Radiation Processing

Basics, Current and Emerging Applications

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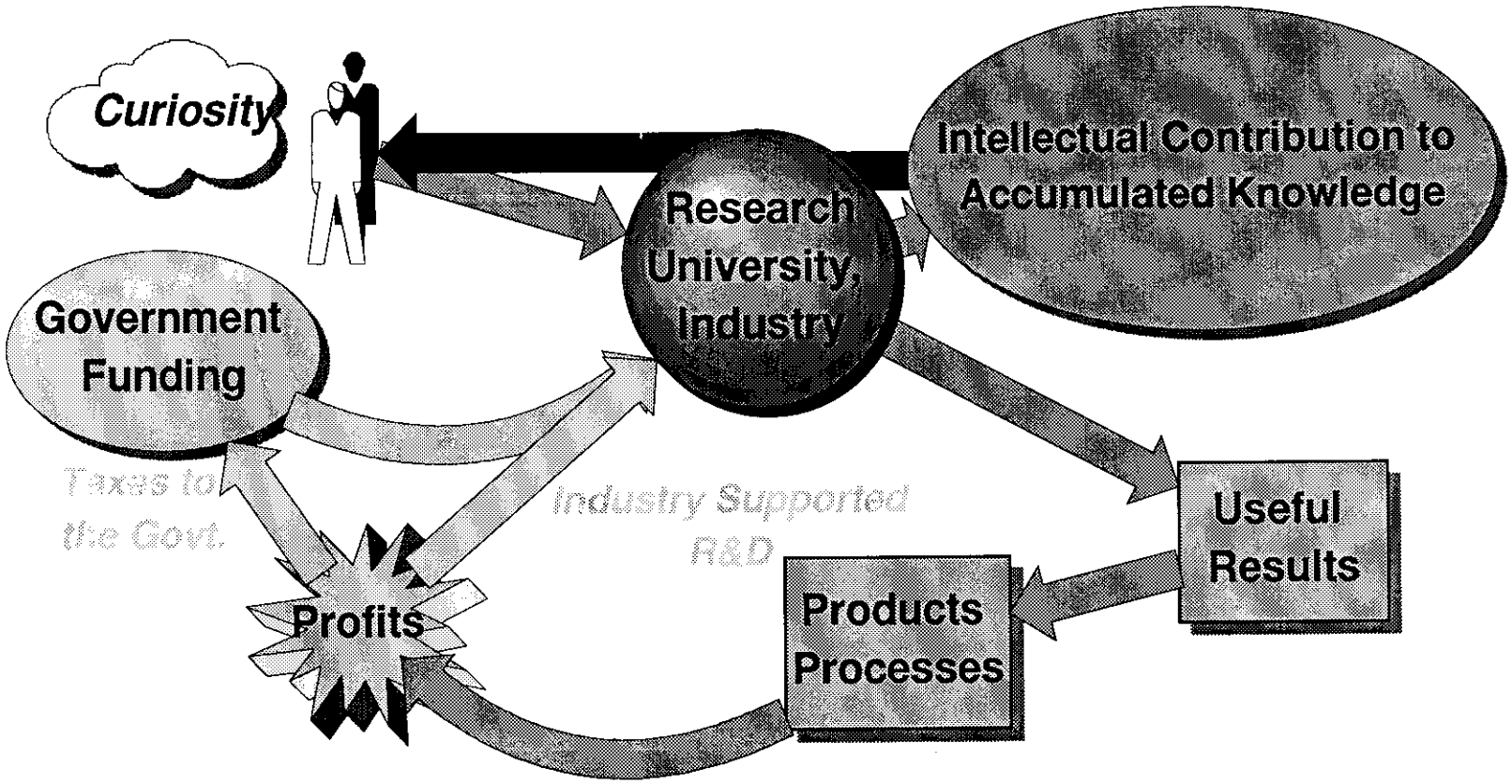


Curiosity Driven by Mental and Physical Human Needs
Emphasis is Shifting to Physical Needs (Applied Research)

