Food Irradiation
What’s out there?
Who’s doing it?

Ronald F. Eustice
Executive Director
Minnesota Beef Council

Fresh Produce & Cut Flower Irradiation Workshop
September 1-2, 2009

What we will learn today

• What’s out there?
  – Foods are approved for irradiation in USA;
  – Pending approvals;
• Who is doing it?
  – Irradiated foods in the marketplace;
  – USA
  – International Markets
• What is next? The future;
  -Some reasons why we will see more irradiated foods on the market in the future;

Meat Recalls & Foodborne Illness
E. Coli O157:H7 & Listeria Monocytogenes

• Jack in the Box (1993)
• Hudson Foods-E. coli O157:H7 (August 1997)
  – 25 million pounds
  (Largest Beef Recall in History)
• Conagra/Swift-E. coli O157:H7
  – 19 million pounds
  (October 2006)
• Thorn Apple Valley-Listeria
  – 12.4 million pounds
  (January 1998)
• El Mer Food-Listeria
  – 25.9 million pounds
  (July/August 2002)
• Wampler Food-Listeria
  – 27.4 million pounds
  (July/August 2002)
<table>
<thead>
<tr>
<th>Recalled for Salmonella</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dole</td>
</tr>
<tr>
<td>Natural Selection Foods</td>
</tr>
<tr>
<td>Pride of San Juan</td>
</tr>
<tr>
<td>Earbound Farm</td>
</tr>
<tr>
<td>Bellisima</td>
</tr>
<tr>
<td>Rave Spinach</td>
</tr>
<tr>
<td>Emeriti</td>
</tr>
<tr>
<td>Sysco</td>
</tr>
<tr>
<td>O Organic</td>
</tr>
<tr>
<td>Fresh Point</td>
</tr>
<tr>
<td>River Ranch</td>
</tr>
<tr>
<td>Superior</td>
</tr>
<tr>
<td>Nature’s Basket</td>
</tr>
<tr>
<td>Pro-Mark</td>
</tr>
<tr>
<td>Compliments</td>
</tr>
<tr>
<td>Trader Joe’s</td>
</tr>
<tr>
<td>Ready Pac</td>
</tr>
<tr>
<td>Jamai Valley</td>
</tr>
<tr>
<td>Cheney Bros.</td>
</tr>
<tr>
<td>Coastline</td>
</tr>
<tr>
<td>D’Arrigo Bros.</td>
</tr>
<tr>
<td>Green Harvest</td>
</tr>
<tr>
<td>Mann</td>
</tr>
<tr>
<td>Mills Family</td>
</tr>
<tr>
<td>Pro* Act</td>
</tr>
<tr>
<td>Premium Fresh</td>
</tr>
<tr>
<td>Snobby</td>
</tr>
<tr>
<td>Farmer’s Market</td>
</tr>
<tr>
<td>Tanimure &amp; Antle</td>
</tr>
<tr>
<td>President’s Choice</td>
</tr>
<tr>
<td>Cross Valley</td>
</tr>
<tr>
<td>Riverside Farms</td>
</tr>
</tbody>
</table>

Recalled for Salmonella

<table>
<thead>
<tr>
<th>Don’t Eat the Spinach</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Don’t Eat the Pistachios</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don’t Eat the Tomatoes</td>
</tr>
</tbody>
</table>

## Irradiation: A Food Safety Solution?

Could irradiation do for meat & poultry & produce what pasteurization did for milk?

1. Learn about the irradiation process
2. Was it effective?
3. Would irradiation affect taste, nutrition etc.
4. Determine Consumer Acceptance

### References

- 1997
Pillars of Public Health

- Pasteurization
- Immunization
- Chlorination

Source: Dr. Michael Osterholm

We Wanted Answers to Certain Questions

- Nutritional loss?
- Excuse to clean up “filthy” food?
- Chemical changes?
- Flavor changes?
- Unknown “Risks”?
- Cost?
**Who Supports Irradiation?**

- American Medical Association
- World Health Organization
- Centers For Disease Control
- American Dietetic Association
- Institute of Food Technologists
- American Council on Science and Health
- Food and Drug Administration
- American Public Health Association
- Every scientific & medical organization

**Benefits of Irradiation**

- Reduces or eliminates harmful food borne pathogens:
  - E. coli O157:H7
  - Campylobacter
  - Salmonella
  - Trichinella
  - Listeria
  - Many others

