

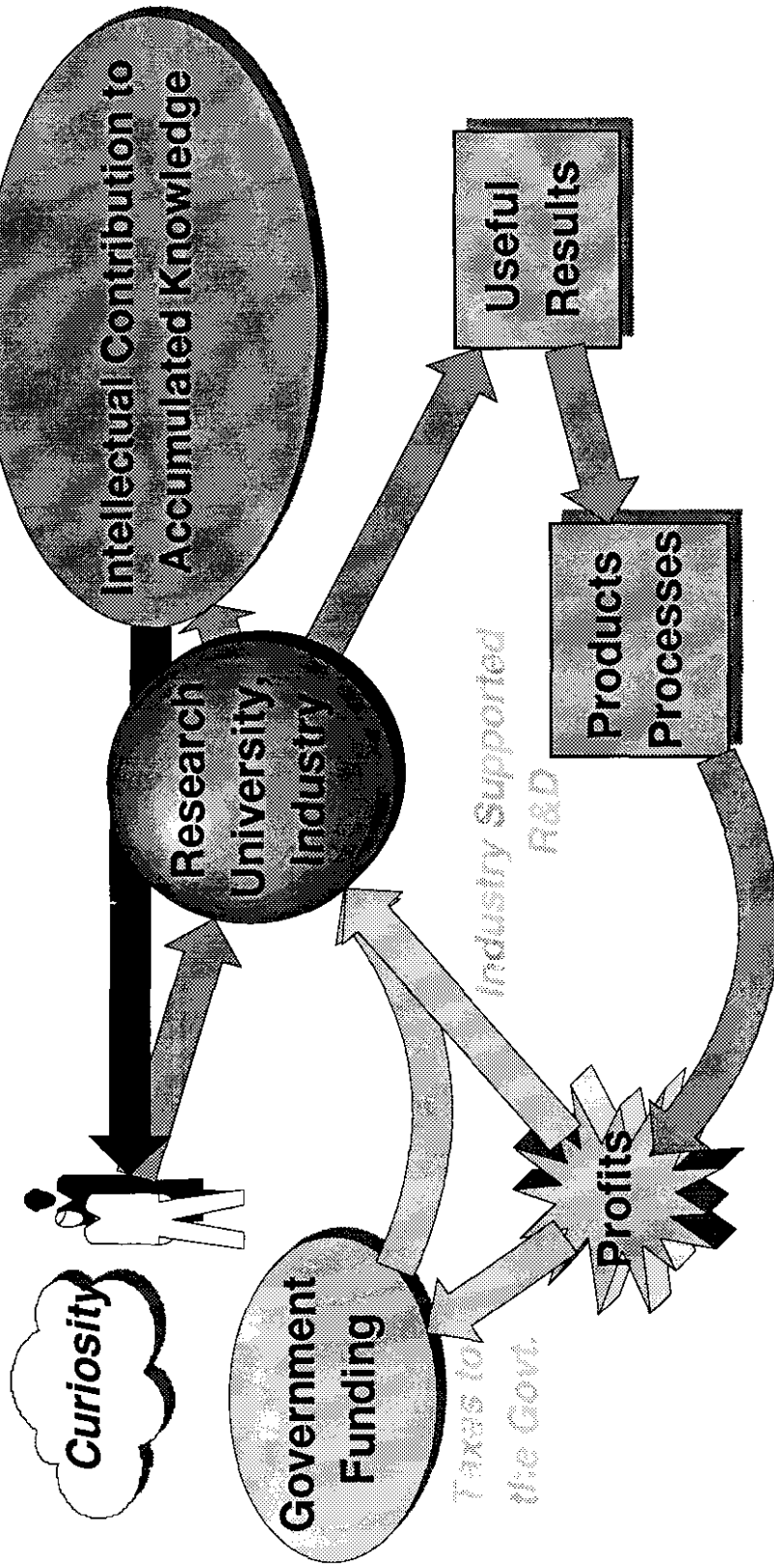
Radiation Processing
Basics, Current and Emerging
Applications

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Curiosity Driven by Mental and Physical Human Exports
 Emphasis is shifting to Physical Nexus (Applied Research)

What is “USEFUL”

(Beauty is in the Eye of the Beholder)

- **If funding can be found for developing a result into a product or process, preferably from industry, it is “USEFUL”**