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

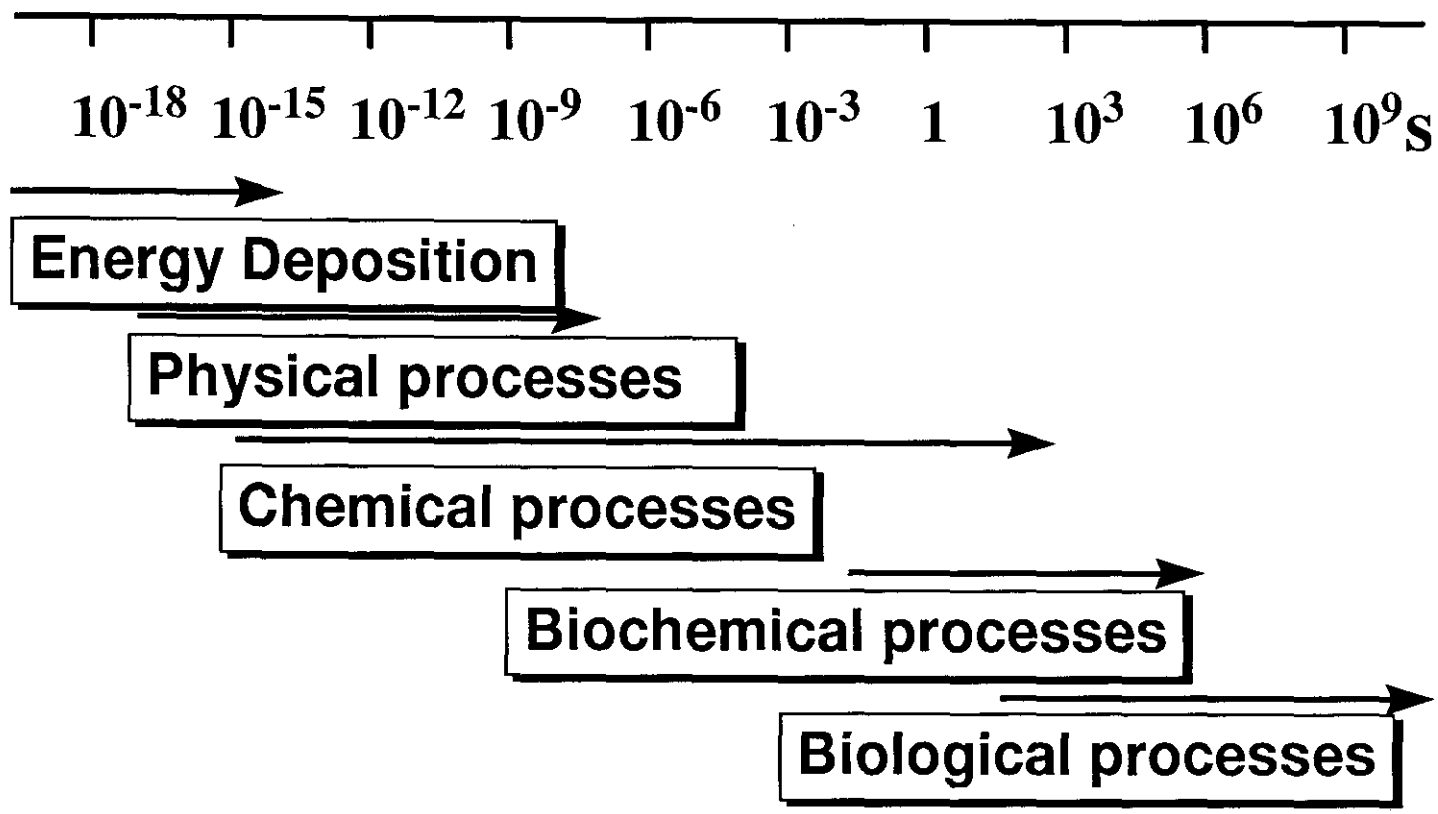
Examples Of Chemical Effects

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

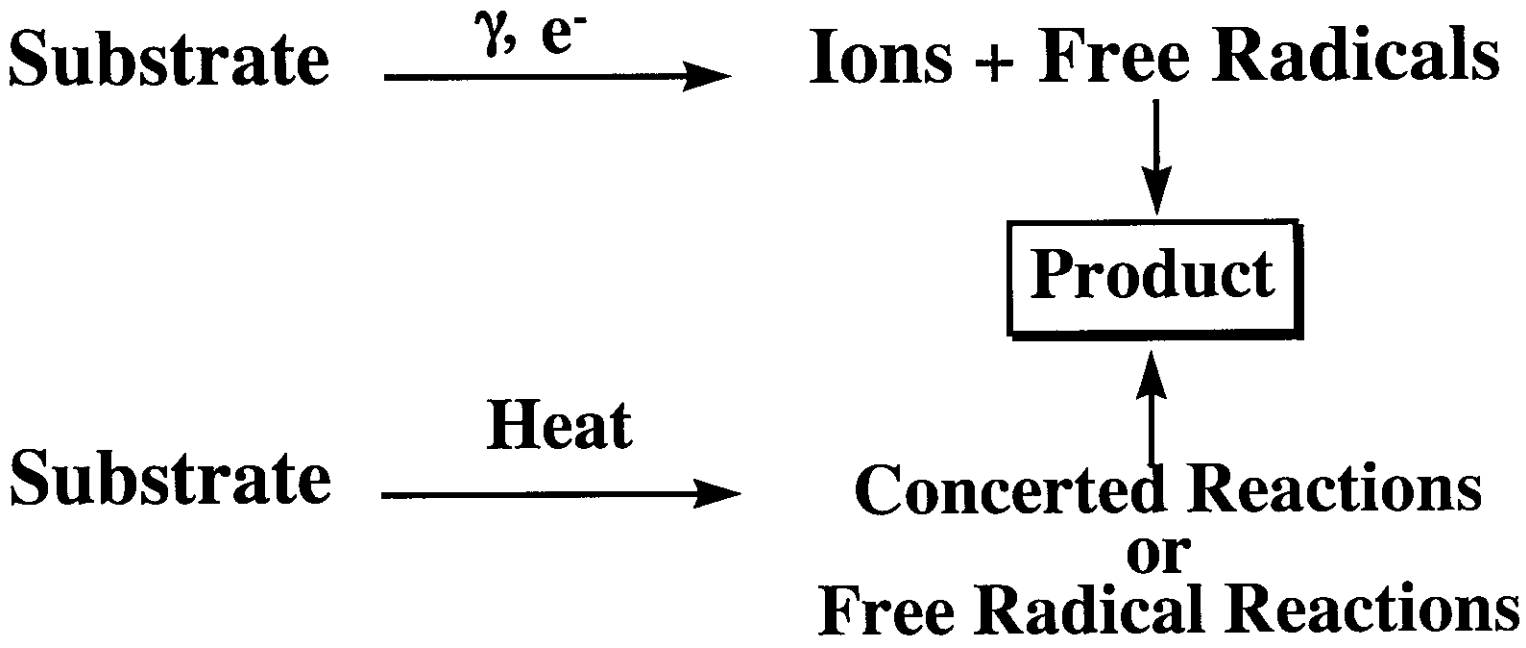
Examples Of Biological Effects

- 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

