

FOOD IRRADIATION – *OPPORTUNITIES AND CHALLENGES*

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- ² Department of Food Science and Technology, Faculty of Agricultural Engineering and Technology, Bogor Agricultural University, and
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ABSTRACT

Food irradiation is a controlled exposure of food to ionizing radiation, capable of inactivating microorganisms without significantly impacting the quality aspect of foods. Food irradiation may potentially (i) reduce or eliminate microbial contamination problems and (ii) reduce food waste due to spoilage and deterioration. It has been reported that about 40 countries worldwide have applied food irradiation as a mean of controlling contamination and prolonging the freshness of foods. Consequently, food irradiation technology has a big potential in improving food security and at the same time may facilitate the economic development through international trade. To take advantage of the potential of food irradiation; overcoming challenges of infrastructure along with technical expertise limitations and the lack of private sector participation are necessary. Food safety and food security are complex problems which involve many stakeholders as well as many countries; therefore international networking and partnerships are considered essential.



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Radiation?

The Electromagnetic Spectrum

- Electromagnetic wave $\rightarrow f = c/\lambda$

where

c = speed of light (3×10^{10} cm/sec, at vacuum).

f = frequency (sec^{-1})

λ = Wave length (cm)

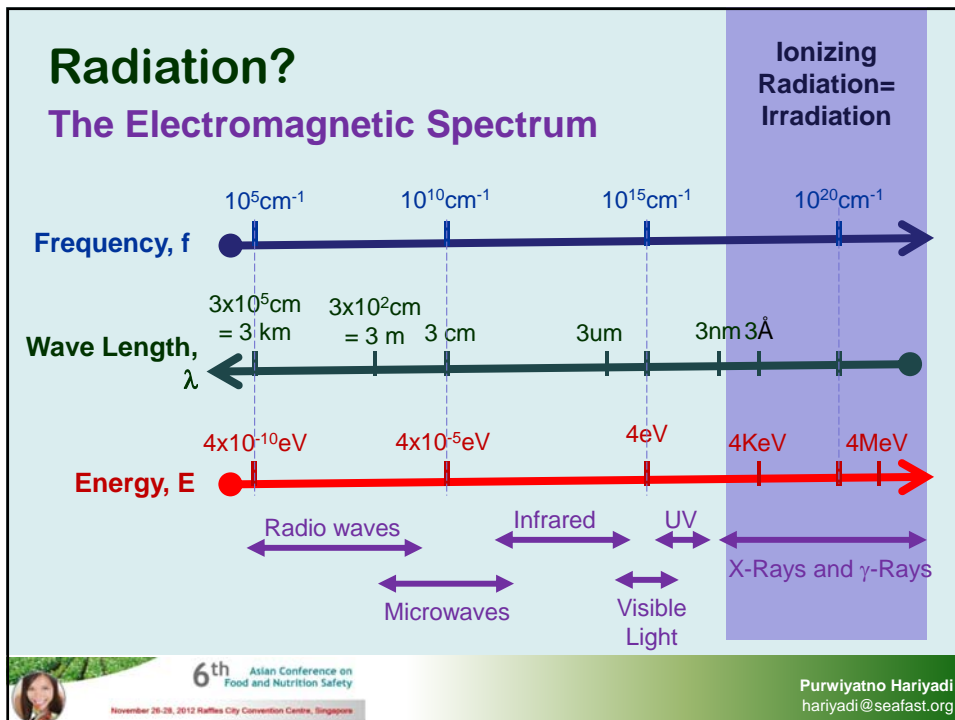
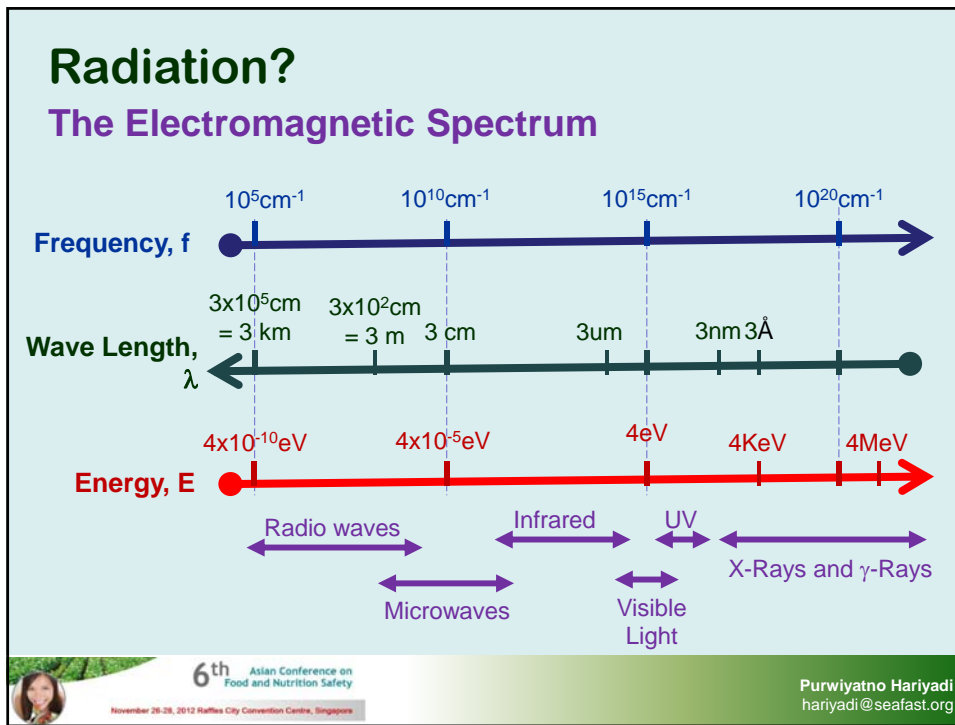
- **Energy (E) = hf**
h = Plank's Constant (6.626×10^{-27} ergs sec)