-Eliminates insects in fruits and vegetables
- Delays ripening of fruits and vegetables
- Inhibits sprouting in onions, potatoes, etc.
- Replaces chemical fumigation
- Extends freshness & shelf life

**Food Irradiation**

- One Process: Multiple Uses
- Insect Disinfestation: Cereals, Pulses, Dry Fruits
- Sprout Inhibition: Onions, Potato, ginger, Garlic
- Pathogen Reduction: Spices, Fresh Foods
- Shelf-life Extension: Chicken, Meat, Fish
- Quarantine: Fruits

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Does irradiation reduce food’s vitamin and enzyme content?

All processing of food – cooking, canning, freezing decreases nutritional content.
• FDA has determined that nutritional loss from irradiation is insignificant.
• Irradiated fruit can be shipped riper than non-irradiated fruit, resulting in higher vitamin A and C content.

<table>
<thead>
<tr>
<th>Nutrient/Vitamin/Count</th>
<th>Non-irradiated Sample</th>
<th>Irradiated Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein (by Dumas)</td>
<td>16.6</td>
<td>16.7</td>
</tr>
<tr>
<td>Iron (milligrams)</td>
<td>2.19</td>
<td>2.31</td>
</tr>
<tr>
<td>Thiamin (milligrams)</td>
<td>.0400</td>
<td>.0400</td>
</tr>
<tr>
<td>Zinc (milligrams)</td>
<td>3.89</td>
<td>3.97</td>
</tr>
<tr>
<td>Niacin (milligrams)</td>
<td>4.68</td>
<td>4.82</td>
</tr>
<tr>
<td>Vitamin B₆ (milligrams)</td>
<td>0.200</td>
<td>0.140</td>
</tr>
<tr>
<td>Vitamin B₁₂ (milligrams)</td>
<td>1.60</td>
<td>1.70</td>
</tr>
<tr>
<td>Phosphorus (milligrams)</td>
<td>135</td>
<td>135</td>
</tr>
</tbody>
</table>

Medallion Laboratories (2002)

Nutritional analysis of irradiated & non-irradiated ground beef Retail Frozen Product
Amounts are for 100 grams of frozen ground beef

<table>
<thead>
<tr>
<th>Nutrient/Vitamin/Count</th>
<th>Non-irradiated Sample</th>
<th>Irradiated Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein (by Dumas)</td>
<td>18.1</td>
<td>20.0</td>
</tr>
<tr>
<td>Iron (milligrams)</td>
<td>2.07</td>
<td>1.98</td>
</tr>
<tr>
<td>Thiamin (milligrams)</td>
<td>.0500</td>
<td>.0500</td>
</tr>
<tr>
<td>Zinc (milligrams)</td>
<td>4.09</td>
<td>3.96</td>
</tr>
<tr>
<td>Niacin (milligrams)</td>
<td>4.16</td>
<td>4.32</td>
</tr>
<tr>
<td>Vitamin B₆ (milligrams)</td>
<td>.230</td>
<td>0.220</td>
</tr>
<tr>
<td>Vitamin B₁₂ (milligrams)</td>
<td>1.96</td>
<td>1.78</td>
</tr>
<tr>
<td>Phosphorus (milligrams)</td>
<td>150</td>
<td>142</td>
</tr>
</tbody>
</table>

Medallion Laboratories (2002)

Nutritional analysis of irradiated & non-irradiated ground beef Foodservice Fresh (Refrigerated) Product
Amounts are for 100 grams of fresh ground beef
RALTECH STUDY

Objective:
- To determine the wholesomeness of radiation sterilized chicken meat

Background:
- Started in 1976 and lasted 7 years
- US ARMY Medical Department / later transferred to USDA
- Cost 8 million dollars
- Consisted of 20 separate research projects, examining effect of consuming radiation sterilized chicken meat, with respect to:
  - Nutritional quality
  - Teratogenicity
  - Carcinogenicity
  - Reproductive performance
  - Genetic toxicity
  - General toxicity
- Test species: Dogs, rats, mice, hamsters, rabbits, fruit flies

RALTECH: Overview of the Study

Five diets compared:
- **N** control diet (dog chow or rodent chow)
- **PC** 35% frozen control chicken; 65% diet N
- **T** 35% thermally processed chicken; 65% diet N
- **E** 35% electron beamed chicken (~60 kGy); 65% diet N
- **G** 35% gamma rayed chicken (~60 kGy); 65% diet N