Radiation Processing

Exposure of substrate to high energy radiation to give products that are

- **Safe**
- **Unique**
- **Useful**
- **Produced cost-effectively**

High Energy Radiation

- α -, β -, and γ - radiation
- X-rays
- Neutrons
- Accelerated Electrons
- Accelerated Positive Ions

Useful Effects of High Energy Radiation

Based on

- **Physical effects**
- **Chemical effects**
- **Biological effects**

Examples Of Physical Effects

- **Medical X-rays**
- **Radiography of materials**
- **Electron beam welding**
- **Electron beam heating in metallurgy**
- **Colour changes of gemstones**
- **Ion Implantation**

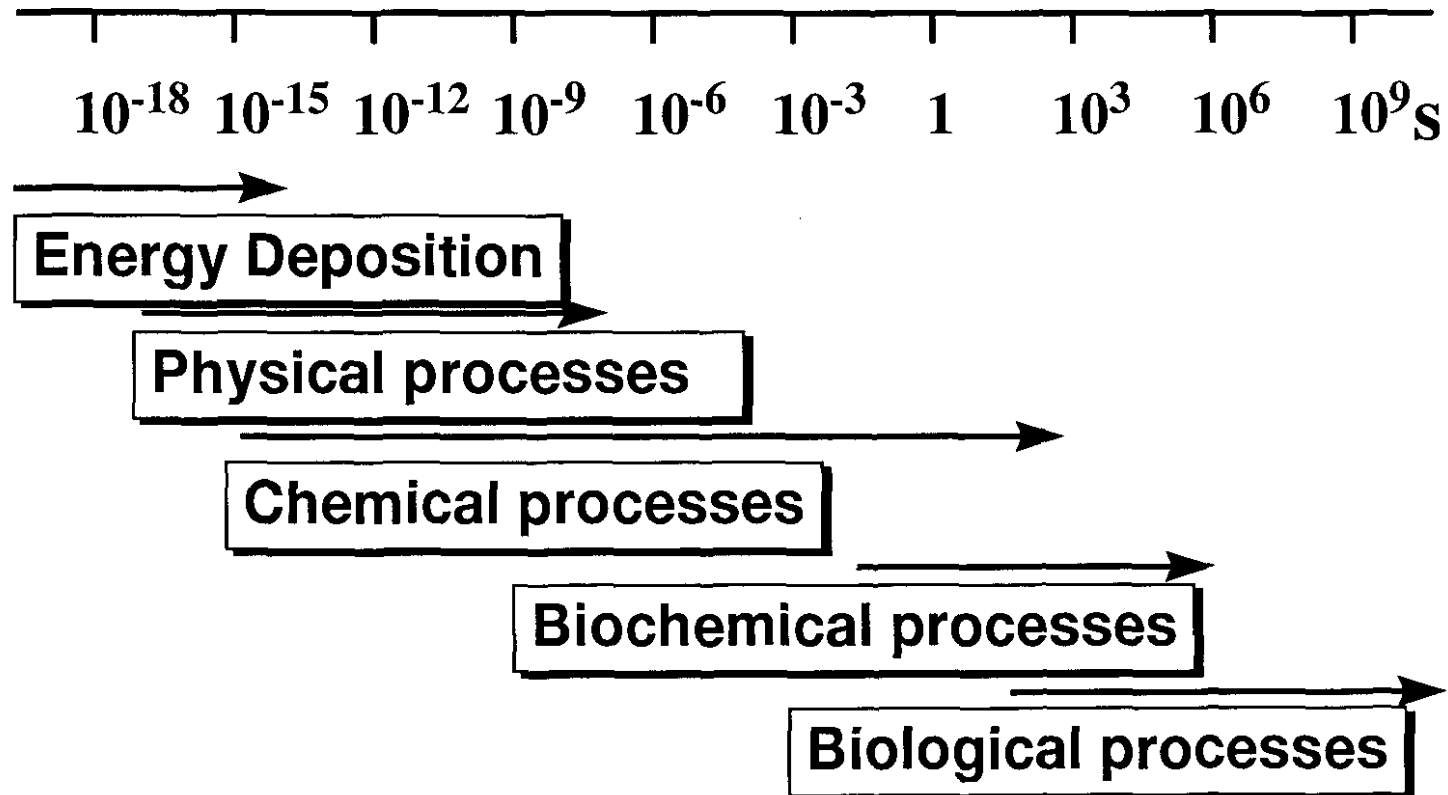
Examples Of Chemical Effects

- **Crosslinking of polyethylene**
- **Water purification**
- **Flue gas treatment**
- **Polymerization and grafting**
- **Curing of latex and rubber**

