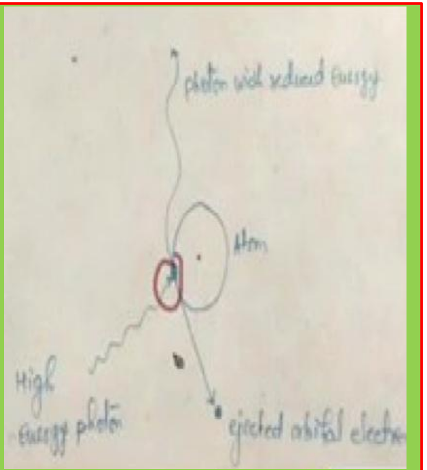
Food Irradiation

RADIATIONS

√ Several radiation types have the characteristic ability to ionize atoms or molecules, thereby producing an electron and a positively charged on

$$M \rightsquigarrow M^{+} e^{-}$$

Where M is an atom or molecule and symbol $\rightsquigarrow$ indicated the action of radiation.



√ High energy photon bombards the atom and excites the electron by absorption of energy. This electron gets ejected from the orbital resulting in a positively charged atom. Compton effect shows that when atom is bombarded by irradiation, positively and negatively charged ions are produced.

Ionizing Radiations :

- √ Ionizing radiations interact with an irradiated material by transferring energy to electrons which are thus raised to a high energy or excited state.

- √ If the transferred energy is large enough, the negatively charged electron can leave a molecule with the result that a +ve ion is formed.

- √ Irradiation creates about one ionization for every two excitations but, because the ionizations are about a thousand times as likely to cause chemical change, the biological effects caused by the radiations are almost entirely due to ionization.

- √ The ejected electron moves through surrounding material and loses it energy by creating further excited molecules and +ve ions.
- √ Eventually the electron is captured by a +ve ion or is trapped by a structure to form a –ve ion which in turn combines with a +ve one.
- √ It is this ability to create +ve and –ve ions that characteristics ionizing radiations.

Ionizing Radiations

Electromagnetic Radiations

γ- rays

x--rays

Particulate Radiations

Electrons

α particles

Protons

Neutrons

Linear Energy Transfer (LET)