Magnitude of the effort:
- >230,000 chilled eviscerated broilers used / 300,000 kg of chicken meat
- >Involved many labs and researchers
- Types of studies
  - Nutrition
  - Genetic toxicity
  - Teratology
  - Chronic toxicity, oncogenicity, and multi-generation general health and reproductive function

Genetic Toxicity Tests

- Four tests used:
  - Ames test (Salmonella typhimurium)
  - Sex-linked recessive lethal mutations (Drosophila melanogaster)
  - Heritable translocation mutations (mice)
  - Dominant lethal mutations (mice)

Conclusion:
All four tests showed NO mutagenic activity present in irradiated chicken meat

(Note that this is for doses approximately 20-fold greater than those used for meat and poultry pasteurization)
RALTECH Study

Summary of Results (from Thayer et al, 1987)

- Overall the studies were consistent in producing negative results in all the variety of tests performed
- The results have been independently reviewed, and endorsed, by
  1. Division of Pathology, FDA Center for Food Safety and Applied Nutrition
  2. National Toxicology program, Technical Reports Review Subcommittee

CONCLUSION:
RALTECH studies confirm the safety and wholesomeness of chicken sterilized by irradiation to a maximum dose of 68 kGy

Could irradiation do for ground beef what pasteurization did for milk?
Education: Key to Consumer Acceptance

Argentina
Brazil
Canada
India
Peru
Spain
Thailand
Uruguay
USA
Foods Approved for Irradiation in the USA

<table>
<thead>
<tr>
<th>Year</th>
<th>Food</th>
<th>Dose</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963</td>
<td>Wheat Flour</td>
<td>0.2-0.5 kGy</td>
<td>Control of Mold</td>
</tr>
<tr>
<td>1964</td>
<td>Milk Powder</td>
<td>0.05-0.1 kGy</td>
<td>Initial Sampling</td>
</tr>
<tr>
<td>1986</td>
<td>Pork</td>
<td>0.3-1.5 kGy</td>
<td>Kil Trichina Parasite</td>
</tr>
<tr>
<td>1986</td>
<td>Fruits &amp; Vegetables</td>
<td>&lt; 1.0 kGy</td>
<td>Inhibit Sprouting/Extend Shelf Life</td>
</tr>
<tr>
<td>1986</td>
<td>Herbs &amp; Spices</td>
<td>&lt; 30 kGy</td>
<td>Sanitization</td>
</tr>
<tr>
<td>1986</td>
<td>Dried Enzymes</td>
<td>10 kGy</td>
<td>Bacterial Reduction</td>
</tr>
<tr>
<td>1990</td>
<td>Poultry</td>
<td>&lt; 3 kGy</td>
<td>Pathogenic Bacteria Reduction</td>
</tr>
<tr>
<td>1990</td>
<td>NASA/Meat</td>
<td>&gt; 44 kGy</td>
<td>Sterilization</td>
</tr>
<tr>
<td>1997</td>
<td>Frozen Meal</td>
<td>&lt; 4.3 kGy</td>
<td>Pathogenic Bacteria Reduction</td>
</tr>
<tr>
<td>2000</td>
<td>Spouts</td>
<td>&lt; 36 kGy</td>
<td>Pathogenic Bacteria Reduction</td>
</tr>
<tr>
<td>2001</td>
<td>Pet Treatments/Kitten Food</td>
<td>&lt; 56 kGy</td>
<td>Pathogenic Bacteria Reduction</td>
</tr>
<tr>
<td>2006</td>
<td>Molluscan Shellfish</td>
<td>&lt; 5.5 kGy</td>
<td>Pathogenic Bacteria Reduction</td>
</tr>
<tr>
<td>2008</td>
<td>Fresh Spinach &amp; Iceberg Lettuce</td>
<td>&lt; 6.0 kGy</td>
<td>Pathogenic Bacteria Reduction</td>
</tr>
</tbody>
</table>

Recent Approvals: Food Safety

Approved on August 26, 2008
Recent Approvals: Phytosanitary

USDA/APHIS began issuing permits for the importation into the United States of fresh guava fruit from Mexico on October 14, 2008. Based on the findings of a pest risk analysis, USDA/APHIS believes that the application of one or more designated phytosanitary measures will be sufficient to mitigate the risks of introducing or disseminating plant pests or noxious weeds via the importation of guavas from Mexico.