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Food irradiation

Sources of Irradiation

- Cobalt 60 - 1.33 MeV
- Cesium 137 - 662 keV
- Electron accelerators operated at 10 MeV or less
- X-ray generators operated at 7.5 MeV or less

Ionizing Radiation= Irradiation

Energy, E

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Food irradiation

Dose of Irradiation

Irradiation doses are measured in gray (Gy)

- Absorbed dose [Gy] = joule/kg absorbed energy
 - Applied dose = energy source x time exposed
 - Absorbed dose = f(applied dose and other factors), determined by dosimetry

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Food irradiation

Significant Dates in Food Irradiation History

- ✓ 1895 – First paper published, on idea of irradiating food
- ✓ 1920 – Discovery that irradiation could be used to preserve food
- ✓ 1957 – First commercial use to kill insects and insect eggs in spices in Germany
- ✓ 1963 – Approved to eliminate insect infestation for wheat and wheat flour
- ✓ 1964 – Approved to prevent sprouting in potatoes
- ✓ 1970s – NASA uses irradiated food for astronauts



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Food irradiation

A variety of foods have been approved for irradiation

- ✓ 1983 – Approved for herbs, spices, and seasonings
- ✓ 1985 – Approved to control trichinella spiralis in pork
- ✓ 1986 – Approved to control insects and maturation of fruits and vegetables
- ✓ 1990 – Approved by FDA to control bacteria in poultry (approved by USDA in 1992)
- ✓ 1997 – Approved by FDA to control microorganisms for red meats (approved by USDA in 2000)



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Food irradiation

- Food irradiation is a controlled exposure of food to ionizing radiation, capable of inactivating targeted microorganisms, pest, parasites, or to preserve its freshness, without significantly impacting the quality aspect of foods
- Research worldwide over the past 50 years has shown that irradiation can :
 - Potentially (i) reduce or eliminate microbial contamination problems and (ii) reduce food waste due to spoilage and deterioration.
 - Re-emerging as a non-thermal processing alternative



Food irradiation

1979, Recommended International Code of Practice for the Operation of Irradiation Facilities Used for the Treatment of Food - CAC/RCP 19-1979 (Rev. 1-1983) 1)

CAC/RCP 19

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RECOMMENDED INTERNATIONAL CODE OF PRACTICE FOR THE OPERATION OF IRRADIATION FACILITIES USED FOR THE TREATMENT OF FOODS

CAC/RCP 19-1979 (Rev. 1-1983) ¹

1. INTRODUCTION

This Code refers to the operation of irradiation facilities based on the use of either a radionuclide source (⁶⁰Co or ¹³⁷Cs) or X-rays and electrons generated from machine sources. The irradiation facility may be of two designs, either "continuous" or "batch" type. Control of the food irradiation process in all types of facility involves the use of accepted methods of measuring the absorbed radiation dose and of the monitoring of the physical parameters of the process. The operation of these facilities for the irradiation of food must comply with the Codex recommendations on food hygiene.

