Improving food safety and extending shelf life thanks to the X-ray technology

Evan XU
IBA in a nutshell

- Based in Belgium, listed on Euronext Brussels
- Focused on particle accelerators
- >400 accelerators worldwide
- 2017 sales of ~€300 million
- 1,500 people worldwide, 40 nationalities
- 15 offices on 3 continents
IBA Main Activities
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Proton Therapy
- Cancer treatment
- The Gulf International Cancer Centre, Abu Dhabi

Dosimetry
- Patient and machine QA

RadioPharma
- Cancer diagnostic

Industrial
- Industrial applications
Industrial Particle Accelerators

Atom

Particle Accelerators

Product (and patients)

protons

electrons

Proton or electron acceleration

5
IBA Industrial - Installed Base

- AM: 16% (36 Rhodotron)
- EMEA: 36% (29 Dynamitron)
- APAC: 47% (12%)

Total Installed Base: 59%
Irradiation applications

- Sterilization
- Crosslinking
- Food
- Gemstones
- Cargo Screening
- Mail Sanitization
- Semiconductor Doping
- Sterile Insect Technique

Irradiation applications include sterilization, crosslinking, food irradiation, gemstones, cargo screening, mail sanitization, semiconductor doping, and the sterile insect technique.
Food Irradiation
Food products: opportunities and challenges
Food irradiation is not new

1953 The U.S. Army develops starts irradiating fruits, vegetables, dairy products, fish and meats
1961 Canada approves the irradiation of potatoes
1964 The U.S. FDA approves the irradiation of potatoes, wheat and flour
1970 The NASA adopts irradiation to sterilize meat for astronauts to eat while in space
1983 Canada and the U.S. approve irradiation of spices
1983 Codex Alimentarius adopts a standard for the application of irradiation to food
1986 The U.S. approves the irradiation of fruits and vegetables up to 1kGy
1988 The FAO, WHO, IAEA, ITC and WTO adopt an international food irradiation trade agreement.
1990 The U.S. FDA approves the irradiation of poultry
1993 The American Medical Association (AMA) endorses food irradiation
1997 The U.S. FDA approves the irradiation of meat products
2000 Omaha Steaks starts irradiating all ground beef products
2005 The U.S. FDA approves irradiation of live mollusks
2007 First legal shipment of Indian mangoes to U.S
2008 U.S. FDA approves irradiation of spinach and leafy greens for pathogen reduction
Food irradiation applications

1. Decontamination

2. Disinfestation

3. Extension of shelf life

4. Inhibition of sprouting
1. Decontamination

- Problem: often heavily contaminated by micro-organisms

Solution: Irradiation

* Cold process (Flavor & Aroma)
* No residue (Safety, Environment, Regulations)
* Widely approved
* High dose
1. Decontamination

5 common food-borne bacteria you’d like to avoid!

- E. Coli, Salmonella enteritis, Campylobacter, Listeria monocytogene, Clostridium botulinum...

- Can be found in:
  - Vegetables
  - Poultry
  - Fish & seafood
  - Meat
2. Disinfestation

Grains, pulses, cereals, …
2. Disinfestation

- Main problem in preservation of grains, pulses, cereals, coffee beans, dry fruits, flowers, …etc is **insect** infestation
  - Beetles, moths, weevils, fruit flies, …

- Solution: **Irradiation**
  - High throughput
  - Cost effective
  - No residue (Safety, Environment, Regulations)
3. Extended Shelf-life

Control vs. Irradiated samples 41 days after storage at 0°C (32°F).
3. Extended Shelf-life

Fruits, vegetables, meat, poultry, fish and seafood

Spoilage micro-organisms (ex.: Pseudomonas, Botrytis,…)

- Example:
  - Papayas: from 15 days to 4 months
  - Strawberries: from 5 days to 3 weeks
  - Onions: from 30 days to 4 months
  - Garlic: from 3 months to 12 months
  - Rice: from 3-18 months to 4 years
4. Inhibition of Sprouting
4. Inhibition of Sprouting

- **Storage of onion bulbs, garlic, ginger, potatoes and other sprouting plant food over many months can be problematic.**
  - Refrigeration in subtropical and tropical regions: $$$
  - Chemical residues (inhibitors as Propham, Chloropropham, Maleic hydrazide, ...)