Measure of the per distance travelled in the biological materials

√ γ - rays

√ x - rays

√ β – rays

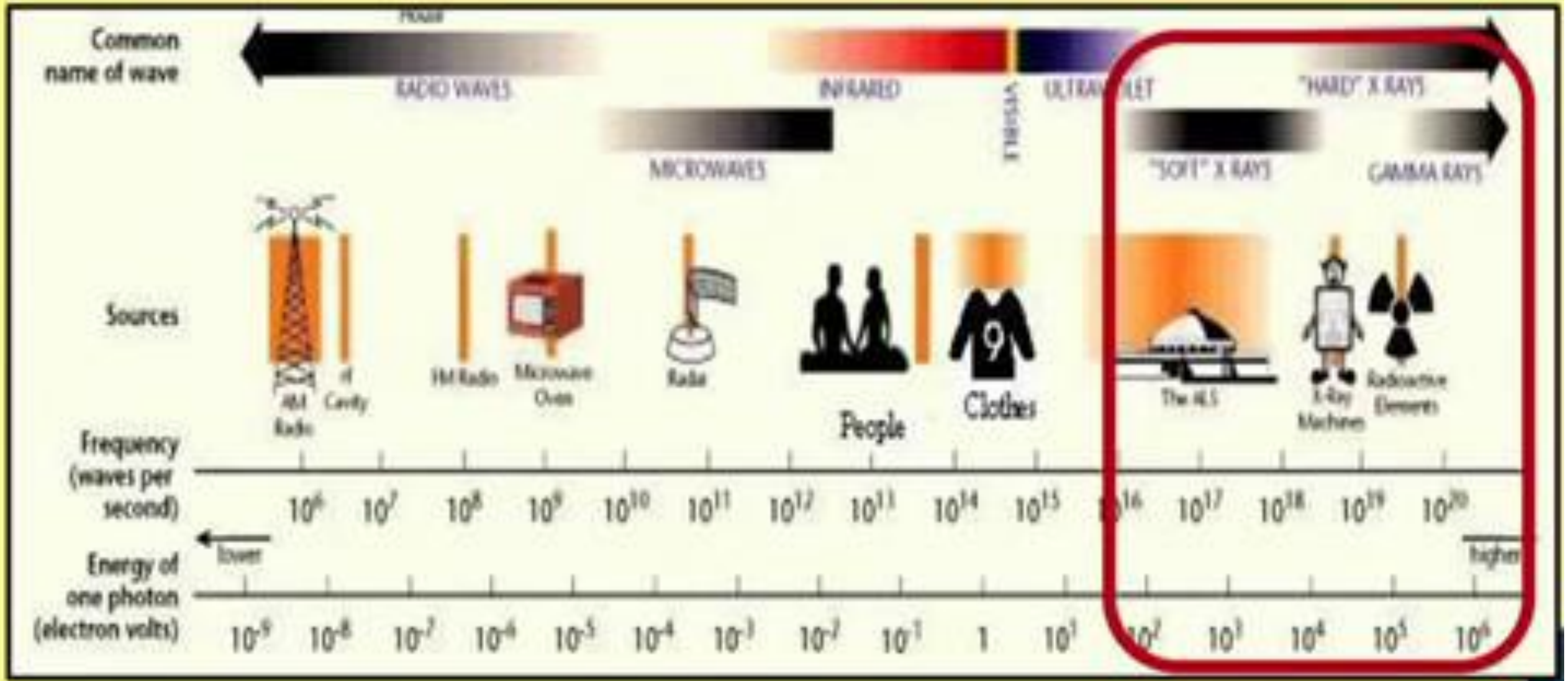
- Low LET
- Sparsely ionizing

√ α particles

√ Protons

- High LET
- Densely ionizing

Radiation spectrum



- √ Unit of Measurement
- √ Dose : The quantity of radiation absorbed by the food.
- √ Radiation Absorbed Dose (rad) :

  The deposition of 100 ergs per gram in the irradiated sample.

  100 rad = 1 krad

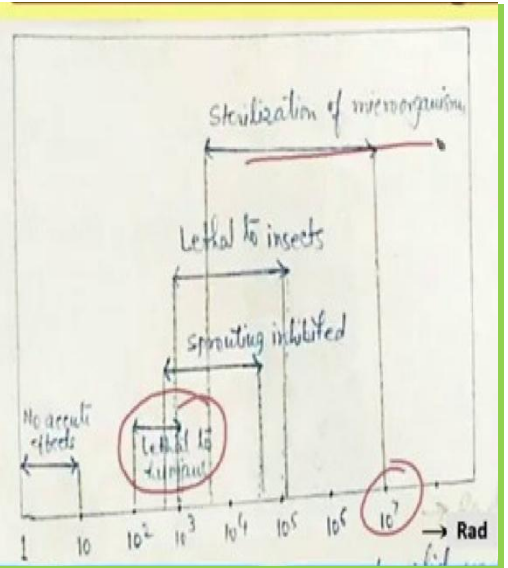
  100 rad = 1 Gy (gray)

  100 k rad = 1 kGy

Effects of Radiation on living Organisms :

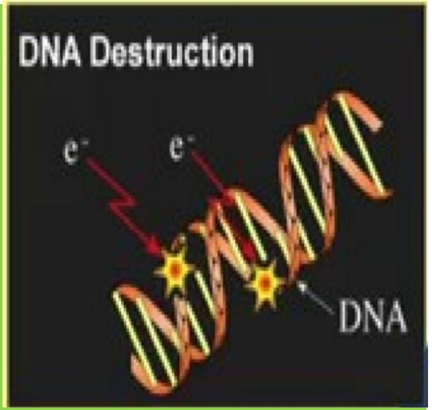
√ The dose of radiation required to produce a lethal effect varies with the complexity of the organism.

√ The most complex organisms tend to be the most sensitive to radiation.



√ A dose of few hundred rad is lethal to human but destruction of some microorganisms require millions of rad.

How Ionizing Radiation works ?



- √ Direct : Chemical events as a result of energy deposition on target molecule (DNA etc)
- √ Indirect : Radicals formed from the radiolysis of water or reactions originating outside the cell.
- √ Electrons disrupt the DNA chain; either destroy or prevent reproduction of the organism.
- √ Living cells cause sprouting and spoilage:

  (1) DNA damage delays spoiling and prevents sprouting

  (2) Promotes longer shelf-life

Food irradiation

Processed, packaged meat
is placed on a conveyor
and guided into a room
with concrete walls
6 to 10 feet thick.

