Canadian Food Inspection Agency | Agence canadienne d'inspection des aliments

Food Import Risk Analysis: The Canadian Experience

Food Import Risk Explorer (FIRE)

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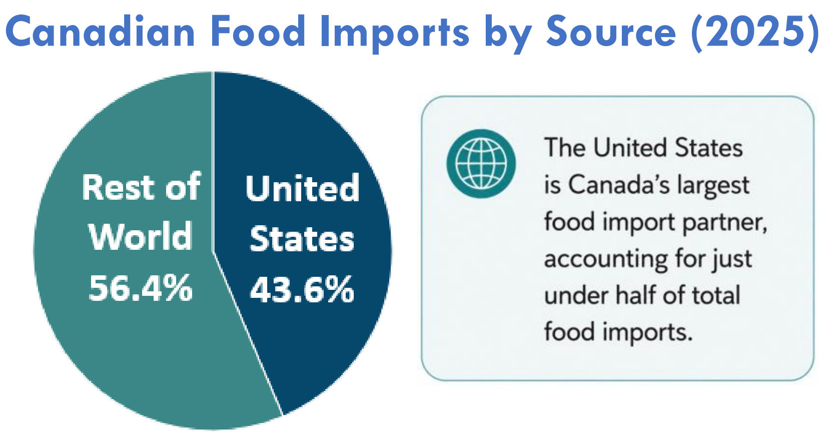
Canada

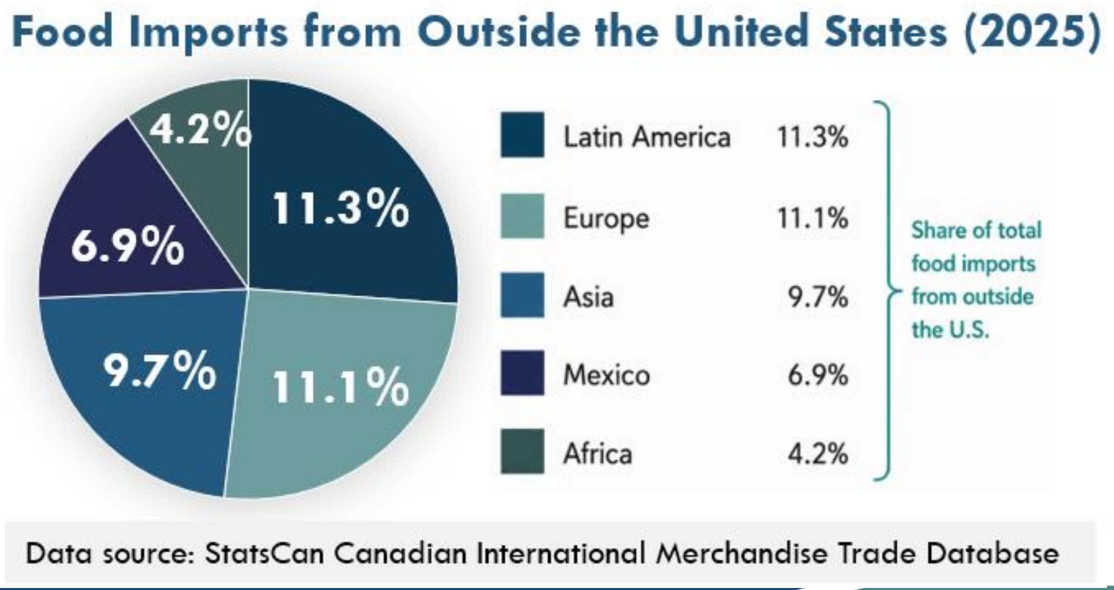
Canadian Food Import Context

Canada is one of the world's largest food importers
In 2025, Canada imported $69.4 billion in agri-food and seafood products from over 220 trading partners.



Canada imports food for a variety of reasons:

- ✓ Seasonal availability
- ✓ Cultural diversity
- ✓ Special events e.g. agricultural fairs
- ✓ Filling gaps in domestic production



What Tool to Use in Which Situation?

