell eggs, spices, fruits and vegetables. Irradiation is likely to have the greatest application for raw foods of animal origin. Examples of meat and poultry that may be irradiated are whole or cut-up birds, skinless poultry, pork chops, roasts, stew meat, liver, hamburgers and ground meat. However, not all foods are suitable for irradiation.The following table 3 shows which food products have been approved for irradiation:

Table 3: Food products suitable for irradiation

Types of Food	Dose	Purpose	Approval Year
Wheat flour	0.20-0.50 kGy	Control of mold	1963
White potatoes	0.05-0.15 kGy	Inhibit sprouting	1964
Pork	0.30-1.00 kGy	Kill Trichina parasites	1986
Fruit and vegetables	1.00 kGy	Insect control, extend shelf life	1986
Herbs and spices	30.00 kGy	Sterilization	1986
Poultry	3.00 kGy	Bacterial pathogen reduction	1990-FDA
Poultry	1.50-3.00 kGy	Bacterial pathogen reduction	1992-USDA
Meat	4.50 kGy	Bacterial pathogen reduction	1997-FDA 2000-USDA
Shell eggs	3.00 kGy	Bacterial pathogen reduction	2000-FDA

Chapter Three

3. Determination dose of Food Irradiation

Radiation dose

The radiation dose - the quantity of radiation energy absorbed by the food - is the most critical factor in food irradiation. Often, for each different kind of food, a specific dose has to be delivered to achieve a desired result. If the amount of radiation delivered is less than the appropriate dose, the intended effect may not be achieved. Conversely, if the dose is excessive, the food product may be so damaged as to be rendered unacceptable.

At present, the dose of radiation recommended by the FAO/WHO Codex Alimentarius Commission for use in food irradiation does not exceed 10 000 grays, usually written 10 kGy. This is actually a very small amount of energy, equal to the amount of heat required to raise the temperature of water by 2.4 ^{0}C. With this small amount of energy, it is not surprising that food is little altered by the irradiation process, or that food receiving this amount of radiation is considered safe for human consumption.

3.1. Dosimeters

The radiation absorbed dose is the amount energy absorbed per unit weight of the target material. Dose is used because, when the same substance is given the same dose, similar changes are observed in the target material.

Dosimeters are used to measure dose and are small components that, when exposed to ionizing radiation, change measurable physical attributes to a degree that can be correlated to the dose received.

Measuring dose (dosimeters) involves exposing one or more dosimeters along with the target material. The ranges of dose commonly used in food irradiation to achieve various effects can be classified as given in the following sections.

a. Applications at low dose levels (up to 1 kGy)

Sprouting of potatoes, onions, garlic, shallots, yams, etc. can be inhibited by irradiation in the dose range 0.02–0.15 kGy.

Radiation affects the biological properties of such products in such a way that sprouting is appreciably inhibited or completely prevented.

Physiological processes such as ripening of fruits can be delayed in the dose range 0.1–1 kGy. These processes are a consequence of enzymatic changes in the plant tissues.

Insect disinfestation by radiation in the dose range 0.2–1 kGy is aimed at preventing losses caused by insect pests in stored grains, pulses, cereals, flour, coffee beans, spices, dried fruits, dried nuts, dried fishery products and other dried food products.

A minimum absorbed dose of about 0.15 kGy can ensure quarantine security against various species of tephretid fruit flies in fresh fruits and vegetables, and a minimum dose of 0.3 kGy could prevent insects of other species from establishing in non-infested areas. In most cases irradiation either kills or inhibits further development of different life-cycle stages of insect pests.

The inactivation of some pathogenic parasites of public health significance such as tapeworm and trichina in meat can be achieved at doses in the range 0.3–1 kGy.

b. Applications at medium dose levels (1–10 kGy)

Radiation enhances the keeping quality of certain foods through a substantial reduction in the number of spoilage causing micro-organisms.

Fresh meat and seafood, as well as vegetables and fruits, may be exposed to such treatments with doses ranging from about 1 to 10 kGy, depending on the product. This process of extending the shelf life.

Pasteurization of solid foods such as meat, poultry and seafood by radiation is a practical method for elimination of pathogenic organisms and micro-organisms except for viruses. It is achieved by the reduction of the number of specific viable non-spore-forming pathogenic micro-organisms such that none is detectable in the treated product by any standard method, for which doses range between 2 and 8 kGy. The product will usually continue to be refrigerated after the radiation treatment. This process is improving the hygienic quality of food by inactivation of foodborne pathogenic bacteria and parasites. This medium dose application is very similar to heat pasteurization, and is hence also called radio pasteurization.

c. Applications at high dose levels (above 10 kGy)

Irradiation at doses of 10–30 kGy is an effective alternative to the chemical fumigant ethylene oxide for microbial decontamination of dried spices, herbs and other dried vegetable seasonings. This is achieved by reducing the total microbial load present in such products including pathogenic organisms.

Radiation sterilization in the dose range 25–70 kGy extends the shelf life of precooked or enzyme inactivated food products in hermetically sealed containers almost indefinitely. This is valid independent of the conditions under which the product is subsequently stored as long as the package integrity is not affected. This effect is achieved by the reduction of the number and/or activity of all organisms of food spoilage or public health significance, including their spores, to such an extent that none are detectable in the treated product by any recognized method. This process is analogous to thermal canning in achieving shelf-stability. (Long term storage without refrigeration)

3.2. What is a Dose of Irradiation?

The dose for food irradiation is the amount of radiation absorbed by the food and is not the same thing as the level of energy transmitted from the radiation source.

The dose is controlled by the intensity of radiation and the length of time the food is exposed.

The absorbed dose (D) = dE/dm

D, is the amount of energy absorbed per unit mass of irradiated matter at a point in the region of interest.

dE, imparted by ionizing radiation to the matter in a volume element

d*m*, the mass of that volume element.

The SI derived unit of absorbed dose is the gray (Gy).

1 Gy = 1 J/kg = 100 rad

Gray is the energy imparted by ionizing radiation to matter per unit mass.

Rad is theunit for "radiation energy absorbed" by food being processes with radiation

For any given irradiation conditions, it is necessary to specify the absorbed dose in the particular material of interest because different materials have different radiation absorption properties.

For food irradiation, the material of interest is generally specified as water. With regard to radiation interaction properties, most foods behave essentially as water regardless of their water content.

Chapter Four

4. Ethiopia Food Items

Ethiopia has a National Drug Policy and a Proclamation on Food, Medicine, Health Care Administration and Control Authority (FMHACA).