Technology of Food Irradiation:

√ Rappertization (High dose, 4.5 Mrad) :

- Can sterilize by killing all bacteria and viruses.
- It is based on the destruction of spores of *Cl. Botulinum*

√ Radurization (Medium dose 100-1000 krad) :

- Vegetable sprouting, fruit ripening, insect sterilization
- Kills 90% of organism.

√ Redicidation (Low dose 400-600 krad) :

- Kills most pathogens and many food spoilage organisms, insects and parasites.

Effects of Irradiation:

- √ Prevents food poisoning by killing :
  - E. Coli 157:H7 (Beef)
  - Selmonella (Poultry)
  - Campylobacter (Poultry)
  - Parasites
- √ Prevents spoilage by destroying moulds, bacteria and yeast.
- √ Controls insects and parasite infestation.
- √ Increases shelf-life by slowing ripening of fresh fruits and vegetables.

Establishing Radiation Stabilization Process for Foods:

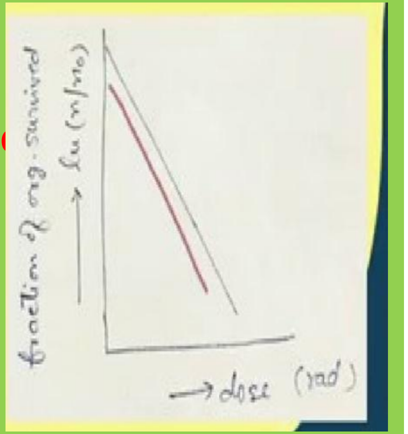
- √ Food may be stabilized by inactivating the microorganisms and enzymes present , and
- √ By protecting the stabilized food from recontamination and access to oxygen.
- √ The stabilization of foods with IR involves two major considerations :

  (1) The food characteristics

  (2) A suitable radiation source

Microbial Death Kinetics :

- √ Death of microorganisms when exposed to radiation can be evaluated by plotting the logarithms of the fraction surviving organisms against dose.
- √ A plot of ln (n/n_o) is linear with dose and it is obvious that for equal doses the microbial population decreases by a given factor.
- √ Relationship between radiation effects to dose can be des



$$n = n_o e^{-D/Do}$$

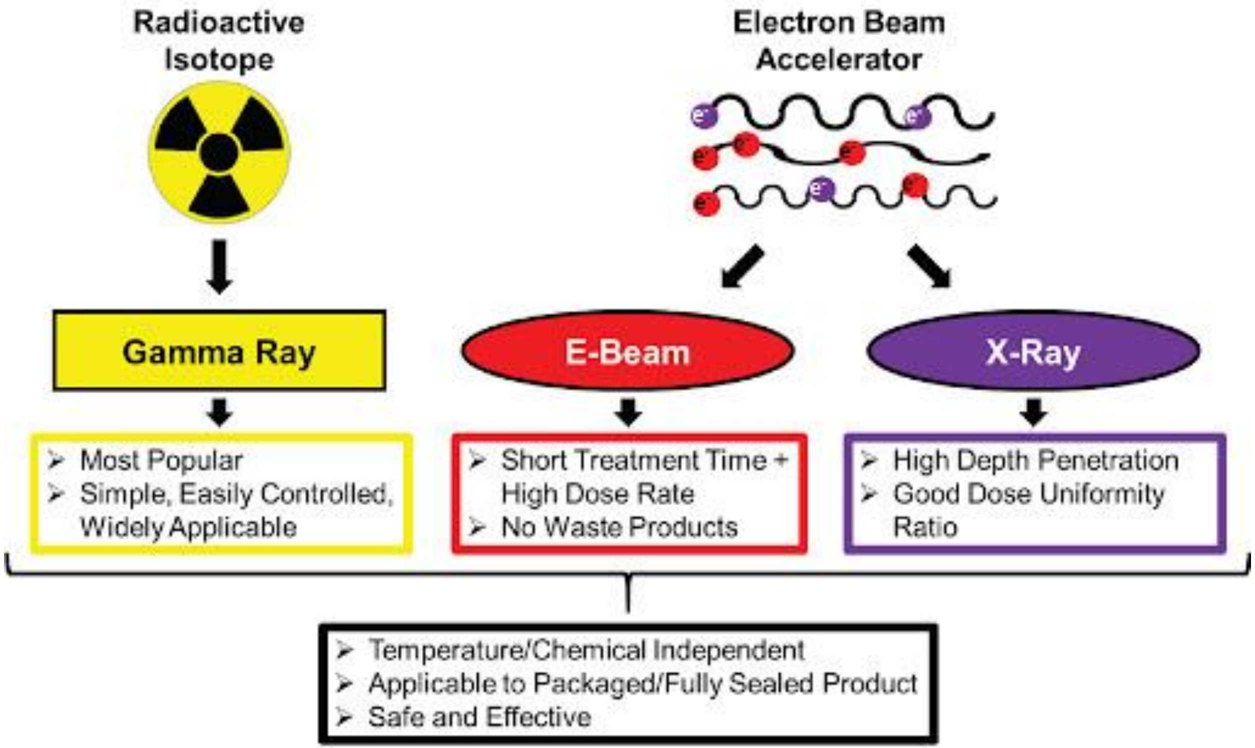
Where n= Number of live organisms after irradiation