Applications/ Pending Approvals

The American Meat Institute (AMI) has submitted a petition to the USDA’s Food Safety and Inspection Service (FSIS) to recognize the use of low penetration and low dose electron beam irradiation on the surface of chilled beef carcasses as a processing aid.

Ready-to-Eat Foods

• Grocery Manufacturer’s Association (GMA) has petitioned FDA to allow irradiation of certain prepared foods including hot dogs, luncheon meats, bologna etc.
Irradiated Food in US Space Program

Irradiated Spices

- It is estimated that approximately 80,000 metric tons (175,000,000 pounds) of commercial spices are irradiated annually in the USA.
- One-third of total US production.

Current Meat Applications of irradiation in the USA

- Poultry
- Ground Beef
Schwan’s markets irradiated beef patties nationwide. All raw ground beef at Schwan’s is irradiated.

**PREMIUM HEARTLAND QUALITY**

**OMAHA STEAKS**

- Mail order nationwide
- 80 stores in 23 states
- 5 additional stores planned in 2008
- Expanding by 8 to 10 stores per year

Colorado Boxed Beef of Auburndale, FL
Irradiated ground beef is a value-added product, and we are proud to offer this alternative to our customers.”

Oyster Irradiation

On 12 June 2009 Food Technology Service Inc. (FTSI) Florida became the first licensed facility to make raw oysters safer by irradiating them.

FTSI applies a proprietary dose to eliminate Vibrio vulnificus, which is a naturally occurring marine bacterium that can make some people very sick or can kill them.
United Fresh Produce Trade Show

Irradiated Fruits & Vegetables in USA

- Guava
- Mango
- Papaya
- Star Fruit

18 Million Pounds Annually

Food Technology Services Inc. (FTSI)
Mulberry, Florida

- Mango
- Guava
- Boniato (Camote)
- Cuban Sweet Potato

Produced in South Florida, irradiated at Food Technology Services. Marketed by distributors to Arizona, Texas and California.
Hawaii Pride

USDA Framework Equivalency Work Plans

- India
- Mexico
- Thailand
- Philippines
- Viet Nam
- South Africa
- Laos
- Malaysia
- Pakistan
- South Africa.

India
A shipment carrying 14 tonne of ‘Kesar’ mango left Mumbai on June 12 and arrived in the US two weeks later. This is the first ever consignment sent through the sea route and is expected to reduce the retail prices of Indian mango in the United States by 50%.

- Shelf life of 30 days required
- Experiment with 4000 boxes (14.5 Tons) of mango
- Antimicrobial dip
  - Irradiation
  - Low Temp
  - MAP

Mangoes from India
350 Metric Tonnes in 2008
Pakistan

- 20 July 2009: Pakistan's mango export during the current season has crossed 60 percent of the total set target of 125,000 tonnes, which was termed as "stupendous" accomplishment by leading exporters and growers.

During the last two months (May-June) since the mango export took off, the total volumes of mango export stand at around 70,000 to 75,000 tonnes which is almost equal to total export achieved by the country previous year during 5 months of export period indicating brisk ongoing pace during the current season.

Queen of Fruits: The Mangosteen

Mangosteens have not been allowed into the United States for centuries, but as of July 23, 2007, they were given clearance for import after the process of irradiation.

Thailand

- Two facilities have been approved by USDA APHIS: the government owned Thai Irradiation Centre and the gamma irradiator of Isotron, both close to Bangkok.

- In 2008, approximately, about 1,700 metric tons of fruit were irradiated and exported to the US, most of which were longans (two thirds of the total) and mangosteens, with small quantities of rambutans and mangoes.

  The total quantity should remain about the same in 2009.
Boxes for products irradiated at the Thailand Irradiation Center near Bangkok bear the above label.
Viet Nam

- An electron beam facility was purchased several years ago by the company Sonson with fruit irradiation as the main purpose.
- USA accepted the import of irradiated dragon fruit from the Binh Thuan province in central Vietnam.
- Since October 2008, approximately 7 tons a week was shipped.
- A second irradiation facility will soon be operational.

China

140,000 MT of food irradiated annually
Mexico

• After a 74 year ban, fresh guavas are arriving in the United States from Mexico thanks to mandatory use of irradiation.