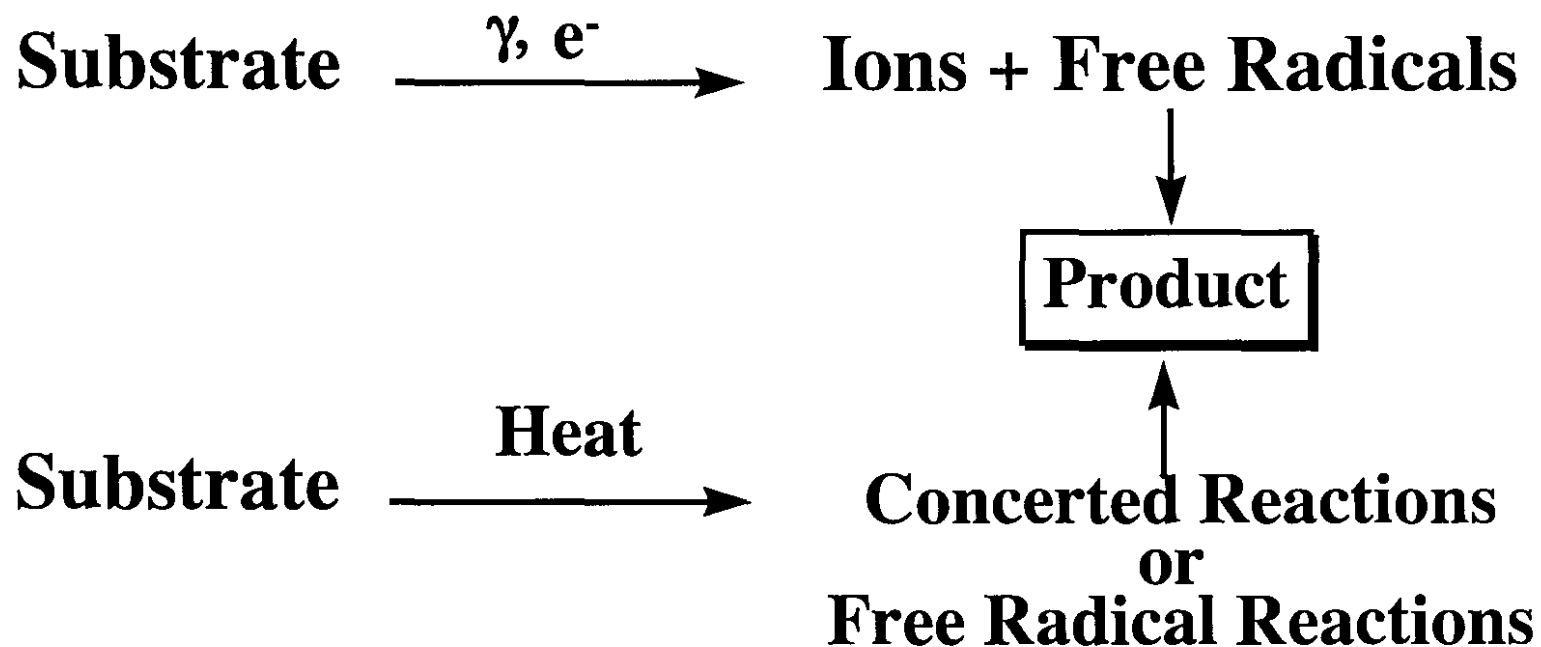
Examples Of Biological Effects

- **Radiation sterilization of medical products**
- **Radiation pasteurization of foods**
- **Radiation sterilization of foods**
- **Prevention of sprouting of tubers
(potatoes and onions)**
- **Delayed ripening of fruits**
- **Sewage sludge irradiation**

Time Scale of Radiolytic Events



Desired Product Formation



- Irradiation, a cold method to produce ions and free radicals

Factors Favouring Radiation Processing

- **Toxicity of traditionally used chemicals, e.g. ethylene oxide and chlorine**
- **Uniqueness of product, e.g. heat shrink items**
- **Quality of product, e.g. coatings**
- **Removal of low concentrations of organic contaminants, e.g., in drinking water**
- **Safe pathogen control**
- **Overall cost savings**