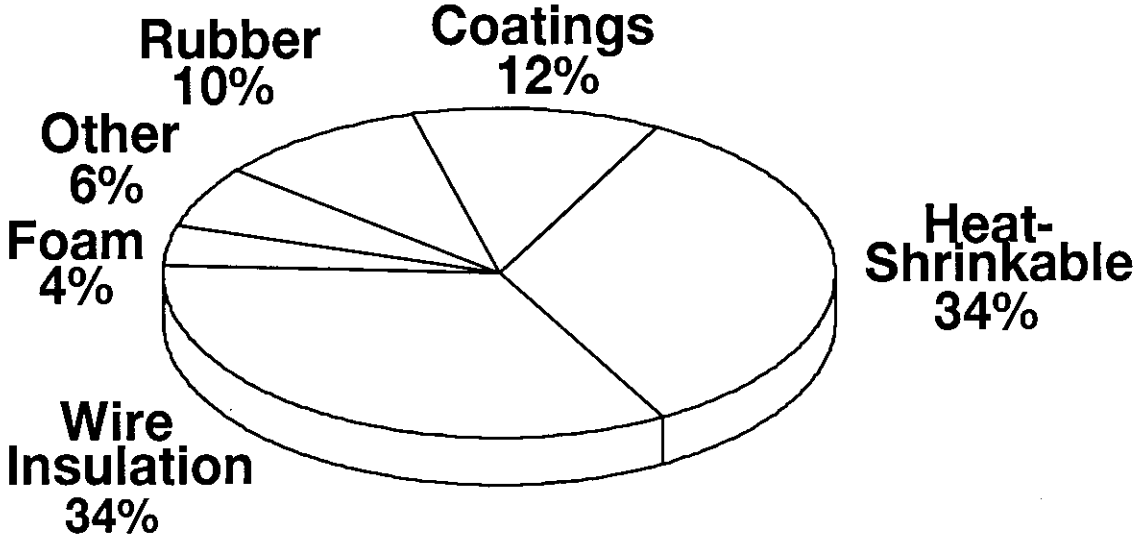
Current γ – and Electron Applications

- 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 Woldwide 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 O_3/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