$n_{o=}$ Initial number of organisms

D=Dose of radiation received (rad)

Do= Constant depending upon type of organism & environment factors; causes death of 63% organism.

√ D_{10}=A value causing a reduction in number by a factor of 10.



Factors affecting Radiation Sensitivity of Microorganisms :

- √ Environmental factors during irradiation as well as physiological and genetic differences between strains and cultures of microorganisms can affect radiation sensitivity.
- √ Type of radiation
- √ Dose rate
- √ Presence or absence of oxygen
- √ State of food
- √ Temperature

Type of Radiation :

√ No significant direct effect on dose response whether it is electrons, X-rays, or γ-rays.

Dose Rate (Intensity of Radiation) :

√ Amount of radiation absorbed by the cell per unit time.

√ Does not seem to affect sensitivity except as it affects other environmental factors such as temperature.

Presence of Oxygen :

√ Does not have a significant effect as do the pH and type of medium in which the microorganisms are irradiated.

State :

√ Irradiation is the frozen state reduces radio sensitivity of some organisms.

√ Sterilization through radiation of foods in frozen state minimizes chemical and flavour charges in food.

√ However, greater dose is required for sterilization in frozen state.

Temperature :

√ Has effects on sterilization requirements.

√ This effect forms the basis for potential combination processes utilizing both heat and radiation (Thermo radiation).

√ Very high temperature adds its own lethal effects.

Food Irradiator Sources :

Radio isotope Source :

√ ^{60}Co (1.33 & 1.17 MeV) is used commonly.

√ ^{137}Cs (662 KeV) can also be used .

√ ^{60}Co emits two gamma rays per disintegration.

√ Has half life 5.27 years.

√ Plaque source consisting of flat strips which may contain more than 10,000 cu per strip.

√ Number of strips are assembled by remote controlled operations.

√ The source is immersed in a 25 ft. deep storage pool of water when not in use.

Food Irradiator Sources :

Radio isotope Source :

- √ ^{60}Co (1.33 & 1.17 MeV) is used commonly.
- √ ^{137}Cs (662 KeV) can also be used .
- √ ^{60}Co emits two gamma rays per disintegration.
- √ Has half life 5.27 years.
- √ Plaque source consisting of flat strips which may contain more than 10000 cu per strip.
- √ Number of strips are assembled by remote controlled operations.
- √ The source is immersed in a 25 ft. Deep storage pool of water when not in use.

Machine Source :

√ Machine generated β or X-rays.

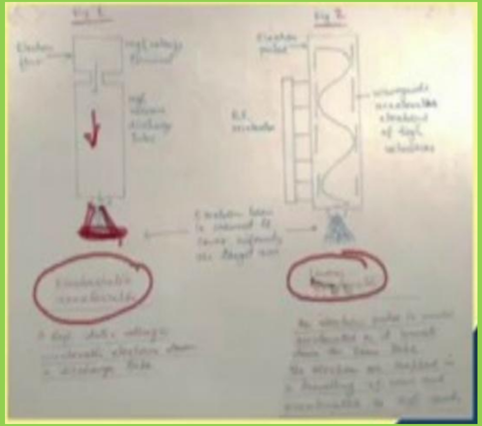
√ Produces no waste outside of the machine used to produce the radiation.