2. IRRADIATION PLANTS

2.1 Parameters

For all types of facility the doses absorbed by the product depend on the radiation parameter, the dwell time or



Food irradiation

1979, Recommended International Code of Practice for the Operation of Irradiation Facilities Used for the Treatment of Food - CAC/RCP 19-1979 (Rev. 1-1983) 1)

CAC/RCP 19

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- Introduction
- Irradiation plants
- Good radiation processing plants
- Product and inventory control
- Appendix A (dosimetry)
- Appendix B (EXAMPLES)



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Food irradiation

1983, international standard for food irradiation was accepted (CODEX STAN 106-1983, REV.1-2003)

General standard for Irradiated Foods

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GENERAL STANDARD FOR IRRADIATED FOODS

CODEX STAN 106-1983, REV.1-2003

1. SCOPE

This standard applies to foods processed by ionizing radiation that is used in conjunction with applicable hygienic codes, food standards and transportation codes. It does not apply to foods exposed to doses imparted by measuring instruments used for inspection purposes.

2. GENERAL REQUIREMENTS FOR THE PROCESS

2.1 Radiation Sources

The following types of ionizing radiation may be used:

- a) Gamma rays from the radionuclides ^{60}Co or ^{137}Cs ;
- b) X-rays generated from machine sources operated at or below an energy level of 5 MeV;
- c) Electrons generated from machine sources operated at or below an energy level of 10 MeV.



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Food irradiation

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General standard for Irradiated Foods Page 1 of 3

- Scope
- General requirements for the process
- Hygiene of irradiated foods
- Technological requirements
- Re-Irradiation
- Labelling



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Food irradiation

2003, Guidelines for the Use of Irradiation as a Phytosanitary Measure

INTERNATIONAL STANDARDS FOR PHYTOSANITARY MEASURES


GUIDELINES FOR THE USE OF IRRADIATION AS A PHYTOSANITARY MEASURE

ISPM No. 18



International standards for phytosanitary measures (ISPM) No 18 (2003)

1. Authority
2. Treatment Objective
3. Treatment
4. Dosimetry
5. Approval of Facilities
6. Phytosanitary System Integrity
7. Documentation by the Treatment Facility
8. Inspection and Phytosanitary Certification by the NPPO (*National Plant Protection Organization*)
9. Research



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Food irradiation

About 40 countries have approved food irradiation on over 50 different foods → Annually, estimated 500,000 tons of food are irradiated.



Countries which apply food irradiation for commercial purposes
 Do not yet apply food irradiation



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Food irradiation

Opportunities:

- Improving food security, and
- Facilitating the economic development through international trade.



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World Food Summit of 1996:

Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.

Aspects of Food Security

Food availability

- Quantity
- Safety
- Quality

Accessibility

- Physical & economic accessibility
- Compliance to preferences
- Compliance to culture & religion

Consumption sufficiency

- Intake sufficiency
- Quality of household food processing,
- Quality of sanitation & hygiene

Stability/ sustainability of food availability, accessibility and consumption

Active & Healthy life of Individual

Aspects of Food Security

.... First thing first

Food availability

- Food Irradiation potentially may improve food availability, thru the improvement of :
 - **Quantity**
 - **Safety**
 - **Quality**

- Compliance to culture & religion

Consumption sufficiency

- Intake sufficiency
- Quality of household food processing,
- Quality of sanitation & hygiene

Active
&
Healthy
life of
Individual

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Food Security - Food Quantity

.... Facts (1)

Food availability

- **Quantity**

International Fund for Agricultural Development

- Estimated 925 million hungry people in the world.
- The world population is expected to reach 9.1 billion by 2050.
- Food production will need to nearly double by 2050 in developing countries.
- About 40% world's arable land is degraded to some degree and will be further affected by climate change.