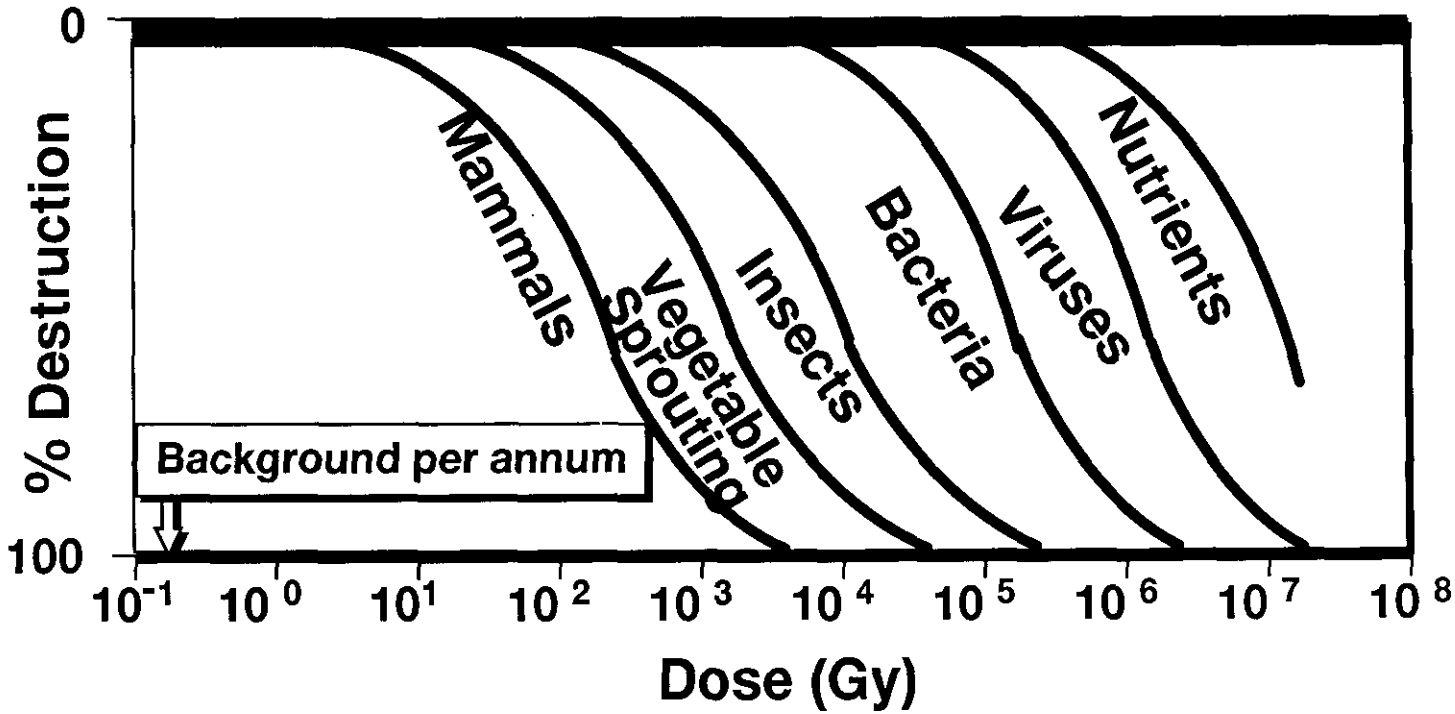
- Foodborne Disease can Cause Serious Illness and Death
  - Morbidity: diarrhea, fever, kidney failure, birth defects
  - Mortality: generally the very young and the very old

- 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 (·OH, ·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

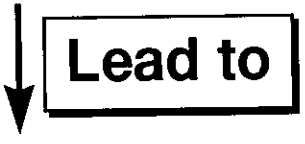
Basis for Beneficial Effect of Irradiation



- These differential senstivities 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