The new proclamation No.661/2009 outlined requirements for registration and licensing food producers, imports and exports, food safety and quality, packaging and libeling’s, nutrition and food irradiation

4.1. Food items

Food is any substance consumed to provide nutritional support for the body. It is usually of plant or animal’s origin contains essential nutrients, such as: carbohydrates, fats, proteins, vitamins and minerals. The substance is ingested by an organism and assimilated by the organisms in an effort to produce energy, maintain life or stimulate growth.

Table 4: Types of food items available

Function	Nutrient	Food
Energy giving	Carbohydrates and fats	Cereals, fats, sugar
Body building food	Proteins	pulse, milk, meat, chicken
Regulatory and protective foods	Vitamins and minerals	Fruits and vegetables

a. Food of plant origin

Figure: 3. Show that some of foods we eat come from plants, including wheat Corn, sorghum, fruit, vegetable, tubers, spices, ginger and oilseeds.

Figure 3: Foods of plants

a. Cereals: a plant (such as a grass) that produces grain that can be eaten. The most important cereals are teff, corn, sorghum, barley, wheat and millet. Teff is native to Ethiopia and a number of varieties are available. The most common are white, red and a mixture of these two. The kind of teff most preferred is white teff. In order to get the bread as white as possible, upper-class families may wash the seeds several times.

Corn, sorghum, barley and wheat are grown at different altitudes and are used instead of or together with teff. Emmer Wheat is a cereal recognized as a suitable food for children. Millet is used in part of the region, mainly for the local beer.

b. Legumes: a type of plant(such as a pea or a bean plant) with seeds that grow in long cases (called pods) .Legumes are grown agriculturally, primarily for their food grain seeds. The most common being is chickpeas, field peas, lentils and broad beans. The legumes are used in the sauce whole, split or as flour, but are sometimes toasted whole and eaten as a snack with coffee.

c. Vegetables: Onions (mainly red onions) are grown in large areas and used in huge quantities. Kale is the next vegetable of importance. It is cheap and is available for most of the year. Pumpkins and green chickpeas are used when available. Cauliflower, cabbage, red beets, tomatoes, etc. are grown mainly for consumption by foreigners.

d. Tubers: a short, thick round stem that is part of certain plant (such as the potato), that grows underground, and that can produce a new plant. Potato, sweet potatoes and in the Oromo communities Oromo potatoes are used in the staple diet.

e. Spices: a substance (such as pepper or nutmeg) that is used in cooking to add flavor to food and that comes from a dried plant and is usually a powder or seed. Spices play an important role in most countries in Asia and Africa, and Ethiopia is no exception. Some of the spices are grown in Ethiopia, either cultivated or wild, and others are imported, mainly from India. The most important spices are chili and bird's-eye chili. These are used in the spice mixtures berberre and mitmitta.

f. Fruit: Fruit means the fleshy seeds associated structure of plants that are sweet or sour and edible in the raw state. The most common fruits are lemons, apples, oranges, grapes, strawberries`` and bananas.

g. Oilseeds: a seeds or crop grown mainly for oil. Oilseeds are important cash crops. Niger flax, sunflowers and safflowers are grown in large areas. Most of the oilseeds are used for producing oil, and the oilseed cakes are exported for cattle feeding.

b. Food of Animals Origin

Figure: 4. Show that some of foods we eat come from animals, include meat, beef, veal, lamb, pork, fish and chicken**.**

Figure 4: Foods of Animals

a. Milk: A white liquid produced by a woman to feed her baby or by female animals to feed their young: specially, milk from cows or goats that is used as food by people. The amount of milk per cow is small. Fresh milk is mainly given to small children. From milk is prepared sour milk, butter and low-fat sour-milk cheese.

b. Meat: The flesh of an animal used as food. The meat of the cow, sheep or goat is eaten in the staple diet. Wealthy families can afford to serve this kind of food often but the majorities of the population are poor and can serve meat only on ceremonial occasions, such as religious feasts. For big feasts the cow's meat is served raw immediately after the animal is killed. The raw meat is spiced with the spice mixture mitmitta or awaze.

c. Chicken: The meat of chicken used as food. Chicken are common, but the eggs are mainly kept for sale, and the chicken are killed for big feasts.

d. Fish**:** The meat of fish used as food. Fish is of very little importance in the staple diet, because of the poor transportation system.

4.2. Established methods of Food Processing

The techniques used for preserving food vary from comparatively simple methods, such as sun-drying, to highly sophisticated processes requiring complex equipment and specially trained personnel. To appreciate how food irradiation fits into this spectrum, it is helpful to have a basic understanding of the traditional methods of food preservation - those surviving from antiquity, as well as those that are the fruits of modern science.

The ability to preserve food helped make civilization possible. Once primitive people had discovered how to keep food for relatively long periods, they could give up the pattern of ceaseless wandering in search of an adequate food supply. They could plant, raise, and harvest enough food to last until the next harvest and, when necessary, to sustain them through times of low food production.

The discovery that food could be processed and preserved enabled human beings to establish settled communities and to live in ways not so very different from the way most people live today. The use of fire for food preservation can be traced to the pre Neolithic period. Other methods - salting, smoking, drying, fermentation, and freezing - are known to have been used by Neolithic people more years ago.

These early peoples did not understand, however, why drying, smoking, freezing, and other methods prevented food from going bad.

The role of microbes in food spoilage was not discovered until the time of Pasteur. But even without a scientific basis, human ingenuity produced sophisticated food-processing techniques. The first successful process for preserving food by heating it in a suitable container that was then tightly sealed was discovered at the time of the Napoleonic Wars in the early 19th century. Indeed, war has played a significant role in the evolution of food processing. In our own times, the special food storage and handling requirements of manned space exploration have resulted in important developments in the freeze-drying and packaging of food.

The traditional methods of preserving food can be divided into five major groups.

Such as: - fermentation, chemical treatment, drying, heat treatment and freezing

a. Fermentation

Fermentation preserves foods by the selective removal of the fermentable substrate and the consequent development of an unfavorable environment for spoilage organisms.

Microorganisms are used to ferment sugars to alcohol or acids. A number of factors determine what kind of product is obtained by fermentation: the kind of organism used, the material being processed, the temperature, and the amount of available oxygen determine whether the end-product of fermentation will be beer, wine, leavened bread, or cheese.