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Food Security - Food Quantity

.... Facts (1)

The Challenge: How to Double Global Food Production and Reduce Environmental Damage?



Image: Kevin Van Aelst
(<http://www.scientificamerican.com/article.cfm?id=can-we-feed-the-world>)

- Food production will need to nearly double by 2050 in developing countries.
- About 40% world's arable land is degraded to some degree and will be further affected by climate change.



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Food Security - Food Quantity

.... Facts (2)



Global Food Losses and Food Wastes, FAO, Rome, 2011

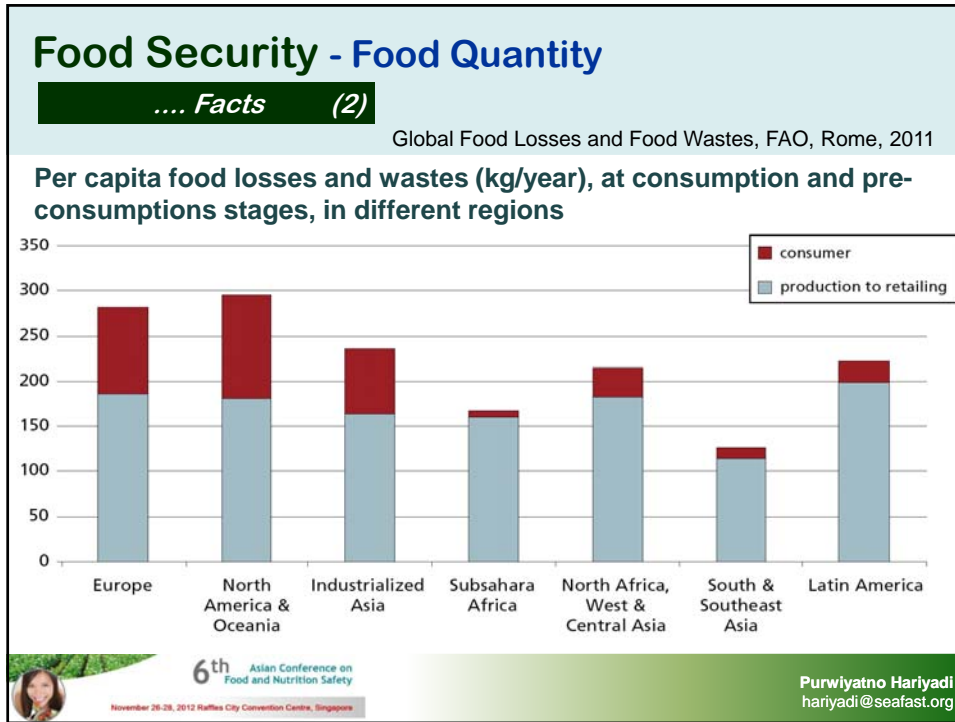
- Roughly one-third of food produced for human consumption is lost or wasted globally
→ about 1.3 billion tons/year.



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Food Security - Food Quantity

.... Facts (2)

Global Food Losses and Food Wastes, FAO, Rome, 2011

Total food losses/wastes	<ul style="list-style-type: none"> Europe and North-America = 280-300 kg/year Sub-Saharan Africa and South/Southeast Asia = 120-170 kg/year.
Characteristics of food losses/food wastes	<ul style="list-style-type: none"> Industrialized countries: more than 40% of the food losses occur at retail & consumer levels. Developing countries: more than 40% of the food losses occur at post harvest and processing levels

! Food waste at consumer level in industrialized countries (222 million ton) is almost as high as the total food production in sub-Saharan Africa (230 million ton).

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Food Security - Food Quantity & Food Irradiation?

.... Opportunity (1a)

Increase food availability
(due to decreased food losses and food wastes)

Characteristics of food losses/ food wastes

- Industrialized countries: more than 40% of the food losses occur at retail & consumer levels.
- Developing countries: more than 40% of the food losses occur at post harvest and processing levels

Application of Food irradiation to decrease the food losses
(due to insect infestation, food borne pathogens, and spoilage).

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Food Security - Food Quantity & Food Irradiation?

.... Opportunity (1b)

Inhibition of sprouting of stored tubers, roots and bulbs 0.05-0.15 kGy

Application of Food irradiation to decrease the food losses and Its recommended dose ranges (EFSA, 2011).