Mexican Guavas

• In 2009 more than 830 metric tonnes (1.8 million pounds) of irradiated guavas and mangoes have entered the US from Mexico.
Irradiation lets Mexican manila mangoes into U.S.

Mexican “Manila” Mangoes

“This is the best quality mango we have here or in the world, but it has very thin skin that can’t resist the hot water treatment.”

César Moreno, general manager, Sterigenics Gamma Mexico

“It has never been in the states, and it will be in the next months (because of irradiation).” The Packer magazine

Steritech, Australia

Mangos are irradiated every day during the 90-120 day harvest season

300 Metric Tonne Irradiated in 2008/09
Australia Produce Irradiation (2009)

Mangoes........300 metric tonnes
Lychees........3 metric tonnes
Papaya.........28 metric tonnes
Paw Paw........Trial amount

(2009 Mango season cut short due to flooding)

Produce is irradiated for disinfection purposes to meet New Zealand import requirements.

Philippines

Mangoes
Peruvian Asparagus
Copitarsia decolora

- Peru is a leading exporter of green asparagus.
- Principal market is the United States which receives 80% of Peru’s fresh asparagus production.

- The US has placed restrictions on import of Peruvian asparagus because of the presence of C. decolora.
- As a result, 100% of Peru’s fresh asparagus exports must be fumigated with Methyl Bromide.

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Quantity of Foods Irradiated Commercially in some Asia-Pacific Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Tons*</th>
<th>Main Commodities Treated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>282</td>
<td>Mango, papaya, kiwi</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>20</td>
<td>Spices, potatoes</td>
</tr>
<tr>
<td>China</td>
<td>500</td>
<td>Spices, dried vegetables, canned foods</td>
</tr>
<tr>
<td>India</td>
<td>1968</td>
<td>Spices, spice mixes, dried vegetable seasonings, mango</td>
</tr>
<tr>
<td>Indonesia</td>
<td>2,256</td>
<td>Spices, dried vegetables, dehydrated products, frozen products, fish, frog legs</td>
</tr>
<tr>
<td>Malaysia</td>
<td>1133</td>
<td>Spices, herbs, vegetable seasonings, rice</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Philippines</td>
<td>326</td>
<td>(i) Solid foods (ii) Dehydrated foods</td>
</tr>
<tr>
<td>Pakistan</td>
<td>147</td>
<td>Dehydrated foods</td>
</tr>
<tr>
<td>Pakistan</td>
<td>560,000</td>
<td>Ready-to-eat meals</td>
</tr>
<tr>
<td>Philippines</td>
<td>350</td>
<td>Spices, dehydrated vegetables and fruits</td>
</tr>
<tr>
<td>Korea (Rep.)</td>
<td>1800</td>
<td>Dried vegetables, spices</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Thailand</td>
<td>Not available</td>
<td>Nham, spices, herbs, vegetable seasonings, sweet tamarind, mango, mangosteen and longan</td>
</tr>
<tr>
<td>Vietnam</td>
<td>350,000</td>
<td>Spices, fruits, fish and frog legs</td>
</tr>
</tbody>
</table>

* approximate values for 2008 or the latest year available; Dr. Arun Sharma

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Can This Meat Still Kill You?

**Yes, This Meat Can Still Kill You!**
**Foodborne Illness is a Problem**

*Foodborne Illness is Very Real!*

- 76 million cases of foodborne illness
- 5,000 deaths

US Centers for Disease Control (CDC)

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**Multiple Hurdle Intervention**

*Firewalls for Microbial Control*

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**Prevalence of Salmonella in Ground Beef**

- **Prevalence of Salmonella in Ground Beef**
  - 0%
  - 1%
  - 2%
  - 3%
  - 4%
  - 5%
  - 6%
  - 7%
- **Year**
  - 98
  - 99
  - 00
  - 01
  - 02
  - 03
  - 04
  - 05
  - 06
  - 07
Prevalence of *E. coli O157:H7* in Ground Beef

![Graph showing prevalence of E. coli O157:H7 in ground beef over fiscal years 2000 to 2008.]

Results of raw ground beef products analyzed for *E. coli O157:H7* in federal plants. 2008 Data as of December 30.

Future Issues?

- *E. coli O157:H7*
- Non-O157:H7 STEC
- Multi-Drug Resistant *Salmonella*
- *Listeria*
CDC reports progress in foodborne illness prevention has reached a plateau.