Radiation Processing Constraints

- **Public concern, particularly about isotope sources**
- **Capital cost of radiation sources**
- **Inadequate knowledge of radiation technology amongst industrialists and industrial workers**
- **Momentum of current technology**

Radiation Processing

An Interdisciplinary Endeavour

Involving

- **Chemistry**
- **Physics**
- **Biology**
- **Engineering**
- **Business aspects**

Radiation Processing

Commercial and R&D Aspects

- **Supply and demand, competition, market trends**
- **Support R&D: trouble-shooting, continued optimization of process**
- **New products/process R&D, as per business plan**

Radiation Processing

In-House vs Service Centre

- **In-house requires sufficient supply of materials for efficient use of the irradiation facility**
- **Irradiation Service Centre requires good market surveys, assured supply of base load work, and presence of potential customers within the target area**

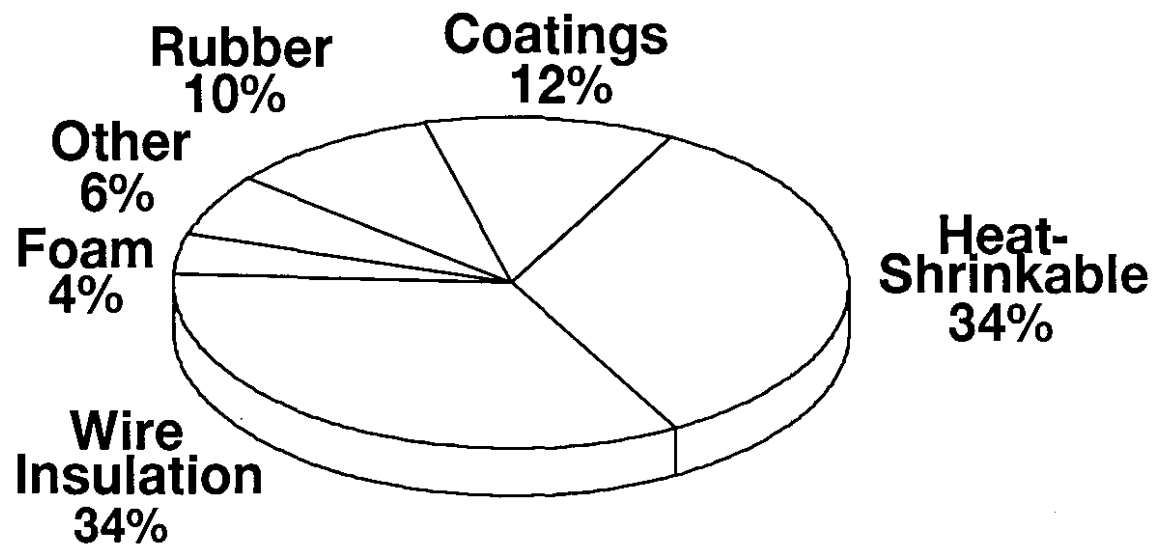
Current γ - and Electron Applications

- Coatings
- Inks/Printing
- Roofing materials
- Grafting
- Tires
- Magnetic media
- Adhesives
- Crosslinked films
- Heat shrink products
- Silicone release films
- Wood products
- Sterilization
- Immobilized enzymes
- Crosslinked PE
- Immobilized pharmaceuticals

And many more

Woods & Pikaev (1994)

Electron Processing



- ~500 Accelerators Worldwide (Saunders, 1988; now ~1000)
- ~150 γ - Sources Worldwide for Medical Sterilization and Food Irradiation

Potential Industrial Applications of Electron- and γ - Sources

- Sterilization of Medical Disposables
- Radiation Crosslinking of Polyethylene Products
- Sewage Sludge Irradiation
- Flue Gas Treatment
- Immobilization of Enzymes and Pharmaceuticals
- Viscose Production
- Food Irradiation
- Advanced Composites
- Wood Plastics Composites
- Mechanical Pulping

See Bradley (1984), Singh and Silverman (1992), Woods and Pikaev (1994)

Further Requirments

- **Entrepreneurs to invest (sterilization, food, PE)**
- **Improve properties of advanced composites**
- **Radiation effects on cellulose and wood**
- **Use of O₃/irradiation (waste waters) in other systems (pulp, pulp mill effluent)**
- **Training of industrial workers and industrialists in radiation technology**
- **Quantum leaps possible (viscose, advanced composites)**