Yeasts are the most efficient microbial converters of sugar to alcohol and are essential for the making of beer and wine. Fermentation that leads to the formation of lactic acid is important in the pickling of vegetables and in the processing of a wide variety of dairy products. Pickling of meat in the presence of salt, nitrates, and smoke is an ancient process that is still being refined and widely used. Modern industrial applications of fermentationdemand careful control of the process to ensure high yields, and to maintain a uniform high product quality.

b. Chemical treatment

Preservation of food by the addition of chemicals is a relatively simple and inexpensive technique. It is especially useful in areas where refrigeration is not readily available. On the other hand, concern about the health risks associated with some of the chemicals traditionally used to preserve food has led some countries to curtail their use or to ban some of them from use in foods.

The substances employed in food preservation are of two general kinds: common food ingredients, such as sugar and salt and specific substances that prevent or retard food deterioration. In the latter category are the so-called food additives and certain other chemicals of value in lengthening the shelf-life of fresh foods or preventing infestation of grains and other foods during bulk storage.

Sugar in concentrations of 65 % or more preserves food by lowering the water activity and hence inhibiting the growth of microorganisms.

Products such as fruit preserves, jams, and syrups are commonly processed with sugar. In the modern industrial setting, sugar preservation is often supplemented by the use of heat, cooling, and air free packaging to help control surface mould formation and to prevent discoloration and loss of flavor. In modern food processing, a non-nutritive sweetener, such as sorbitol, may be used as a substitute for sugar.

The use of salt to cure meat, fish, and vegetables is an ancient practice that is widely, if somewhat differently, applied today. Salt keeps spoilage organisms under control and acts as a drying agent, again by reducing the water activity. It is often combined with use of nitrites and external drying, especially in the preservation of meat and fish. In those products, the destructive action of bacteria and enzymes is retarded. In recent years, changes in taste, combined with growing concern about health hazards associated with a high intake of salt, have led to a significant lessening in the use of salt as a food preservative.

Improved sanitation combined with refrigeration can make it less necessary to employ high concentrations of salt to preserve meats, fish, and vegetables.

The preservative action of the smoking of food can be attributed to the combined effect of smoke and heat, or to smoke alone. In any case, while this method of food preservation has been known for centuries, it is used much less today because some of the constituents of smoke are now known to be carcinogenic. Liquid substitutes are increasingly being employed to impart a smoked flavor to foods.

Among the food additives approved for use as chemical preservatives in many countries are propionic acid, benzoic acid, sorbic acid, and their salts and derivatives. Sulfur dioxide and sulfites have a long history as important preservative agents, but recently their use has been severely limited in several countries because of health concerns. All these substances are most effective in foods that are dry or fairly acidic; they are of limited or no value in watery low acid foods, such as mushrooms and certain green vegetables. In addition to its wide use in beverages, carbon dioxide at higher than normal atmospheric pressure can help retard the maturation of some fresh fruits and maintain the quality of fresh meats, fish, poultry, baked goods, and salads. Carbon dioxide extends shelf-life and is relatively inexpensive, although refrigeration is required in addition for foods of animal origin.

Several other chemicals, notably methyl bromide, ethylene bromide, and ethylene oxide, have been widely used as antimicrobial agents and as fumigants to destroy insects in various foods, such as spices, copra, and walnuts. Evidence that ethylene bromide and ethylene oxide are harmful to man has led to their being banned by some national regulatory authorities in the last few years. The use of other fumigants is also under review because of the potential dangers to human beings and the environment.

c. Drying

In addition to protecting perishable foods against deterioration, drying offers other important advantages. The removal of water reduces both the weight and the bulk of food products and thus lowers transportation and storage costs. Dehydration can also make foods suitable for subsequent processing that may, in turn, facilitate handling, packaging, shipping, and consumption. Both physical and chemical changes take place during food drying, but not all of them are desirable. In addition to changes in bulk density, foods may undergo unwelcome color changes, such as browning; they may also lose nutritional value, flavor, and even the capacity to reabsorb water.

Successful food dehydration depends on the correct selection of the method and equipment to be used. That depends on the type of food to be dried, what properties the final product must have, and the size and capacity of the processing unit. The most widely used drying methods involve exposing food to heated air. Forced-air drying is used largely with grains, fruits, and vegetables. The so-called atmospheric batch-driers, such as kilns, are generally used when the drying operation is small or seasonal. Atmospheric-drying, in which the food moves through tunnels on a conveyer belt while the air flow is carefully controlled, is a technique commonly employed when the drying operation is more or less continuous.

Other methods of drying foods expose the product to a heated surface in a revolving drum. In this conductive drying method, the equipment may operate at atmospheric pressure or in a vacuum, which accelerates drying. Certain liquids (e.g., milk) can be spray dried to produce powders suitable for later dissolution. Spray-drying can be effective for liquid foods that are especially vulnerable to heat and oxidation.

In the method known as freeze-drying, water is removed from foods by changing it from a solid (ice) to a gaseous state (water vapor), without permitting it to pass through the intermediate liquid phase, a transformation known as sublimation. Freeze-drying is carried out in a vacuum and at very low temperatures. It produces the best results of any drying method, principally because the food does not suffer significant loss of flavor or nutritional value. The process is expensive, however, because it requires both low and high temperatures and vacuum conditions. Its use seems justified only when the food being processed is very heat-sensitive and the resulting product must meet the highest possible standards of quality.

Suitable packaging is required for a great number of dehydrated foods to ensure satisfactory shelf life and to minimize losses due to water absorption and oxidation, as well as insect infestation.

d. Heat treatment

Cooking of food is such a ubiquitous and ancient practice that its role in food preservation is easily overlooked. Yet various forms of heat treatment baking, broiling, roasting, boiling, frying, and stewing are among the most widely used food processing techniques, in industry as well as in the home. Heat not only produces desirable changes in food, but can also lengthen safe storage times.

Heating reduces the number of organisms and destroys some life threatening microbial toxins. It inactivates enzymes that contribute to spoilage, makes foods more digestible, alters texture, and enhances flavor. But heating can also produce unwanted results, including loss of nutrients and adverse changes in flavor and aroma.

The temperature and length of time involved are critical in heat processing, especially when heat is being used to destroy microorganisms. A major goal of thermal processing is to achieve maximum destruction of organisms with minimum loss of food quality. This balance is often struck by the use of high temperatures for a comparatively short time.

As a method for reducing the number of microorganisms, heat treatment of food consists primarily of blanching, pasteurization, and sterilization. Blanching, exposing food briefly to hot water or steam, is normally used before foods are further processed by freezing, drying,or canning. In addition to cleansing the raw food product, blanching reduces the microbial load, removes accumulated gases, and inactivates enzymes.