• "We recognize that we have reached a plateau in the prevention of foodborne disease and there must be new efforts to develop and evaluate food safety practices from the farm to the table."
  • Robert Tauxe, M.D., M.P.H, deputy director of CDC’s Division of Foodborne, Bacterial and Mycotic Diseases.

According to the Centers for Disease Control and Prevention (CDC), 900,000 cases of illness, 8,500 hospitalizations, and 404 deaths could be avoided annually if just 50 percent of raw meat and poultry consumed in the U.S. were irradiated.

Dr. Robert V. Tauxe, Centers for Disease Control and Prevention, Atlanta

Arguments against pasteurization

• This is little more than an excuse for the sale of contaminated milk.
• Pasteurization will be used to mask low-quality foods. Better controls and inspection are what is needed.
• Pasteurization decreases the nutritional value of milk.
• It leads to formation of harmful products in milk. Possibly dangerous substances could be formed.
• This process will increase the price of the product. It is not necessary. We have a direct and prompt food distribution system.

Sources:
• Milk Pasteurization, Hall & Trout (1968)
• Technology Review (December 1981)
Yes, Meat Can Still Kill You!!

- So can:
  - Spinach
  - Lettuce
  - Peppers
  - Peanut Paste
  - Bean Sprouts
  - Alfalfa Sprouts
  - Pistachios
  - Etcetera, etcetera, etcetera
Irradiation in the USA Today

- Approximately 8,000 MT (15-18,000,000 pounds) of ground beef irradiated annually in USA.
- Approximately 8,000 MT (18,000,000 pounds) of produce irradiated annually.
- Approximately 70-80,000 MT (175,000,000 pounds) of spices irradiated annually.

Reasons Why the Amount of Irradiated Food in Will Increase Significantly

- Food Safety Concerns
  - Leafy vegetables, meat, poultry
  - Pathogenic Bacteria Reduction in meat has slowed.
- Market Access (Framework Equivalency Work Plans) India, Thailand, Mexico & more
- Increase available food supply & reduce “Carbon Footprint”
  - Reduce wasted food
  - Extend freshness
  - Reduce storage losses
  - Ship by surface instead of air

Food Economics & Technology

- Global population is expected to exceed 9 billion by 2050, up from the 6.76 billion people on earth today.
We need to use technology to meet a growing need for safe, nutritious & affordable food

- Thanks to improved genetics, animal care and husbandry, modern technology and environmental stewardship, farmers and ranchers are producing more food than at any time in history.
How will we feed the people?

- Added farmland will produce only 20% of the additional food we need in 2050, and 10% will come from increased cropping intensity;  
- FAO concludes that 70% of world’s additional food needs must come from new and existing agricultural technologies.

Over half of the food produced globally is lost, wasted or discarded as a result of inefficiency in the human-managed food chain.

The Environmental Food Crisis: A Crisis of Waste
• Losses and food waste in the United States could be as high as 50 percent, according to some recent estimates. Up to one-quarter of all fresh fruits and vegetables in the United States is lost between the field and the table.

• In Australia it is estimated that food waste makes up half of that country's landfill. Almost one-third of all food purchased in the United Kingdom every year is not eaten.

• Losses in the field between planting and harvesting could be as high as 40 percent of the potential harvest in developing countries due to pests and pathogens.

• In Africa, the total amount of fish lost through discards, post-harvest loss and spoilage may be around 30 percent of landings. The report estimates that globally about 30 million metric tonne of fish are discarded at sea every year.

Iceberg Lettuce
after 14 Days in MAP at 4 C

Xuetong Fan, USDA, ARS
Spinach after 14 Days in MAP at 4 C

Blackberries

Blueberries
Asparagus

Comparison of asparagus tips by treatment group at day 0

Control
X-ray 400Gy
X-ray 1,000Gy

Shelf Life Extension

Control
Irradiated at 400Gy
36 days at 34F
36 days at 34F

Tomatoes

Control compared to tomatoes irradiated at 1.0 kGy at 10 days
Strawberries

Control not edible at 7 days storage

Irradiated at 1.0 kGy; stored at 40 F

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Chapter Five: Consumer Acceptance & Marketing of Irradiated Foods;
By Dr. Christine Bruhn & Ronald Eustice

Thank You!!!

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