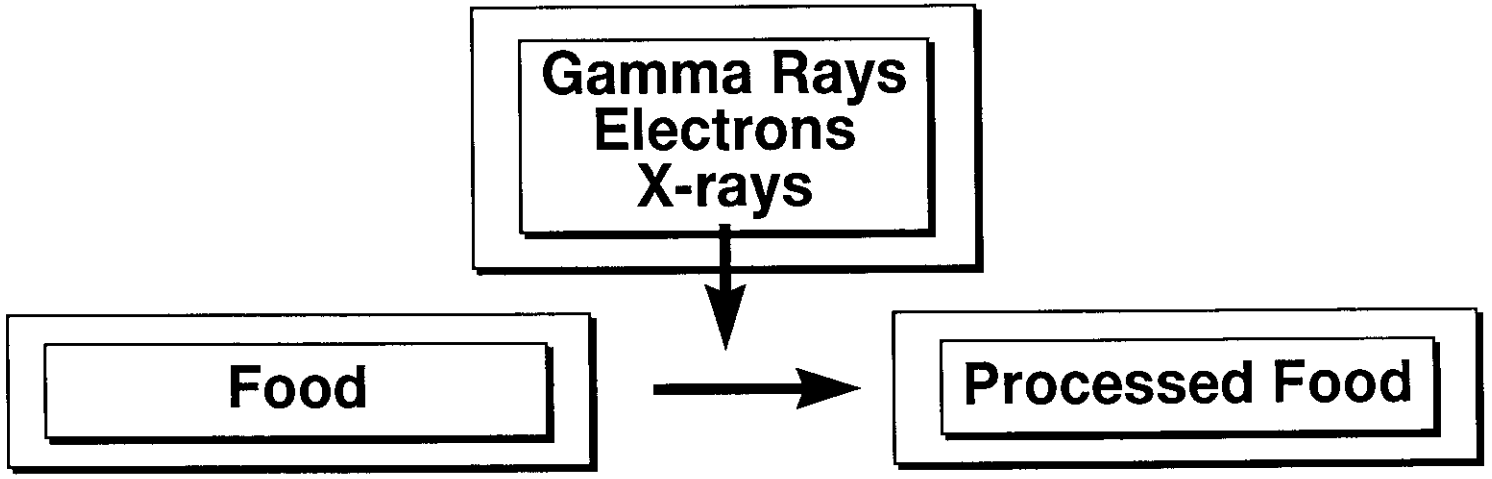


Consumer and Social Benefits

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

Technology for Food Irradiation

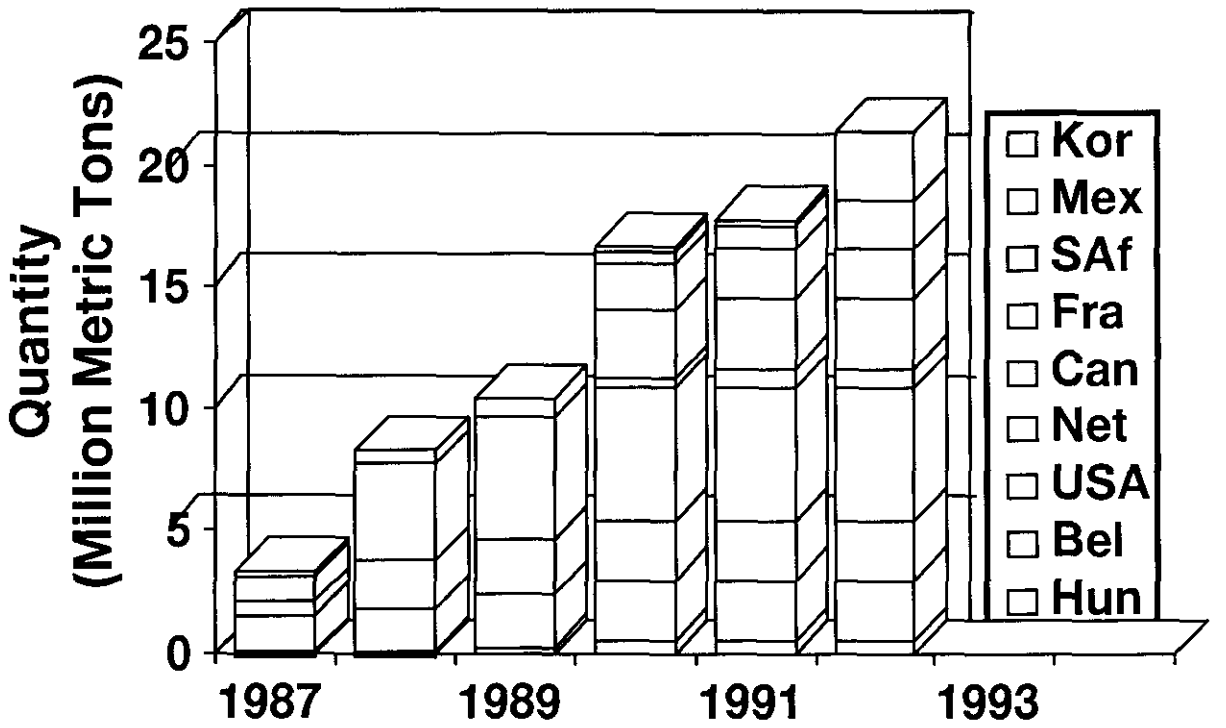
- Involves the exposure of a food to ionizing radiation for the purpose of achieving desired technical benefit