In the industrial setting, problems associated with food blanching, and with pasteurization or sterilization, include the disposal of large amounts of waste water, the unintended removal of solids from the food, damage to heat sensitive products, and energy conservation.

The heat tolerance of microorganisms is influenced by acidity. Therefore, the temperature at which foods are canned depends on the acidity of the food being processed. Low-acid foods must be heated to high temperatures, under pressure, in specially designed pressure vessels (retorts) to ensure that hazardous microorganisms are effectively controlled. Acid foods or foods that contain low levels of preservatives can be processed at lower temperatures.

Depending on the product and process employed the food may be packaged before or after heat treatment.

In the heat treatment of low-acid foods by sterilization, the objective is what is termed "commercial sterility", and the most important goal is destruction of spores of the bacterium Clostridiumbotulinum.A toxin produced by this organism is the cause of botulism, one of the most lethal forms of foodborne disease. Some low-acid foods are also processed at lower temperatures in order to destroy pathogenic microorganisms and extend their shelf-life. This process is usually referred to as "pasteurization".

The resulting product is not always stable indefinitely, and unless the distribution system can ensure that the product can be distributed rapidly to the consumer, or else kept at adequately low temperatures, the product may deteriorate quickly. The range of products treated in this way is quite large, and the conditions of treatment and distribution vary considerably. Pasteurization can be applied to milk, beer, and fruit juices, and even to some solid products such as canned meats.

The health protection benefits of heat treatment are lost, of course, if the food is not packaged in a way that protects it against subsequent contamination. Thermally processed products are normally packed in metal (e.g., tinplate, aluminum), glass or laminated plastic containers. Aseptic packaging of foods is a relatively new technique, in which the unpackaged product is heated quickly to a sterilization temperature, held there until sterile, aseptically cooled and poured into sterilized containers, which are then sealed.

The facilities and equipment necessary to ensure proper handling and packaging of processed foods is complex. As is the case with all modern food processing, these facilities require constant surveillance by trained personnel and frequent inspection by public health authorities responsible for the enforcement of food safety regulations.

If properly processed and packaged, heat-treated foods are microbial stable for long periods. Shelf-life is limited only by the slow physical and chemical changes caused by the interaction of contents and packaging and by the conditions in which the packaged food is stored.

e. Freezing

Freezing is the best method now in general use for the long-term preservation of food. Frozen food retains most of its original flavor, color, and nutritive value. Despite its superiority, however, freezing often produces detrimental effects on food texture as a result of ice formation. Fast freezing minimizes this problem.

Preservation by freezing is achieved by lowering the temperature of the food to at least -18 ^{0}C, which crystallizes all the water in the product to ice. At these low temperatures, microbial growth ceases and destructive enzyme activity, while not completely stopped, is reduced to an acceptable level. With some foods, such as vegetables, where enzyme activity during storage or thawing is critical, heat treatment, or some other means of destroying enzymes, is carried out prior to freezing. Food can be frozen before or after packaging.

Unpackaged foods freeze faster but are subject to considerable water loss unless they are frozen very rapidly.

Initially, the practice was to freeze food by placing it in a cold room (-l8°C to -40°C) and allowing air to circulate slowly over the food - a technique known as sharp-freezing. Later, air-blast freezers were developed for both batch and continuous processing. Their use has significantly reduced processing time and improved the quality of frozen products.

Food can also be frozen by being placed between, and in direct contact with, two hollow metal surfaces that are cooled by chilled brine or vaporizing refrigerants (ammonia or Freon). This method, called plate-freezing, is slower than freezing in circulating air, but it minimizes dehydration. The food product must be packaged before it is processed by plate-freezing. In the process called cryogenic freezing, the product, usually unpackaged, is exposed to an extremely cold refrigerant that is undergoing a change of phase, e.g., from liquid to gas. The refrigerants most commonly used in the food industry are liquid nitrogen and liquid carbon dioxide. This method affords very fast freezing; hence damage to the product is kept to a minimum. Obviously, frozen food must be maintained at or below freezing temperatures at all times if this method of preservation is to be effective.

In addition, frozen food must be packed in containers that prevent moisture loss and oxidation, example, freezer burn. While the overall costs of thermal treatment and freezing are similar up to the completion of the processing operation, the need for an unbroken chain of transportation and storage at freezing temperatures places serious economic constraints on the use of freezing for the preservation of food. Each method used to control spoilage and deterioration of food and to protect the consumer against foodborne disease has both advantages and disadvantages.

Chapter Five

5. PracticalApplication of Food Irradiation

5.1. Food irradiation applications

Extensive research during the past four decades has documented the usefulness and safety of ionizing radiation as a food processing technique. But its potential value, of course, can be realized only if the technique is put to practical use. This chapter summarizes information on the practical application of irradiation in the processing of food - how it is used and with what results.

Doses and effects of irradiation

For each application of food irradiation there is a minimum dose below which the intended effect will not be achieved. **Table 5** shows the dose requirements for some typical uses of food irradiation. Because irradiation causes only a slight temperature rise in the food being processed, it can kill microorganisms without thawing frozen food. Moreover, an effective radiation dose can be delivered through most standard food packaging materials, including those that cannot withstand heat. This means that irradiation can be applied to hermetically sealed products without the risk of recontamination or re-infestation of properly packaged foods.

Some food products may have to be irradiated under special conditions, for example at low temperature or in an oxygen-free atmosphere.Others, as noted previously, may undergo multiple processing, using, for example, both ionizing radiation and heat. This particular combination may allow the use of lower radiation doses because heat makes microorganisms more sensitive to the effects of radiation. Since radiation does not damage packaging materials designed to hold food during irradiation, multiple processing is facilitated and is more economical.

The actual dose of radiation employed in any food processing application represents a balance between the amount needed to produce a desired result and the amount the product can tolerate without suffering unwanted change.

High radiation doses can cause organoleptic changes (off-flavors or changes in texture), especially in foods of animal origin, such as dairy products. In fresh fruits and vegetables,radiation may cause softening and increase the permeability of tissue. These effects may limit the permissible dose because they are often accompanied by accelerated spoilage if the product becomes contaminated by microorganisms after irradiation treatment. On the other hand, since irradiation slows the rate of ripening of fresh fruits and vegetables, properly stored and/or packaged products remain in a usable condition considerably longer than they would without radiation processing. The extent of radiation-induced organoleptic changes in fruits and vegetables is dose-related: there seems to be a threshold dose below which these changes are not detectable. For that reason, the selection of dosage and, often, the decision to employ supplementary processing to contribute to the intended result are critical factors. The environmental conditions may also strongly affect the dose response of the product from both textural and organoleptic aspects.