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Food Security - Food Quantity & Food Irradiation?

.... Opportunity (1b)

Inhibition of sprouting of stored tubers, roots and bulbs 0.05-0.15 kGy

Prevention of post-harvest losses by destruction of insects in stored cereals, fresh and dried fruits, nuts, oilseeds and pulses, or phytosanitary (quarantine) treatment for insect pests infesting fresh fruits and vegetables 0.15- 1 kGy

Application of Food irradiation to decrease the food losses and Its recommended dose ranges (EFSA, 2011).



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Food Security - Food Quantity & Food Irradiation?

.... Opportunity (1c)

Delay of ripening of fruits 0.2-1 kGy

Shelf-life extension of fruit and vegetables, meat, poultry, fish and ready meals by reduction of micro-organisms that cause spoilage 0.5-3 kGy

Application of Food irradiation to decrease the food losses and Its recommended dose ranges (EFSA, 2011).



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Food Security - Food Safety

.... Facts (3)

Food safety have become increasingly important globally

1. → protecting the health of the consumer.
2. → meeting requirements for international trade.
 - This is especially important for many developing countries that export foods to the major trading blocks of the developed world, or that have the potential to do so.



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Food Security - Food Safety

.... Facts (3)

Food safety have become increasingly important globally

1. → protecting the health of the consumer.
 - Food borne diseases are caused by various microorganisms: parasites, bacteria, and viruses.
 - The global incidence of foodborne disease (WHO, 2005) : 1.8 million people died from diarrhoeal diseases.



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Food Security - Food Safety

.... Facts (3)

Food safety have become increasingly important globally

1. → protecting the health of the consumer.
 - CDC (2011) estimates that each year roughly 1 in 6 Americans (or 48 million people) gets sick, 128,000 are hospitalized, and 3,000 die of food borne diseases.



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Food Security - Food Safety

.... Facts (3)

Food safety have become increasingly important globally

1. → protecting the health of the consumer
 - economic burden
 - USA (1997), diseases caused by the major pathogens alone are estimated to cost up to US \$35 billion annually in medical costs and lost productivity.
 - The re-emergence of cholera in Peru in 1991 resulted in the loss of US \$500 million in fish and fishery product exports that year.



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Food Security - Food Safety

.... Facts (4)

Food safety have become increasingly important globally

2. → meeting requirements for international trade.

World trade of agricultural products
(Brodeser, J, FAO)

Category	Percentage	Value
Other products	91%	-
Agricultural products	9%	560 US\$ Billions

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Food Security - Food Safety

.... Facts (4)

2. → meeting requirements for international trade.

Percentage increase per year of world trade & production by main product groups

Already ~ 40% of all trade in food, agriculture, fisheries occurs between developing & developed countries.
(World Integrated Trade Solution Database
(<http://wits.worldbank.org/wits/gptad.html>))

Product Group	Export rate (%)	Production rate (%)
Total merchandise	~12	~5
Industry products	~1	~4
Agricultural products	~8	~1
Manufactures	~15	~6

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Food Security - Food Safety

.... Facts (4)

2. → meeting requirements for international trade.

Meeting Standards, Winning Markets

Trade Standards Compliance **2010**



**Meeting Standards, Winning Markets:
Trade Standards Compliance (2010)**

- Norwegian Agency for Development Cooperation and
- United Nations Industrial Development Organization (UNIDO)

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Food Security - Food Safety

.... Facts (4)

2. → meeting requirements for international trade.

Table 3. Number of EU rejections of food and feed products from Third Countries, 2002-2008

Country	Year							Total	Annual Average
	2002	2003	2004	2005	2006	2007	2008		
Iran	63	492	491	470	243	130	172	2,061	294.4
China	149	133	158	253	262	354	498	1,807	258.1
Turkey	141	200	180	198	250	294	302	1,565	223.6
India	60	119	110	137	86	111	157	780	111.4
United States	25	53	52	74	231	184	144	763	109.0
Thailand	143	85	45	117	85	92	103	670	95.7
Brazil	102	116	109	124	91	58	61	661	94.4
Vietnam	67	35	56	124	68	44	55	449	64.1
Argentina	11	42	46	57	75	47	58	336	48.0
Indonesia	39	36	70	58	43	25	14	285	40.7
Ghana	1	8	78	59	44	31	23	244	34.9
Egypt	9	40	33	24	30	35	48	219	31.3
Nigeria	1	7	15	30	28	49	25	155	22.1

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Food Security - Food Safety

.... Facts (4)

2. → meeting requirements for international trade.