√ A beam of electrons is accelerated by an electron gun similar to a TV tube, accelerating electrons toward the screen.

√ It can be turned on or off since it uses no radioactive material.

√ Electron beams can only penetrate about 1” into material.

Linear Accelerators



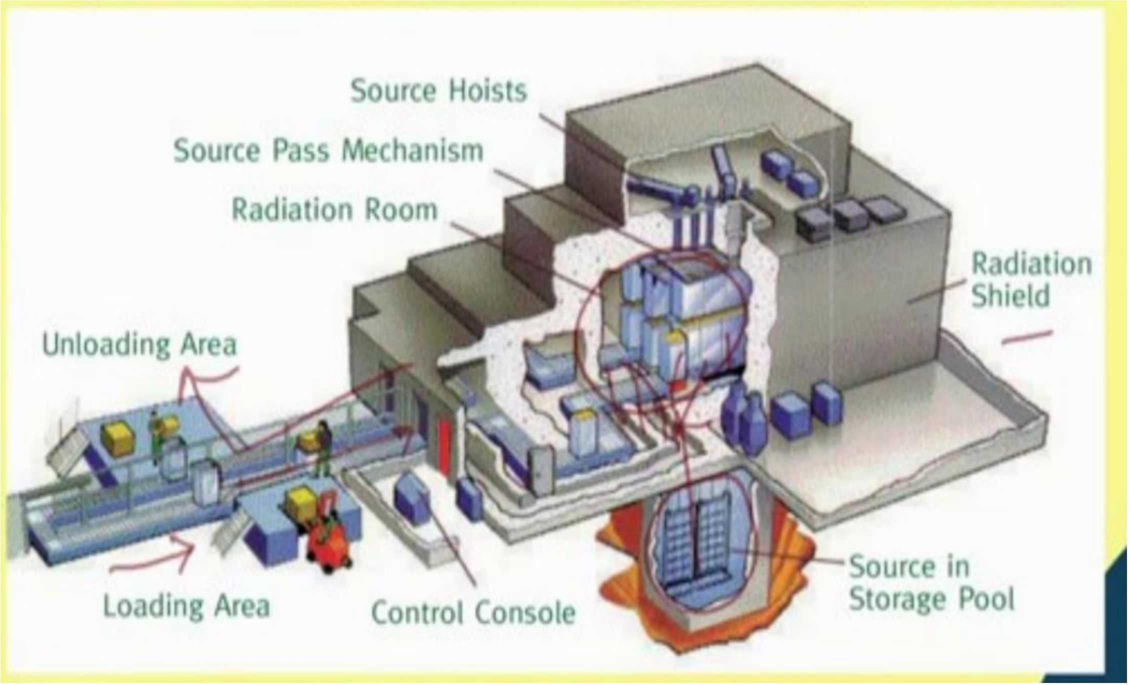
Irradiation Sources and its Characteristics :

Sr No	Radiation Source	Characteristics
1	Cobalt-60	1.High penetrating power
		2. Permanent radioactive source
		3. High efficiency
		4. Source replenishment needed
		5. Low throughput
2.	Electrons Beams	1. Low penetrating power
		2. Switch on- switch off power capability
		3. High efficiency
		4. High throughput
		5. Power and cooling needed
		6. Technically complex

Irradiation Sources and its Characteristics : Continue...