Cost Effectiveness of Radiation Processing

Depends on

- **Uniqueness of the desired change**
- **Efficiency (chain length) of the radical reactions**
- **Large volumes, use of high power electron accelerators**
- **Use of the lowest energy electrons appropriate for a process**
- **Combination treatment (synergistic effect)**

Food Irradiation

Safety and Wholesomeness of Irradiated Foods

**An Examination of the Scientific Evidence
and
Applications**

Safety and Wholesomeness of Irradiated Foods

- **The term “wholesome” means nutritious, clean, and otherwise fit for human consumption**
- **With regard to irradiated foods, considerations of wholesomeness or safety for consumption involve aspects of radiological safety, toxicological safety, microbiological safety, and nutritional adequacy**
- **Confidence in safety and wholesomeness of irradiated food is central to consumer acceptance of such food**
- **Consumer acceptance is central to industry acceptance**
- **Therefore, when examining questions associated with safety and wholesomeness of irradiated foods, one must consider all of the above**

Why Food Irradiation?

1. **Pathogen Control**
 - *Salmonella* (chicken)
 - Enteropathogenic *E. coli* (O157 : H7, Hamburger)
2. **Substitute for Toxic Fumigants (for Quarantine)**
 - Methyl Bromide
 - Ethylene Oxide
3. **Shelf-life Extension**
 - Fruits/Vegetables
 - Meats
 - Fish/Sea Food