Table 5: Dose requirement in various application of food irradiation

purpose	**Dose (kGy)**	**product**
Low-dose (up to 1 kGy)		
(i) Inhibition of sprouting	**0.05 - 0.15**	**Potatoes, onions, garlic, root ginger, yam etc.**
(ii) Insect disinfestation and parasite disinfection.	**0.15 - 0.5**	**Cereals and pulses, fresh and dried fruits, dried fish and meat, fresh pork, etc.**
(iii) Delay of physiological processes	**0.25 -**	**Fresh fruits and vegetables.**

(e.g. ripening)	**1.0**	
Medium-dose (1 up to10)kGy		
(i) Extension of shelf-life	**1.0 - 3.0**	**Fresh fish, strawberries, mushrooms etc.**
(ii) Elimination of spoilage and pathogenic microorganisms	**1.0 - 7.0**	**Fresh and frozen seafood, raw or frozen poultry and meat, etc.**
(iii) Improving technological properties of food	**2.0 - 7.0**	**Grapes (increasing juice yield), dehydrated vegetables (reduced cooking time), etc.**
High-dose (10 up to 50) kGy		
(i) Industrial sterilization (in combination with mild heat)	**30 - 50**	**Meat, poultry, seafood, prepared food sterilized Hospital diets**
(ii)Decontamination of certain food additives and ingredients		**Spices, enzyme preparations, natural gum, etc.**

Some typical applications of food irradiation

Some examples of the use of radiation to enhance the safety and quality of food are explained below: these illustrations are representative of actual applications now being carried out industrially or experimentally in various countries.

a. Control of sprouting and germination

Radiation treatment at low doses (0.05 - 0.15) inhibits the sprouting of potatoes and yam tubers, onions and garlic, ginger, and chestnuts. The appropriate dose within these ranges depends on the variety and other properties of the product.Although, with some varieties, cooking darkens irradiated potatoes more than non-irradiated, and although irradiated potatoes are less resistant to rotting, commercial irradiation has been carried out since 1973 in Japan, where chemical sprout inhibitors are banned.

The success of the Japanese system is due in large measure to careful handling of the product before and after treatment, including careful sorting, curing, and storage.

Controlling the germination of barley during malting is of considerable economic importance. Doses of 0.25-0.50 kGy applied to air-dried barley do not prevent the emergence of shoot tips and tendrils during malting, but markedly retard root growth. In this way, high quality malt can be obtained while the losses resulting from root growth are reduced. Since this effect of radiation processing persists for at least seven months, treatment can be applied before the barley is put into storage, with the added benefit of destroying any insect pests that may be present in the grain.

Very small radiation doses (0.01-0.10 kGy) stimulate the germination of barley, a result that can be used to shorten the malting process and increase the production capacity of malting plants.

b. Insect disinfestation

Radiation at relatively low doses (up to 0.50 kGy) kills or sterilizes all the developmental stages of the common insect pests of grain, including eggs deposited inside the grain.Dried fruits, vegetables, and nuts are liable to insect attack, and some of these products, especially fruits, cannot be effectively disinfested by either chemical or physical means other than irradiation.

Application of 0.2-0.7 kGy to products that have been suitably packaged to prevent re-infestation eliminates the insect problem in dried fruits and vegetables and in nuts. The same technique could sharply reduce losses of dried fish, an important source of protein in many developing countries.

Radiation disinfestation can contribute significantly to improving trade in certain tropical and subtropical fruits, such as citrus fruit, mangoes, and papayas. Because it affords a residue-free means of preventing the importation of harmful insects, radiation treatment offers a viable alternative to fumigation to satisfy the quarantine regulations in a number of countries. Fruit flies, for example, and even the weevil that lodges deep inside the seed of the mango can be controlled by irradiation.

c. Shelf-life extension of perishable foods

One of the principal uses of food irradiation is for killing the microorganisms that cause spoilage or deterioration of the product.

The amount of radiation needed to control or eliminate these organisms depends on the radiation tolerance of the particular organism and the number or "load" of such organisms in the particular volume of food to be treated.The shelf-life of many fruits and vegetables, meat, poultry, and fish and other seafood’s can be considerably prolonged – certainly doubled - by treatment with combinations of refrigeration and relatively low doses of radiation that do not alter flavor or texture.

Most food spoilage microorganisms are killed at doses of less than 5 kGy. Various fresh fruits, including strawberries, mangoes, and papayas, have been irradiated and marketed successfully. A combination of mild heat treatment (immersion in hot water), low dose irradiation, and proper packaging may be successfully applied to fruits that are sensitive to higher radiation doses.

d. Delaying ripening and aging of fruits and vegetables

Exposure to a low dose of radiation delays the ripening and/or senescence of some fruits and vegetables, thereby extending their shelf-life. This effect of radiation treatment was discovered in the course of studies of the role of radiation in controlling microorganisms. The magnitude and even the direction of such changes depend on the size of the dose and the state of ripeness at the time of treatment. A measurable extension of shelf-life may be obtained with doses of 0.3-1.0 kGy. This level of exposure will increase the shelf-life of mangoes by about one week and that of bananas by up to two weeks. Maturation of mushrooms and asparagus after harvesting can be retarded with doses in the range of 1.0-1.5 kGy.

e. Destruction of parasites

Irradiation inactivates certain parasitic organisms that are responsible for both human and animal diseases. The parasitic roundworm Trichinella spiral is,which causes trichinosis and is found in pork, is inactivated by radiation at a minimum dose of 0.15 kGy. Other parasites,including pork and beef tapeworms, the protozoon in pork responsible for toxoplasmosis, and various flukes that infest fish are rendered non-infective by low-dose radiation treatment.

f. Control of foodborne diseases

Foodborne illness caused by microorganisms is a major and increasing problem for the food processing and food service industries. For this reason, an important potential application of food irradiation is for decontamination to control foodborne disease. Radiation could play an equally important role in the processing of solid foods ofanimal origin and dry foods as does heat treatment (pasteurization)in the processing of fluid milk and fruit juices.

The relatively low dose of radiation needed to destroy non-spore forming pathogenic bacteria in food, such as Salmonella, Campylobacter,Listeria and Yersiniacan be very useful in controlling the serious public health problems caused by these organisms.