Sr No	Radiation Source	Characteristics
3.	X-Rays	1. High penetrating power
		2. Switch on-switch off capability
		3. Low efficiciency
		4. High throughput
		5. Power and cooling needed
		6. Technically complex

Gamma Irradiator Facility for Food Processing :



What foods can be Irradiated ? : Dose & Purpose:

Dose Limit	Purpose	Dose Limit (kGy)	Examples
1. Low dose (‹1kGy)	-- Sprouting inhibition -- Insect and parasite disinfection -- Delay of ripening	0.05-0.15 0.15-0.50 0.50-1.00	-- Potatoes, onions, garlic --Cereals, pulses, dried fruit pork -- Fresh fruits and vegetables
2. Medium dose (0 – 10 kGy)	-- Reduction of spoilage microorganisms -- Reduction of non spore pathogens -- Microbial reduction in dry products	1.0-3.0 2.0-7.0 7.0-10.0	-- Fish, strawberries -- Poultry, shellfish -- Herbs, spices
3. High dose (10-50 kGy)	-- Sterilization	25-50	--Sterile diet meals
4.Very High dose (10-100 kGy)	-- Reduces or eliminates virus contamination	10-100	

Scope of Irradiation in Food Processing :

Changes during Irradiation of Food:

- √ Irradiation is a cold process referred to as a cold pasteurization or cold sterilization process.
- √ It can accomplish the same objective as is done by thermal pasteurization/sterilization processes in food.

  -- Very little or no change in physical appearance.

  -- No textural or colour changes.
- √ Possible Chemical Changes:

  (1) Off-flavours

  (2) Tissue softening

Chemical effects of Ionizing Radiation:

√ Ionizing radiations are capable of initiating a vast array of chemical changes in gaseous, liquid and solid systems.

-- Radiolysis of water

-- Effect on macromolecules & other components.

Radiolysis of Water:

- √ Ionizing radiation split, or as it is more technically called Radiolyze water.
- √ Since most foods are aqueous systems, this effect of IR on water is of key importance.
- √ The passage of ionizing radiation through water results in the formation of the following intermediates.

(1) Excited water $(H_2O)^*$

(2) Free radicals OH^o and H^o

(3) Ionized water molecules $(H_2O)+$

(4) Hydrated water molecules $e-_{aq}$

√ These species then react among themselves or with other components of the system.

√ In pure water, and in the presence of air, they produce

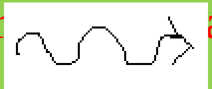
-- Hydrogen gas (H_2), Hydrogen peroxide (H_2O_2), Water (H_2O), Hydronium ion (H_3O^+), Hydroxide ion (OH^-)

√ Reactions these intermediates can undergo with food components are too numerous to list.

√ Every class of food constituents, including carbohydrates, proteins and other nitrogenous compounds, fats and oils, vitamins, enzymes and pigments can react with at least some of the intermediates to produce new intermediate compounds, many of which are highly reactive themselves.

√ Oxidation reactions, free radical reactions and reduction reactions are particularly significant in this respect.

Effect on Hydrocarbon Chain:

- √ Hydrocarbon chains are presents in lipids as well as in many polymers of food packaging materials.
- √ In direct actions of IR on hydrocarbon chains, a number of primary events can occur.
- √ The most important event is the abstraction of a hydrogen and the concurrent for  a free radical.

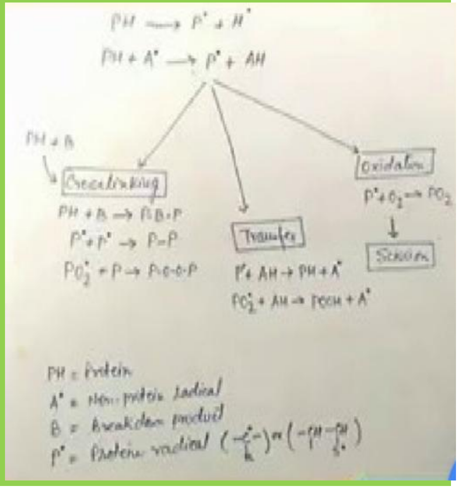
$$-(CH_2) \qquad -(CH^{o})- + H^{o}$$

- √ The hydrocarbon radicals can undergo a very large number of reactions, among which those involving reactions with atmospheric or dissolved oxygen and cross linking are the most important.

Deamination, Oxidation, Polymerization and Decarboxylation

Have all been implicated in protein changes during Irradiation :

- √ Reactions of proteins exposed to irradiations have similarities to those caused by organic peroxides.
- √ In both the cases, free radicals of proteins can either cross-link, recombine with hydrogen, or result in scission depending on various environmental factors, including the presence of water and oxygen.



√ In lipids, including fats, many of the reactions are akin to oxidative rancidity,, i.e. peroxidation by molecular oxygen; various radiation specific reactions also can be initiated.