- Pathogen concern
- Limited shelf-life

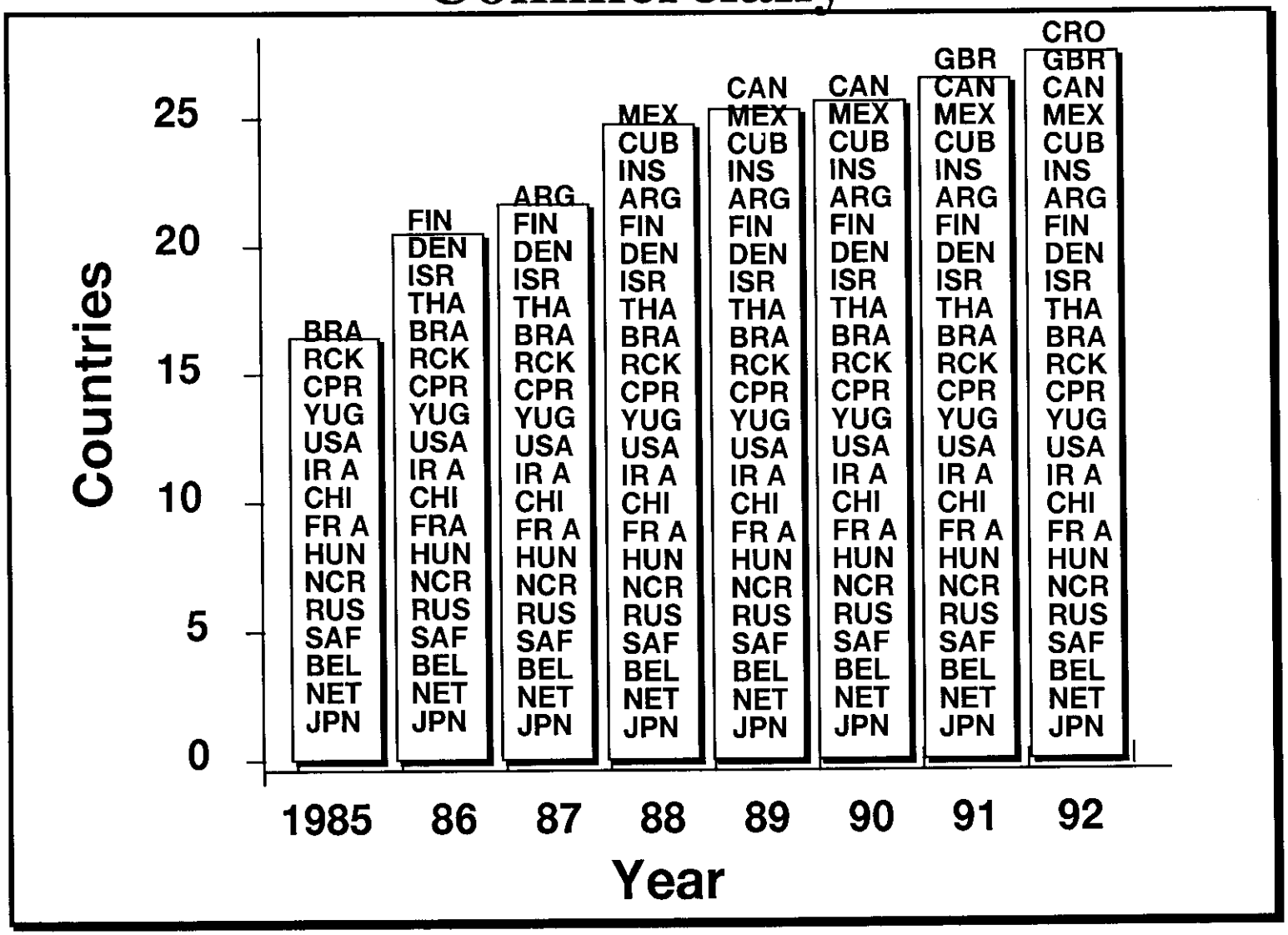
- Improved shelf-life
- Pathogen eliminated/reduced

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