Goal:
Apply risk control measures at the most effective point in the import process

→

Import program design and prioritization

Based on a range of inputs:

- **Risk and impact**
- **Operational data**
- **Risk intelligence**
- **Available resources**

→

Dynamic, responsive, flexible risk-informend system

The Challenge

Enhance the ability of CFIA's Food program to systematically identify and prioritize risks related to imported food

- Rigour and transparency to enhance accountability
- Direct resources to where they will be most efficient and effective at mitigating risks

FIRE – the Business Solution

An innovative model that **estimates imported food safety risks in Disability Adjusted Life Years (DALYs)** at the **food-hazard-country of origin** (F/H/COO) level

FIRE allows us to:

- **Better understand the risk landscape** with respect to imported foods
- **Compare relative risks** across different:
  - food-microbial hazard-COO combinations (current model)
  - hazard types: microbiological, chemical, allergens (future)
- **Monitor & forecast** the trends in imported food risks over time
- **Prioritize risks** to be analyzed to inform program design and work plans

How FIRE supports risk-informed oversight

Food Import Risk Explorer (FIRE)

Risk ranking by Food-Hazard-Country

- Inform and prioritize PrMF topics for future program reviews
- Provide comprehensive analyses to support program reviews

- Inform offshore workplans
- Confirm commodities in scope of offshore audits
- Targeted PCIs at importers
- Inform sampling plan design

FISHnet FIRE results help estimate risk of import shipments to recommend what to sample

FIRE estimates:

- Relative risks at F/H/COO
- New and emerging trends
- Forecasted changes in risk

Generating Intelligence about Risks

Program Management Framework

Control Measures

Reporting & Feedback Mechanism

ML/AI Enabled End-to-End Solution for FIRE

- In addition to it's core purpose, FIRE also serves as a data hub to access key **integrated** data related to imported food.
- To improve the timeliness of results, **large language models (ML/AI)** are applied to external data sources to classify foods and hazards into a common description.
- ML/AI models are trained on past data to generate Trend and forecast information

DATA SOURCE

- StatsCan CIMT
- FDA Recalls
- USDA FSIS Recalls
- FDA Import Refusals
- CDC Outbreaks
- RASFF
- LSTS
- IMS
- PHAC Outbreaks
- CBSA EDI-IID

EXTRACTION

Automated (via API request) or Semi-automated

TREND/FORECASTING MODELS

TRANSFORM

1. Pre-processing (*e.g.*, filtering, deduplicating)
2. **Machine Learning** classification (Large Language Model) for food and hazard names
3. Output into consistent structured format

RISK/AI Models

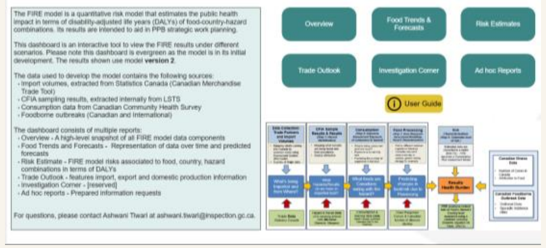
Examples:

- Food Import Risk Explorer (FIRE)
- FishNet
- Integrated Recall Intelligence System (IRIS)

REPORTING

- Descriptive Statistics
- Trend Analysis & Forecasting
- Comparative Analysis
- GenAI reports

FIRE Dashboard



Other Governmental Department (OGD) | International (external data) | CFIA CFIA-owned

Current Challenges & ML/AI Solutions

Challenge

Inconsistent classifications used in data sources
Unable to combine data to build models efficiently

- Type of Food is not captured consistently in different data sources
- Example: Enoki mushrooms

Recall data:

product_description
enoki mushroom;product of korea;net wt. 7.05 oz., (200 g)upc: 7 426852 625810the enoki is packaged in a clear
red clover 4 oz, red clover 2 lbs. products have red clover as an ingredient.
spring salad 6 oz. product contains red clover sprouts.
sprout salad 6 oz. product contains red clover sprouts.

Food import volume data:

commodity_description
BLACKOUT TRUFFLE APPLE SEEDS Other-Other
BROWN BEECH MUSHROOM
BROWN BEECH MUSHROOM 150g*40
ENOKI MUSHROOM
ENOKI MUSHROOM - CULTIVATED

Solution

Harmonize data sources
Classify text with Large Language Models (LLM) and transform into structured data

Fresh Enoki Mushroom

Fresh → State
Enoki → Type
Mushroom → Food product

common_name	brand_name	storage	consumption
TRESSÉ	CLIC		
MOUJADÉLÉ	CLIC		
RIVIERA	CLIC		
FROMAGE SULUGUNI CHEESE	BIO-LIFE	Refrigerated	Ready To Eat
NABULSI	CLIC	Refrigerated	Ready To Eat
QUESO PARILLA	DESCHAMPS	Refrigerated	Ready To Eat

tier1	tier2	tier3
Dairy	Cheese	Brined cheese - Pasteurized
Dairy	Cheese	Brined cheese - Pasteurized
Dairy	Cheese	Brined cheese - Pasteurized
Dairy	Cheese	Brined cheese - Pasteurized
Dairy	Cheese	Brined cheese - Pasteurized
Dairy	Cheese	Brined cheese - Pasteurized