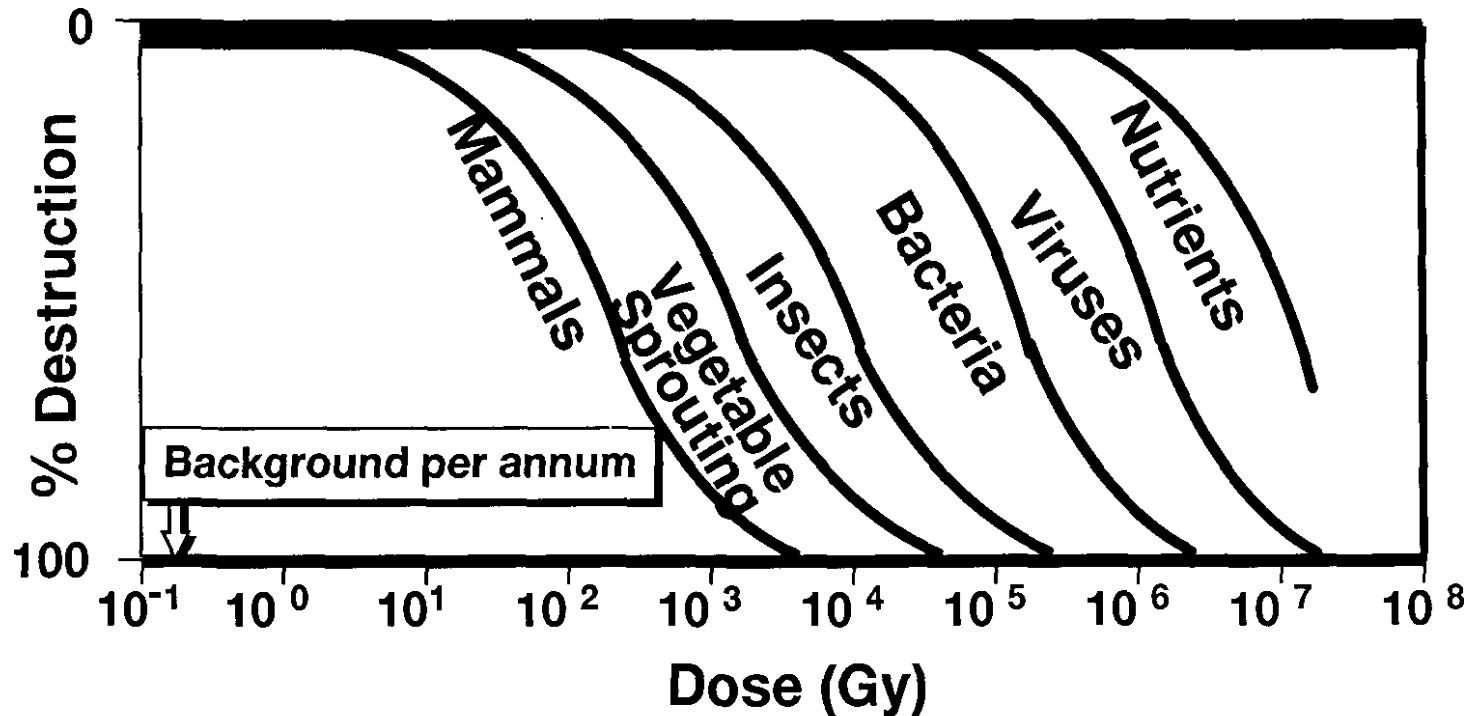
Foodborne Disease is Serious Business

- **Foodborne Disease can Cause Serious Illness and Death**
 - **Morbidity: diarrhea, fever, kidney failure, birth defects**
 - **Mortality: generally the very young and the very old**
- **Significant Costs to National Economies**
 - **Health care costs**
 - **Loss of productivity**
 - **Loss estimates are in billions of dollars annually for North America**

Technical Basis for Food Irradiation

- **The beneficial effects of irradiation are due to differential sensitivities of different biological species, to inactivation by irradiation**
- **Free radicals ($\cdot\text{OH}$, $\cdot\text{H}$ and e^-_{aq}) formed from water present in foods are responsible for most of the radiation effects observed in foods**
- **The most crucial target of the free radicals is DNA (or the genome) which results in inactivation (killing) of the microbes/insects**
- **It does not significantly affect the nutritive value of the food**

Basis for Beneficial Effect of Irradiation



- These differential sensitivities of different functional entities to inactivation are the basis of beneficial effects of irradiation

Achievable Technical Benefits

- **Pathogen control**
- **Spoilage microorganism control**
- **Insect disinfestation**
- **Delay of ripening or maturation**
- **Sprout inhibition**