Extensive experience has demonstrated that radiation treatment under normal industrial conditions, at a dose that does not produce unacceptable changes in the food product, will eliminate pathogenic non-spore bacteria in red meat, poultry, and fish. While all these food products are distributed both fresh and frozen, it appears that in some countries irradiation of frozen commodities is more feasible. A dose of 2-7 kGy is sufficient to control food borne pathogens in frozen meats, poultry, egg pulp, shrimp, and frog legs without causing unacceptable changes in the product.

Irradiation is beneficial in controlling the microbial contamination of dry food ingredients, and this improves the safety and storage properties of foods prepared with them. Spices, dry vegetable seasonings, herbs, starch, protein concentrates, and commercial enzyme preparations used in the food industry are very often heavily contaminated with spoilage and pathogenic organisms, and can be decontaminated with radiation doses of 3-10 kGy with no adverse effects on their flavor, texture, or other properties. Microorganisms that survive this treatment are more susceptible to subsequent processing.

5.2. The Process of Food Irradiation

Irradiation has the same objectives as other food processing methods - the reduction of losses due to spoilage and deterioration and control of the microbes and other organisms that cause foodborne diseases. But the techniques and equipment employed to irradiate food, the health and safety requirements that have to be taken into account, and a variety of problems that are unique to this way of processing food, put food irradiation into a category by itself. An understanding of how irradiation compares with the more conventional ways of processing food should begin with a brief, on-technical account of what the process is and how it works.

Ionizing radiation

Many of the traditional methods of food processing make use of energy in one form or another the heat used in canning and sun-drying, for example. Food irradiation employs a particular form of electromagnetic energy, the energy of ionizing radiation. X-rays, which are a form of ionizing radiation, were discovered in 1895.

Radioactivity and its associated ionizing radiations, alpha, beta, and gamma rays, were discovered the following year. (The term "ionizing radiation" has been used to describe these various rays because they cause whatever material they strike to produce electrically charged particles, called ions.)

Early experiments showed that ionizing radiation kills bacteria. There followed a number of isolated efforts to use this newly discovered energy to destroy the bacteria responsible for food spoilage. Promising and scientifically interesting as they were, these early efforts did not lead to the use of ionizing radiation by the food industry. At the turn of the century and for many years thereafter, there was no cost-effective way of obtaining radiation sources in the quantity required for industrial application. The X-ray generators of the day were very inefficient in converting electric power to X-rays, and the naturally occurring radioactive materials, such as radium, were too scarce to provide gamma rays, or other forms of radiation, in sufficient quantities for food processing.

In the early 1940s, advances in two areas paved the way for the economic production of sources of ionizing radiation in the amounts needed for industrial food processing. Machines, principally electron accelerators, were designed and developed that could generate ionizing radiation in unprecedented amounts and at acceptable cost. The other avenue of discovery was the study of atomic fission, which produced not only nuclear energy, but also fission products, such as caesium-137, that were themselves sources of ionizing radiation. The related discovery that certain elements could be made radioactive led to the production of other gamma-ray sources, such as cobalt-60.These advances stimulated renewed interest in food irradiation.Investigations using these new energy sources made it increasingly evident that ionizing radiation had the potential, at least, to become a powerful weapon in the battle against preventable food loss and foodborne illness.

Uses of food irradiation

Many of the practical applications of food irradiation have to do with preservation. Radiation inactivates food spoilage organisms, including bacteria, moulds, and yeasts. It is effective in lengthening the shelf-life of fresh fruits and vegetables by controlling the normal biological changes associated with ripening, maturation, sprouting, and finally aging.

For example, radiation delays the ripening of green bananas, inhibits the sprouting of potatoes and onions, and prevents the greening of endive and white potatoes. Radiation also destroys disease-causing organisms, including parasitic worms and insect pests, that damage food in storage. As with other forms of food processing, radiation produces some useful chemical changes in food.

For example, it softens legumes (beans), and thus shortens the cooking time. It also increases the yield of juice from grapes, and speeds the drying rate of plums.

Studies carried out since the 1940s demonstrating the benefits of food irradiation have also identified its limitations and some problems.

For example, because radiation tends to soften some foods, especially fruit, the amount (or dose) of radiation that can be used is limited. Also, some irradiated foods develop an undesirable flavor. This problem can be avoided in meats if they are irradiated while frozen. However, no satisfactory method has yet been found to prevent the development of an off-flavor in irradiated dairy products. In some foods, the flavor problem can be prevented by using smaller amounts of radiation. The small amount of radiation required to control Trichinella spiral isin pork, for example, does not change the flavor of the meat.

Sources of ionizing radiation

As has been mentioned, an essential requirement for the industrial use of food irradiation is an economic source of radiation energy.

Two types of radiation source can satisfy this requirement today: machines and man-made materials. Although they differ in the method of operation, both types of source produce identical effects on foods, microorganisms, and insects.

Machines called electron accelerators produce electron radiation, a form of ionizing radiation. Electrons are sub-atomic particles having very small mass and a negative electric charge. Beams of accelerated electrons can be used to irradiate foods at relatively low cost.

'This cost advantage is offset, however, by the fact that accelerated electron beams can penetrate food only to a maximum depth of about 8 em, which is not deep enough to meet all the goals of food irradiation. Accelerated electrons are, therefore, particularly useful for treating grain or animal feed that can be processed in thin layers; electron beam irradiation is particularly suitable for these applications because of the very high throughputs involved in grain handling and the convenience of being able to switch the machine on and off at will.

Another machine source of ionizing radiation is the X-ray generator. An X-ray is a wave-form of energy similar to light. Unlike accelerated electrons, X-rays have great power to penetrate some materials. But as the early experimenters found, converting electricity into X-rays is a very inefficient, hence expensive, operation. The X-ray machines available for food processing have generally been adapted from those used in medical and industrial radiography and are not well suited to supply the power needed for food processing. Recent developments suggest that these problems of cost and power output may be solved by a new type of X-ray generator.

Man-made radionuclides constitute the other main source of ionizing radiation; radionuclides are radioactive materials that, as they decay, give off ionizing gamma-rays that can be used for food processing. One radionuclide that is readily available in large quantities is cobalt-60, which is produced by exposing naturally occurring cobalt-59 to neutrons in a nuclear reactor. The availability of another radionuclide, caesium-137, a by-product of nuclear reactor operations, is limited and it is not used widely at present. Gamma rays from either of these radionuclides will penetrate deeply enough to meet virtually all food irradiation needs. The cost of man-made radionuclide sources is considered acceptable for industrial food irradiation in view of the great versatility and penetrating capacity of the gamma-rays.