- **Solution:** Irradiation
  - Very low doses (0.10 kGy)
  - Allow storage at higher temperature (10-15°C)
  - Authorized and used for 40 years+ (Canada, Japan, China, India...)
Absorbed dose

Absorbed dose (in Gray) is the quantity of radiating energy absorbed per unit of mass of a specified product.

Typical dose ranges
- Phytosanitary Irradiation 100 – 400 Gy
- Pathogen Reduction (Meat and Poultry) 1 500 Gy
- Spice Sanitation 6 000 Gy
- Medical Device Sterilization 25 000 Gy
- Food Sterilization (NASA) 45 000 Gy

Dose limits vary per product
- Min dose depends on target resistance (insect, bacteria)
- Max dose depends on host product tolerance to radiation
**Clearance database:**


>>Refer to the Explanatory Notes and ** <<

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Effects of Radiation on living cells

➢ Product is exposed to a **controlled** amount of ionizing energy.

➢ Radiation damages DNA -> living cell will be **unable to reproduce**.
Benefits of Food Irradiation

- The **nutritional value** of the food is preserved (WHO)

- **Reduction of global food spoilage** (estimated at 25% of global production)

- Radiation is a **cold process**

- Number of Parasites can be reduced substantially

- Insects are eliminated

- **No chemicals harmful to human health and the environment**

- **Bulk and packed products** ready for consumers can be treated
Regulations

- More than **60 countries** authorize food irradiation
  - Authorized food varies widely per country

- **Labeling**
  - Irradiated foodstuff containing irradiated ingredient(s) must be labeled
Quoted Statement from Experts

Food Irradiation Update is published monthly by Ronald F. Eustice, a food quality & safety assurance consultant based in Tucson, Arizona. He can be reached at: reustice@gmail.com and at 612.202.1016

There is growing interest in using irradiation as a tool to improve the safety of seafood.

Bonamar® Corporation, a leading U.S. seafood company, has partnered with Gateway America to innovate food safety by launching the first nationally marketed line of ES (Extended Safety) crab meat products to the food industry.

IN THIS ISSUE

Featured Article: Florida crab supplier Bonamar moves westward with new partnership

MYTH of the MONTH: Talk is Cheap!

SAVE THE DATE: INTERNATIONAL IRRADIATION FORUM

Also in the News: ESTABLISHMENT OF MULTIPURPOSE IRRADIATION FACILITY IN TANZANIA

Also in the News: Vietnam Mangoes cleared for US market USA

Also in the News: Darwin, Australia Mangoes Reach USA

ADDITIONAL RESOURCES
Myth: Irradiation makes food radioactive!

Irradiation (gamma, e-beam, X-ray) **DOES NOT** make products radioactive.
Myths: Food irradiation replaces GMP

- Food irradiation is not the silver bullet

- Additional step to food safety

- It must be integrated

- It is always better if the bio burden is low
Myth: Irradiation is expensive!

- An irradiator is designed to work 24/7/365
- Additional cost from US$ 0.01/kg
- Go for the low dose!
- Cost of recall?
- Liability?
- Impact of brand?
- What if people got sick or died?
Myth: Irradiated food taste bad!

- Protein degradation may induce bad smell
- Fatty acids may affect the taste
- It's all about DOSE!
Myth: All foods should be irradiated!

- Other technologies may sometimes be more appropriate like heat
  - Example: Spinach
    - Consumed raw \( \square \) Irradiation
    - Heat for canned
The technologies
Irradiation Processing Comparison

**E-beam**
- E-Beam accelerator

**X-ray**
- E-Beam accelerator
- Electron -> X-Ray Converter
- X-rays

**Gamma**
- Gamma Rays
- Cobalt 60

Same technologies from a radiation point of view
# E-beam vs X-ray: key differences

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<tr>
<td><strong>Product Penetration</strong></td>
<td>Low</td>
<td>Very High</td>
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<tr>
<td><strong>Dose Uniformity Ratio</strong></td>
<td>Average</td>
<td>Excellent</td>
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<tr>
<td><strong>Dose Rate</strong></td>
<td>Very high</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Treatment Time</strong></td>
<td>Seconds</td>
<td>Hours</td>
</tr>
<tr>
<td><strong>Cost Efficiency</strong></td>
<td>Excellent</td>
<td>Good</td>
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Dedicated vs Combined Configurations