Table 4. Number of US rejections of food products, 2002-2008

Country	Year							Total	Annual Average
	2002	2003	2004	2005	2006	2007	2008		
Mexico	1,804	1,502	1,581	1,735	1,477	1,270	1,066	11,926	1490.7
India	746	725	871	1,026	1,132	1,113	707	7,223	902.9
China	541	667	616	672	664	740	479	5,005	625.6
United Kingdom	377	288	325	245	369	430	1,262	3,767	470.9
Dominican Republic	263	266	535	415	663	512	77	3,121	390.1
Canada	414	543	551	284	246	238	361	3,014	376.7
Vietnam	428	332	478	350	300	378	306	2,939	367.4
Japan	755	241	192	147	285	203	319	2,448	306
Indonesia	138	269	331	214	313	374	250	2,159	269.9
Thailand	280	258	351	307	216	233	212	2,122	265.3
France	461	365	345	223	159	155	113	2,081	260.1
South Korea	297	344	285	205	112	166	287	1,938	242.3
Philippines	203	456	248	214	135	244	168	1,906	238.3



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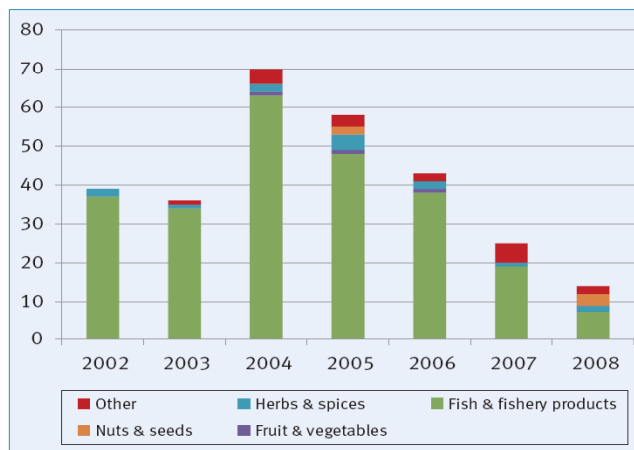
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Food Security - Food Safety

.... Facts (4)

2. → meeting requirements for international trade.