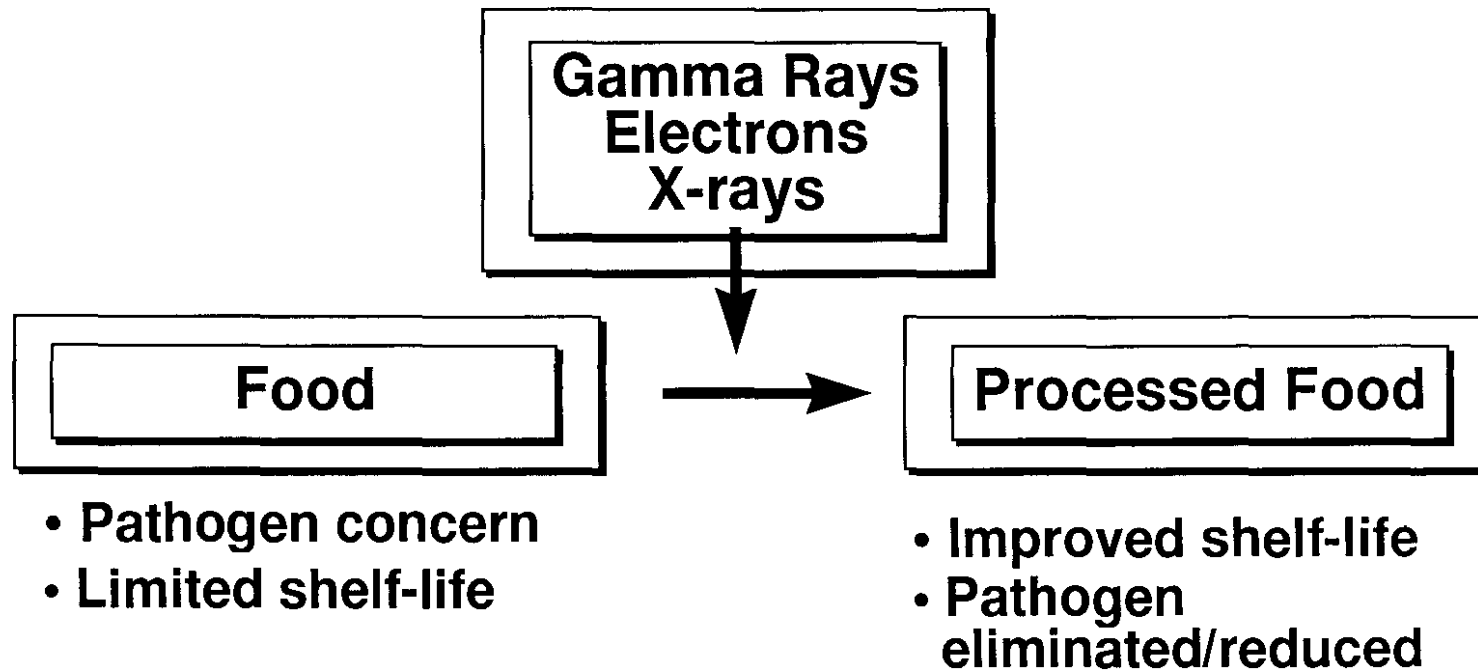


Consumer and Social Benefits

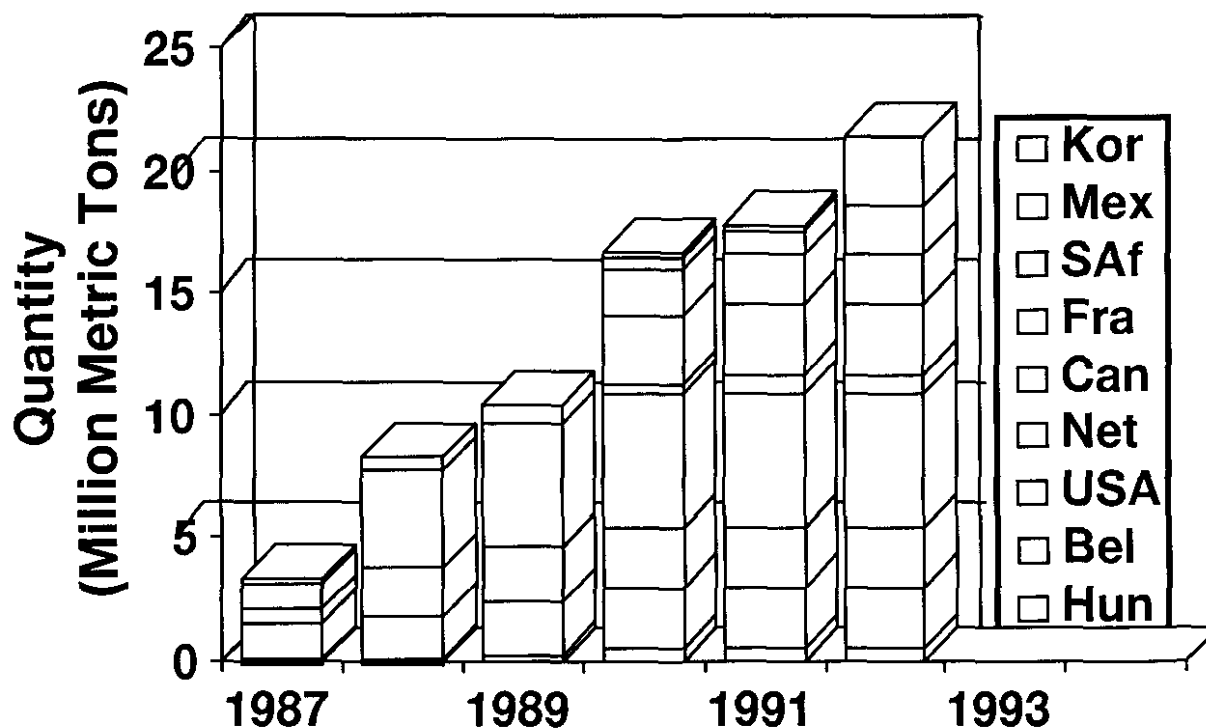
- **Safer foods**
- **Better quality**
- **Less spoilage (shelf-life extension)**
- **Overall economic gain**

Technology for Food Irradiation

- Involves the exposure of a food to ionizing radiation for the purpose of achieving desired technical benefit