5.3. Effects of Ionizing Radiation

When ionizing radiation passes through matter such as food, the energy is absorbed and leads to the ionization or excitations of the atoms and molecules of the food constituents, which in turn, results in the chemical and biological changes known to occur when food is irradiated.

a. Chemical effects of food irradiation

The chemical effect of irradiation results from breakdown of the excited molecules, ions and their reaction with neighboring molecules giving a cascade of reactions.

The primary reactions include isomerization and dissociation within molecules and reactions with neighboring species to produce series of new products including the highly reactive free radicals. Usually the free radicals generated in food on irradiation have a short lifetime. However, in dried or frozen foods containing hard component such as bone, the free radicals will have limited mobility and therefore, persist for a longer period of time. Another important chemical reaction resulted from ionizing irradiation is water radiolysis.

Hydroxyl radicals and hydrogen peroxide generated upon the irradiation of water molecules are highly reactive and readily react with most aromatic compounds, carboxylic acids, ketones, aldehydes, and thiols.

These chemical changes are important in terms of their effects on the elimination of living food contaminants in foods. However, undesirable side effects, such as off-flavor, will be inevitable for certain food commodities if condition of irradiation is not well controlled.

b. Biological effect of food irradiation

The major purpose of irradiating food is to cause changes in living cells. These can either be the contaminating organisms. The major purpose of irradiating food is to cause changes in to reduce pathogenic microorganisms or cells of the living foods to achieve better quality.

The biological effect of ionizing radiation is inversely related to the size and complexity of the organism. The exact mechanism of action on cells is not fully understood.

However, the chemical changes described in the previous paragraphs are known to alter cell membrane structure, reduce enzyme activity, reduce nucleic acid synthesis, affect energy metabolism through phosphorylation and reduce compositional changes in cellular DNA.

The DNA damage may be due to direct but random strikes of the ionizing radiation that causes the formation of lesions on either both or one of the DNA strands. Double strand lesions are almost invariably lethal. This direct effect on DNA predominates under dry conditions, such as when dry spores are irradiated. Alternatively, the radiations may produce free radicals from other molecules, especially water, which diffuse towards and cause damage to the DNA.

5.4. Factors affecting the Efficacy of Food Irradiation

The efficacy of ionizing radiation for microorganism inactivation depends mainly on the dose of use and the level of resistance of the contaminating organisms. Radiation resistance varies widely among different species of bacteria, yeasts and mold. Bacterial spores are generally more resistant than vegetative cells, which is at least partly due to their lower moisture content. Yeast is as resistant as the radiation-tolerant bacterial strains.

Viruses are highly radiation resistant. Other factors such as temperature, pH, presence of oxygen and solute concentration have also been shown to correlate with the amount of radio lytic products formed during irradiation which in turn affect the ultimate effectiveness of ionizing radiation.

Chapter Six

6. Impacts on Food Security for Ethiopia

6.1. Definition and concept of Food Security

Food security is a dynamic concept which has continuously a new dimension and level of analysis over the year. This continuing evolution of food security concept reflects the wider recognition of the complexity of concept in research and public policy, because of this food security issue has long history starting from time wide when global food crisis take place in the first half of the 1970s.

Food security is concept that has evolved considerably over time and its definitions developed complex notion that it is virtually impossible to measure it directly and a variety of proxy measure have been suggested consumption and expenditure, nutritional status; coping strategies are the most frequently used measures of food security.

In the mid of 1970s and 1974s world food conference was held to solve the problem of world food crisis and major famines around the world. Food security and insecurity are the terms used to describe weather or not households have access to sufficient quality and quantity of food .with progress in time and severity of the problem, food security issue gained prominence and great attention at the global, national, household and individual levels such progress work by scientists led to redefine the scope and depth of Food security concept. For instance,explained the concept starting that food security at global level does not guarantee Food security at the household or individual level. Without much change in the basic concepts, different institution and organization define Food security in different ways. According to Food security is a situation that achieved at the individual, household, national, regional and global levels when all people, at all times , have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preference for an active and health life . On the other hand, in the resent studies, food security is defined as adequate availability of and access to food for household to meet the minimum energy requirements as recommended for an active and heath life.

According to 1996 world food summit Food security exists", when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meet their dietary needs and food preference for an active and heath life".According to the definition adopted in the Plan of Action of the Rome Declaration stated in the World Food Summit of 1996, and reconfirmed in 2002 (Webb and Rogers 2003), food security: "exists when all people at all-time have both physical and economic access to sufficient food to meet their dietary needs for a productive and healthy life" (FAO 1996a) (**Table 6**).

Table6 :Basic definitions food security

Concept	Definition
Food security	All people at all-time have both physical and economic access to sufficient food to meet their dietary needs for an active and healthy life
Vulnerability	Exposure to factors that place at risk food security
Malnutrition	All deviations from adequate nutrition
Undernourishment	Food intake continuously insufficient to meet the dietary energy requirements
Under nutrition	The result of undernourishment. Dietary energy intake below the minimum requirement level to maintain the balance between actual energy intake and acceptable levels of energy expenditure

Levels of food security

Food security can be at the global, national/regional, households, or individual level, where one level does not imply food security at a lower level of aggregation (**Table 7)** (FIVIMS 2003; Thomson and Metz 1996). Food security at the global level describes a situation in which enough food is produced in the world. National/regional food availability occurs when there is a satisfactory balance between food demand and supply at reasonable prices. In other words, it describes a situation in which there have been no major upheavals in food market in the recent past, food availability is adequate, and most of the populations have access to food.