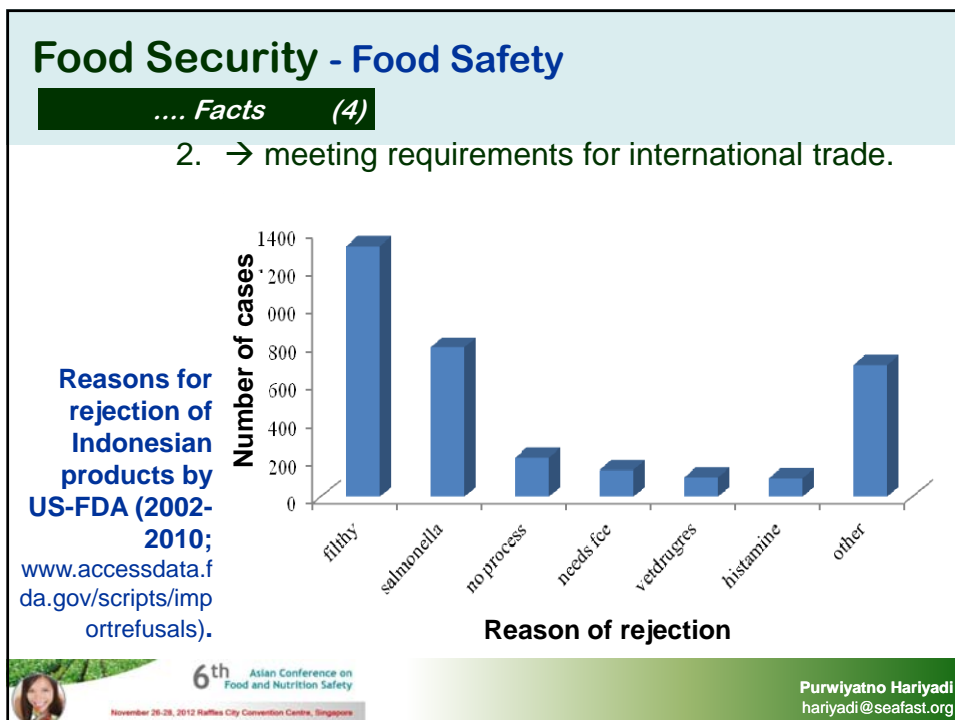
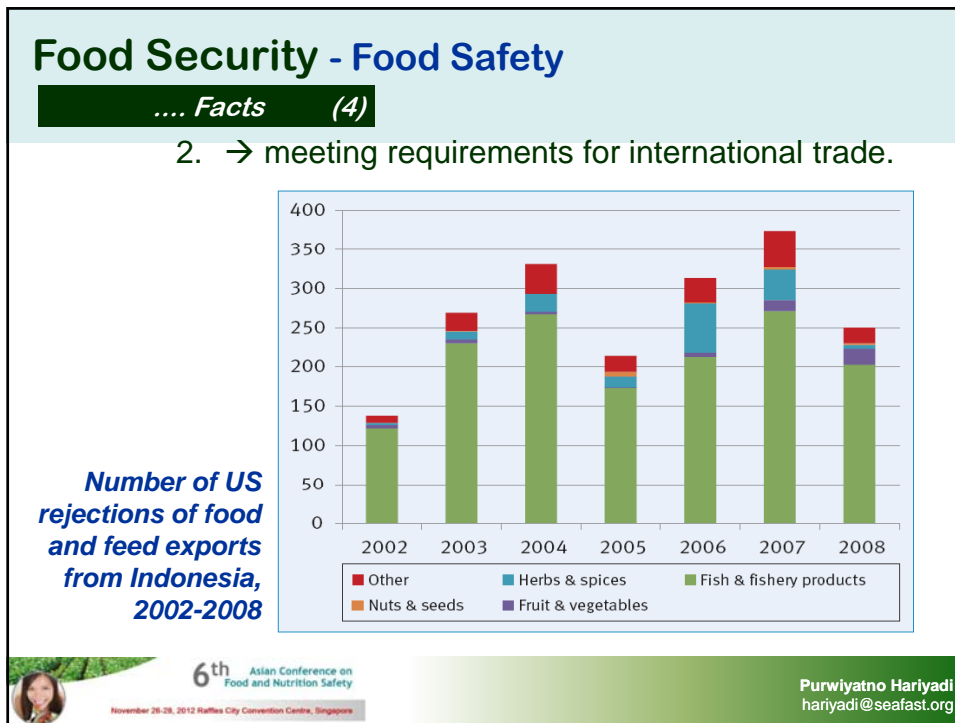
Number of EU rejections of food and feed exports from Indonesia, 2002-2008



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Food Security - Food Safety

.... Facts (4)

2. → meeting requirements for international trade.
 → Economic losses for developing countries

Value of EU rejections of fish and fishery products, 2004-2008 (US\$ million)

Country	2004	2005	2006	2007	2008	Total
Indonesia	0.9	0.4	1.9	0.8	8.1	12.0
Australia	0.0	0.7	10.7	0.3	0.0	11.7
Vietnam	1.0	3.3	1.8	0.6	0.6	7.3
China	0.4	0.9	0.9	1.9	1.3	5.3
India	0.6	1.1	1.1	0.8	1.4	5.1
Bangladesh	0.4	0.3	1.4	0.5	0.8	3.4
Russia	2.0	0.8	0.1	0.1	0.0	2.9
Greenland	0.0	0.0	0.1	0.0	2.0	2.1
Other	4.9	4.1	4.9	6.2	2.3	22.5
Total	10.3	11.6	23.3	11.6	17.4	74.3



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Food Security - Food Safety

.... Facts (4)

2. → meeting requirements for international trade.
 → Economic losses for developing countries

Value of US rejections of fish and fishery products, 2004-2008 (US\$ million)