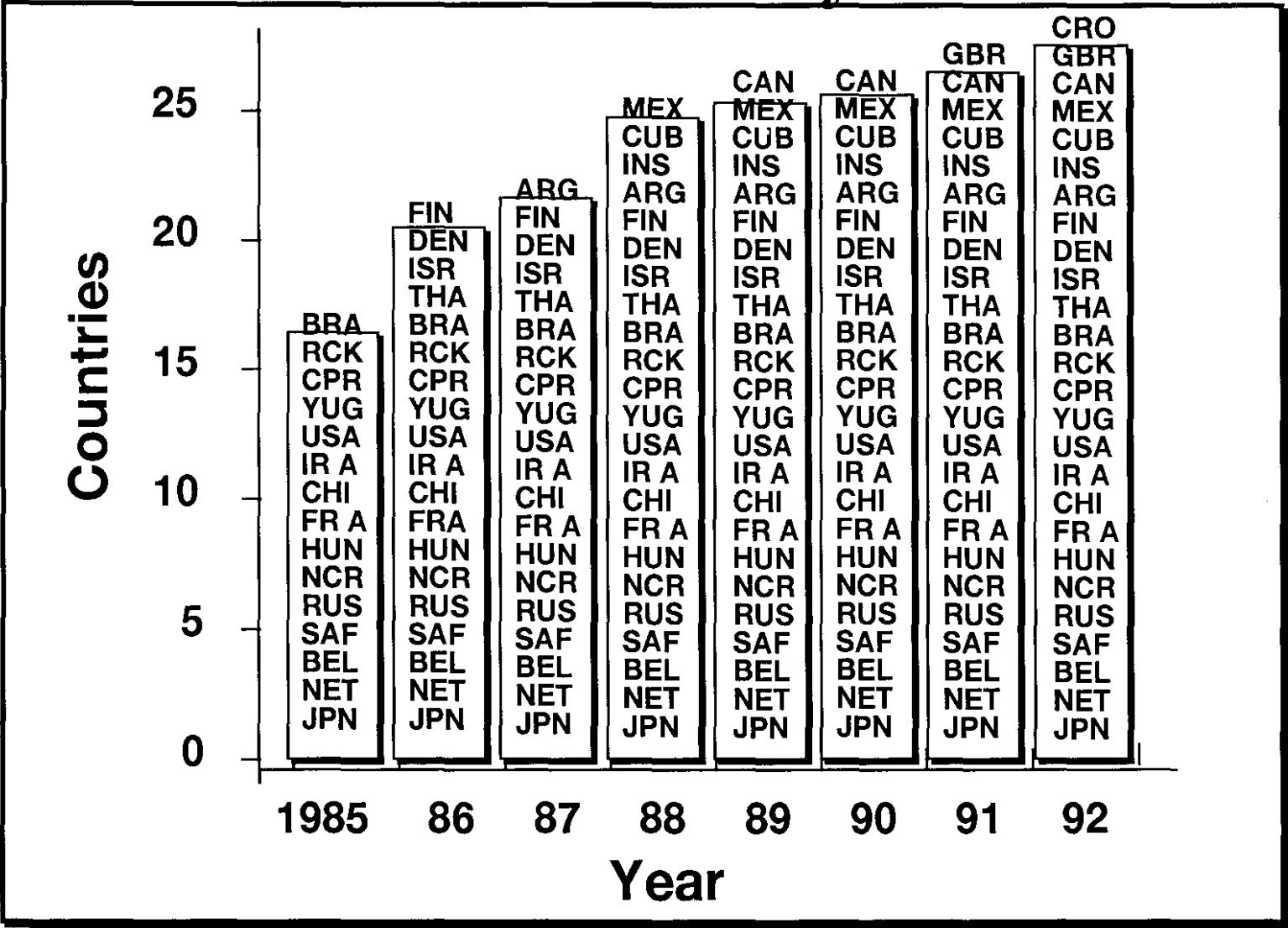


Commercial Irradiation of Spices and Vegetable Seasonings in Different Countries



- Since 1992, the number of countries irradiating spices and seasonings has grown enormously

Countries Irradiating Food/Ingredients Commercially



List of Foods Cleared for Irradiation in Thailand (1986)

Product	Purpose	Clearance	Dose (kGy)
Potatoes, onions & garlic	Sprout inhibition	Unconditional	0.15
Dates	Disinfestation	Unconditional	1
Mangoes, papayas	Disinfestation and delay of ripening	Unconditional	1
Wheat, rice, pulses	Disinfestation	Unconditional	1
Cocoa Beans	Disinfestation	Unconditional	1
Fish and fishery products	Disinfestation	Unconditional	1
Fish and fishery products	Reduce microbial load	Unconditional	2.2
Strawberries	Shelf-life extension	Unconditional	3
Nham	Decontamination	Unconditional	4
Moo yor	Decontamination	Unconditional	5
Sausage	Decontamination	Unconditional	5
Frozen shrimps	Decontamination	Unconditional	5
Cocoa beans	Reduce microbial load	Unconditional	5
Chicken	Decontamination and shelf-life extension	Unconditional	7
Spices & condiments, dehydrated	Insect disinfestation	Unconditional	10
Onions and onion powder	Decontamination	Unconditional	10