√ Carbohydrates are very sensitive to radiation. Oxidation reactions predominate as well as some condensation reactions similar to non-enzymatic browning.

-- It has been suggested that some products of irradiation of sucrose may have toxic effects on cells.

Summary of effects of Irradiation on Food Constituents:

√ Radiolysis of water :

-- $3H_2O$ ------- $H_2O_2 + H_2 + H^{\cdot} + OH^{\cdot}$

-- Free radicals are formed.

-- The lowering of temperature reduces the effects of free radicals.

√ Formation of peroxides and hydroperoxides.

√ Half (50%) cysteine is lost.

√ About 10% tryptophan is lost.

√ Development of oxidative rancidity.

√ Pectin is degraded; causes softening of fruits and vegetables.

Summary of effects of Irradiation on Food Constituents :

- √ Higher dozes cause off flavours because of formation of carbonyls, volatile constituents, hydrocarbons, etc.

Lipids ------O_2------ Peroxides

Irradiation

Lipids ---------------- Carbonyl compounds

Irradiation

Effects on Food Constituents can be mimimized by :

√ Lowering of Water Content:

-- Less free radicals will be formed because of less radiolysis of water.

√ Less Aerobic Conditions :

-- Off flavour & odours are minimized due to lack of oxygen agencies necessary to form

peroxides.

√ Reducing Temperatures:

-- Sub freezing radicals or immobilized free radicals.

√ Additions of free radical scavengers:

-- Free radicals react with scavengers and are then removed or bound and are not available for reactions.

Effects on Food Constituents can be mimimized by:

√ Simultaneous distillation:

-- Helps removal of volatile off flavours or off flavour precursors.

Practical Applications – Uses in Foods :

- √ Sterilization of army rations and other self stable foods.
- √ Extension of shelf life of various foods to be distributed and stored at refrigerated temperature e.g. Fresh fish, poultry meats, fresh fruits and vegetables, milk, eggs, and cheese.
- √ Treatment of water and food processing wastes. An interesting application in this respect is the treatment of cooling water for fish on board ships.

  -- By maintaining the microbial count in this water at a low level, without heating the water, it should be possible to retard deterioration of fish prior to the time of their delivery for subsequent processing at the harbour.

- √ Disinfestations of grain or dried fruits and of other commodities subject to insect attack.
- √ Inhibition of sprouting in onion, potatoes and carrots.

  -- Only about 15000 rad and is required the chemicals effects of these low dose are negligible.
- √ Delay in ripening of fruits.
- √ Irradiation of dehydrated vegetables which causes scission of polymer chain contributing to the structure of these vegetables.

  -- This scission is beneficial in accelerating rehydration of otherwise poorly rehydrating vegetables.
- √ Accelerated ageing of scotch whisky.

Wholesomeness of Irradiated Foods:

- **Induction of Radioactivity:**

√ The induction of radioactivity in foods depends on

  - √ Type of radiation and its energy
  - √ The dose applied to the food, and
  - √ The abundance of specific elements in the food.

. In addition, half life of the induced isotopes is important since if it is very short these isotopes disappear before reaching the customer.

Nutrient Losses :

√ Radiation processing does cause some nutrients losses.

√ These losses depends greatly on the conditions of irradiation.

√ Conditions of irradiation may be adjusted to greatly minimize these losses.

√ Radiation is the frozen state greatly reduce losses of thiamine and exclusion of oxygen protects fat soluble, radiation sensitive vitamins and some oxidation susceptible amino acids.

Toxicity & Cacinogenicity:

√ No other physical food preservation process has received such a severe test in this regard as irradiation.

√ All the data obtained indicate that there are no acute toxic effects or obvious dangers of chronic toxicity or carcinogenicity.

√ However, the process has to be used with caution.

Advantages of Food Irradiation:

Minimize Food Loss

↓

Improve Public Health

↓

Increase International Trade

↓

An alternative to fumigation of Food Grains

↓

Increase Energy Saving

Labelling of Irradiated Food:

√ The FDA requires that irradiated foods bear the "radura" label and state on the label 'Treated with Radiation" or "Treated by Irradiation".

√ Many countries have their own regulatory requirements for food irradiation.

√ There is no statutory requirement specific to irradiation in many countries.

THANK YOU