Country	2004	2005	2006	2007	2008	Total
China	3.5	6.9	21.5	13.2	7.9	53.0
Vietnam	12.0	9.7	6.7	8.3	6.1	42.8
Indonesia	7.2	6.3	5.8	6.3	5.6	31.2
Bangladesh	6.3	3.8	1.0	0.8	1.9	13.8
India	3.5	3.8	2.0	1.8	0.5	11.6
Thailand	2.3	2.6	1.7	2.5	1.6	10.7
Honduras	0.0	7.9	0.2	0.0	0.1	8.2
Taiwan	1.9	1.3	0.9	1.6	2.0	7.7
Philippines	2.2	1.3	0.6	1.7	1.2	7.0
Mexico	1.7	1.2	1.0	0.6	0.7	5.2



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Food Security - Food Safety & Food Irradiation?

.... Opportunity (2c)

Inactivation/destruction of various food-borne parasites 0.3-6 kGy

Prevention of food-borne illness by destruction of non-sporeforming pathogenic bacteria (e.g. *Salmonella*, *Campylobacter*, *Listeria*) in fresh or frozen foods 3-7 kGy

Application of Food irradiation to decrease the food losses and Its recommended dose ranges (EFSA, 2011).



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Food Security - Food Safety & Food Irradiation?

.... Opportunity (2b)

Reduction in viable counts of microorganisms in spices and other dry ingredients to minimize contamination of food to which the ingredients are added 5-10 kGy

Production of microbiologically shelf-stable, vacuum-packaged meat, poultry and ready-to-eat meals by heat-inactivating of their tissue-enzymes and sterilizing them by irradiation in deep-frozen state up to 50 kGy

Application of Food irradiation to decrease the food losses and Its recommended dose ranges (EFSA, 2011).



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Food Security - Food Safety & Food Irradiation?

.... *Opportunity (2c)*



Food Irradiation may be used as a Sanitary and Phyto-sanitary control measures to protect against pests and diseases and to provide safe food



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November 26-28, 2012 Raffles City Convention Centre, Singapore

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Food Security - Food Quality

.... *Opportunity (3)*

- Irradiation at 10, 20 and 30 kGy has been shown to improve functionality of soy protein (improve solubility, emulsification activity, foam stability) and improve yield for protein isolate [Pednekar *et al.* 2010]
- Irradiation at 2,5-10 kGy destroy anti nutritive agent (trypsin inhibitor, phytic acid) of *Phaseolus vulgaris* bean [Al-Kaisey *et al.* 2003]



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Food Security - Food Quality

.... Opportunity (3)

- Irradiation at 10 kGy is more effective to reduce phytic acid of Sorghum as compared with cooking treatment [Duodu *et al.* 1999]
- Irradiation at 5-10 kGy reduced phytic acid at several bean (*pea, cowpea, lentil, kidney bean, dan chickpea*) [El-Niely 2007].



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CONCLUSIONS

Food Irradiation – the Opportunities

FOOD IRRADIATION technology has a big potential in improving **FOOD SECURITY**

- Reduce food losses and food wastes
- Improve food safety → improve public health
- (potentially) Improve food quality and
- at the same time may facilitate the economic development through international trade.



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CONCLUSIONS

Food Irradiation – the Challenges

Food irradiation is one of the most extensively studied technology → but it is still relatively underutilized to address the global food security & food safety problem.

- The challenges is to develop better communication/education
→ risk/benefit analysis and communication



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CONCLUSIONS

Food Irradiation – the Challenges

With the emergence of “international trade”, strengthening global food security/food safety system is a shared responsibility.

- **The Challenge is to establish stronger partnership.**
 - Using approach of “form **farm** to **fork**”, international community have to remember that **farm** (may be in country A) and **fork** (may be in country B, C).
 - Food Irradiation? → Partnership is needed to overcome problem of (i) lack of irradiation infrastructure, (ii) limited technical expertise, and (iii) lack of private sector participation



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CONCLUSIONS

Food Irradiation – the Challenges

With the emergence of “international trade”, strengthening global food security/food safety system is a shared responsibility.

.....
Meaning that

Mutual partnership in food irradiation development -between **producing country** and **consuming country**- is **essential** in strengthening global food security/food safety.



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Thank You



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