**Dedicated E-beam**
10 MeV Rhodotron Boxes

**Dedicated X-ray**
5 or 7 MeV eXelis Pallets

**Combined E-beam & X-ray**
Rhodotron DUO Boxes

10 MeV E-beam & 5 / 7 MeV X-ray
Example of a treatment facility
The new TT50 Rhodotron: Designed for food irradiation

- 5, 7 or 10 MeV
- E-beam or X-ray
- Economical Design
- Up to 20 kW
- Small footprint
- Transport and install frame
10 MeV E-beam for Food: Typical configurations

E-beam Bulk
A Typical dedicated X-ray Center

http://www.iba-sterilization.com
Why X-Rays?

- **Electrically powered**
  - No Cobalt, easier consumer acceptance

- **Flexibility**
  - Seasonal products
  - ON / OFF when needed
  - Power / Capacity « on Demand »

- **Pallet treatment**
  - Low product handling costs & damages

- **Excellent Dose Uniformity**
  - No overdosing

- **Short Treatment Time**
  - No refrigeration during treatment
5 MeV X-ray for Food: Typical configurations

**X-ray pallet**
- Separate entry and exit

**2 side irradiation**

**Rotating pallets**

**Typical performances**
- Power: 30 kW → 400 kW (@ 5 MeV)
- Throughput: ~270 kg/h/kW
- DUR: ~2.8 (full pallets)

*Optimized for throughput*

**Typical performances**
- Power: 30 kW → 400 kW (@ 5 MeV)
- Throughput: ~200 kg/h/kW
- DUR: ~1.6 (full pallets)

*Optimized for DUR*

Assumptions: 0.4 gr/cc, 5 MeV X-ray, 2m³ pallets, 1 level
Treatment configuration

Treatment Path: (Top view of a facility)
X-ray technology

**p X-Ray is the appropriate tool for Phytosanitary applications**
- Electricity Powered
- Flexible
- Pallet Treatment
- Excellent DUR
- Short Treatment Time

**p Treatment Configuration is influenced by :**
- Density range
- **DUR** (Dmin required, Dmax allowed)

**p X-Ray Costs are driven by :**
- Volume
- Seasonality
- **Electricity actual use**
- **Electricity Cost** (night/days rate, peak consumption)
Example of fruits with high irradiation tolerance

- Dragon fruit
- Apples
- Blueberries
- Cherries
- Guava
- Longan
- Grapes
- Pomegranates
- Lychees
- Mangoes
- Papaya
- Figs
- Pitaya
- Rambutan
- Peaches
Case study

Products:

- $\rho = 0.3 \text{ gr/cc} \Rightarrow \text{Mangoes}$
- $\rho = 0.5 \text{ gr/cc} \Rightarrow \text{Dates}$

Doses:

- $D = 400 \text{ Gy}$

Accelerator Power:

- $100 \text{ kW} \ (14.3 \text{ mA} @ 7 \text{ MeV})$

Mangoes: 29 MT/h
Dates: 33 MT/h

Price ~ € 10/MT
Economics: examples

- **Fruits:**
  - **Large scale X-ray unit**
  - **Investment:** US $6,000,000 to 8,000,000
  - **Capacity:** 300,000 MT/Y
  - **Dose:** 500 Gy (Phytosanitary & Extended shelf-life)
  - **Cost:** US $3 to 5 per MT

- **Potatoes/Onions**
  - **Medium size X-ray unit**
  - **Investment:** US $4,000,000 to 6,000,000
  - **Capacity:** 350,000 MT/Y
  - **Dose:** 100 Gy
  - **Cost:** US $2 to 4 per MT
Conclusions

- Food irradiation is a **cold treatment process** for applications such as:
  - Phytosanitary
  - Sanitary
  - Shelf life extension

- Food irradiation has been used since the 60’s

- FDA, FAO, WHO, IAEA, ITC and WTO approve food irradiation

- E-beam and X-ray technologies are the **ideal alternative to radioactive sources**
Thank you!

Evan Xu

evan.xu@iba-group.com