Level of food security Definition Global Enough food produced at global level National/regional Satisfactory balance between food demand and supply at reasonable prices Household The alternative commodity bundles a household con command in a society that meet its needs in terms of energy requirement Individual food consumption meets individual food needs in terms of energy requirement

Food security at the household level is reached when the set of alternative commodity bundles that a household can command in a society, using its totality of rights and opportunities, meet the household's needs in terms of energy requirement. Food security at the individual level is a situation in which individual food consumption meets individual food needs, again expressed by the energy requirement. The concept of energy requirement is fundamental to characterize, form a theoretical point of view, and to measure the state of food

Table7: Levels of food security definition

Level of food security	Definition
Global	Enough food produced at global level
National/regional	Satisfactory balance between food demand and supply at

	reasonable prices
Household	The alternative commodity bundles a household can command in a society that meet its needs in terms of energy requirement
Individual	Individual food consumption meets individual food needs in terms of energy requirement

6.2. Dimensions of Food Security

Elaborated on four dimensions of food security:-Such as: Food availability, Food accessibility Food utilization and Food stability.

a. Food availability

Refer to presence of food at Global, National, Regional, Household, and Individual level.Example, when sufficient quantities of appropriate necessary types of food from domestic product, commercial food imports, commercial aid programs, or food stocks are consistently available to individual or nations . Hence, Food availabilityis largely a function of macroeconomic factor.The Food availability indicators capture not only the quantity but also the quantity and diversity of food. For assessing Food availabilityadequacy of dietary energy supply, share of calorie derived from cereals, roots and tubers average protein supply and average value of food production should be analyzed. Similarly, explained that food availability refer to the physical existence of food stocks for consumption be it from own production or on the markets.

b. Food access

Refer to the source that household to obtain food either through own production or through purchase. So, individuals need to have assets or income to maintain their consumption. Hence food access is largely related to household income and own production. On the other hand, explained that food access is determined by physical and financial resources as well as by social and political factors.Food access depends on:

a. Income available to the household

b. The distribution of income within the household and individual's

c. The price of food and other factors worth mentioning are access to market, social and institutional entitlement or rights.

c. Food utilization

Refer to the nutritional benefits derived from food consumption which is related to proper food processing, storage techniques, adequate knowledge of nutrition and adequate health and sanitation service exist. Hence Food utilization is largely related to nutrition health and sanitation. The same to this defined food utilization as proper biological use of food, requiring a diet that contains sufficient energy and essential nutrient as well as knowledge of food storage, processing, basic nutrition, child care, and illness management.

d. **Stability of food**

Refer to the stability of all other dimension of food security over time. Even if your food intake is adequate to day, you are still considered to be food insecure if you have inadequate access to food or aperiodic basis, risking a deterioration of their nutrition

Adverse weather condition, political instability or economic factor (unemployment, rising food price) may have an impact on your food security status. Therefore, food security to be insured at global, regional, nation, household and individual level food stability should be maintained. The concept of stability can refer to both: - The availability and access dimensions of food security.

6.3. Food Security in Ethiopia

Ethiopia is one of many African countries deeply affected by food insecurity estimates of the portion of Ethiopia's population without secure access to food exceeds 3 million in some seasons.

That means in a given year, almost 1 in 10 Ethiopians will struggle to have access to sufficient, safe and nutritious for themselves and for their families. Yet, in 2013, the World Food Prize an organization that highlights individuals and groups who have increased the quality, quantity, or availability of food in the world recognized Ethiopia for demonstrating some of the greatest progress measured in the Economist magazine's Global Food Security Index.

As we look ahead at global food security planning for the next century, Ethiopia is an important example of how leaders in government and other sectors can successfully align their food systems planning.

The Government of Ethiopia's Productive Safety Net Program (PSNP) is one of the largest safety net programs in the world. The PSNP is a major component of Government of Ethiopia's Food Security Program and plays a critical role in building the resilience capacity of chronically food insecure communities to shocks and climate change.

The Three food security Frameworks

The food security frameworks employed by the Government of Ethiopia, the European Commission and the U.S. Agency for International Development.

In general, all three use a similar set of definitions of the term 'food security.' All three, for example, recognize the need to increase food availability in Ethiopia a country with a serious and growing gap between what is being produced and marketed domestically and both market and nutritional demands. Also, give equal emphasis to the needs of rural and urban poor households to increase access or entitlement to the food they need for a healthy and productive life. In one way or another, all three note the close relationship between the achievement of improved food security and overcoming the constraints, which have held the vast majority of Ethiopians in dire poverty.

Important food security

Food security is an important objective for Ethiopia and state of the developing countries.

One dimension of food security is issue is show by percent damaging under incoming in sample.

Percent = Damage/ Income/Year

Table 8: damage per income per year

Food items	Income in kg	Damage in kg	Year 2018-2028	Percent %
Cereals	100000	200	10	.02
Pulse	20000	30	>>	.15
Vegetable	15000	100	>>	.06
Fruity	10000	15	>>	.015
meat	300000	50	>>	.0016

In general the purpose of treatment impact food security in Ethiopia

Food items	purpose of treatment
1. Bulbs stem and root tubers	- Inhibit sprouting
2. Fresh fruity and vegetable	- Delay ripening
	- Insect disinfestation
	- Shelf life extension

3. Cereals and their mild product, pulse - Insect disinfestation
and other mild products ,nuts, oil, seeds - Reduction of microbial load
dried fruits and their products

4. Fish, seafood and their products - Elimination of pathogenic microorganism
(Fresh or frozen) - Shelf life extension
- Control of human parasites

5. Eggs poultry and meat product - Elimination of pathogenic microorganism
- Shelf life extension
- Control of human parasites

6. Dry vegetables, spices, condiments, dry herbs -Elimination of pathogenic
, Tea, coffee, cocoa, and plant products -Insect disinfestation

7. Dry food of animal's origin -Insect disinfestation
- Control of human parasites
- Elimination of pathogenic microorganism

8. Ethnic food, military ration, spaces food, - Quarantine application
minimally processed foods - Reduction of microorganism
-Sterilization

Conclusion

Food irradiation preserves meat, produce, and seasonings with high-energy gamma rays to improve product safety and shelf life. Spices, seasonings, potatoes, fresh fruits and vegetables, and meats and poultry may be irradiated. This method of preservation prevents growth of food poisoning bacteria, destroys parasites, and delays ripening of fruits and vegetables.

Irradiated food is not radioactive because no contact between food and radiation sources, but it has an effect on public health when the processors not follow the appropriate procedure.

Food irradiation makes food safer to eat, improves quality, and extends shelf life.

The amount of radiation absorbed during irradiation processing is measured in units called rads (radiant energy absorbed).

Food irradiation has been endorsed by FAO, WHO, USDA, AMA, IFT as a safe and practical method for preserving a variety of foods and reducing the risk of foodborne disease. International imports and exports of fresh foods could be expanded, increasing the abundance of food worldwide.

Ethiopia has a National Drug Policy and a proclamation on food, medicine, health care administration and control.

Food security is defined as adequate availability of and access to food for households to meet the minimum energy requirements as recommended for an active and healthy life.

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