Value added with ML/AI in FIRE model

FIRE: An innovative model that **estimates imported food safety risks** in Disability Adjusted Life Years (DALYs) at the **food-hazard-country of origin** (F/H/COO) level, to **compare and prioritize risks and analyse trends**

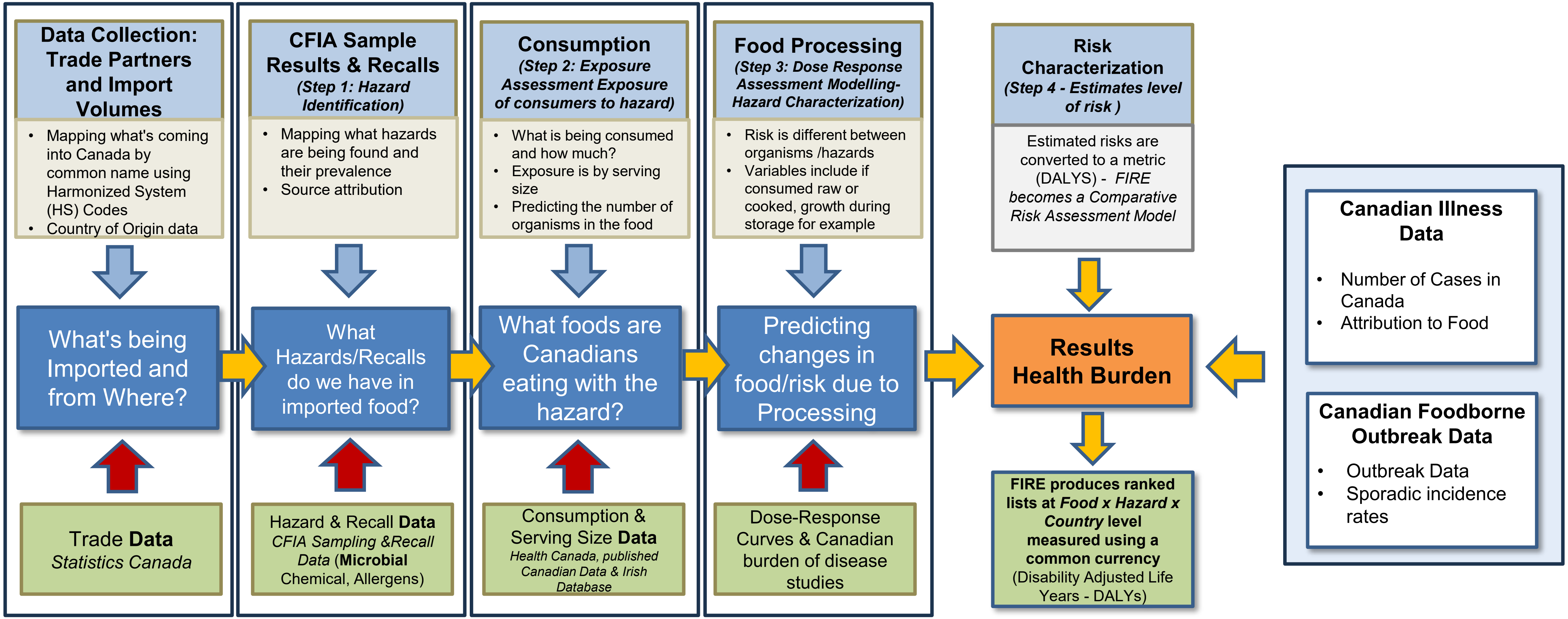
Previous approach:

- Data gathered **manually** from multiple sources
- Data structures **inconsistent and siloed** leading to challenges in interpretating results
- Assessments of perceived **risks were subjective**, based on experience and gut-feeling

FIRE approach:

- **One cleaned data repository** connected to PowerBI dashboard to visualize data, available to everyone
- **Seamless integration of datasets**, unlocking deeper insights through ML/AI models
- Objective **DALY-based risks** from a scientifically-defensible model

FIRE Building Blocks & Architecture



*EFSA Panel on Biological Hazards. (2015). Scientific Opinion on the development of a risk ranking toolbox for the EFSA BIOHAZ Panel. *Efsa Journal*, *13*(1), 3939.

Hybrid model*

Bottom-up → **DALYs** ← **Top-down**

FIRE Bottom-up Methodology

$$\boldsymbol{DALYs_{CFH} = \frac{Trade_{CF}}{SS_F} \times P(Exp)_{CFH} \times P(Ill|Exp)_{CFH} \times DALYs_H}$$

Where the output ($\boldsymbol{DALYs_{CFH}}$) is **Canadian DALYs** for a food-hazard-country of origin combination, and:

C, F, H - Country, food, and hazard respectively.

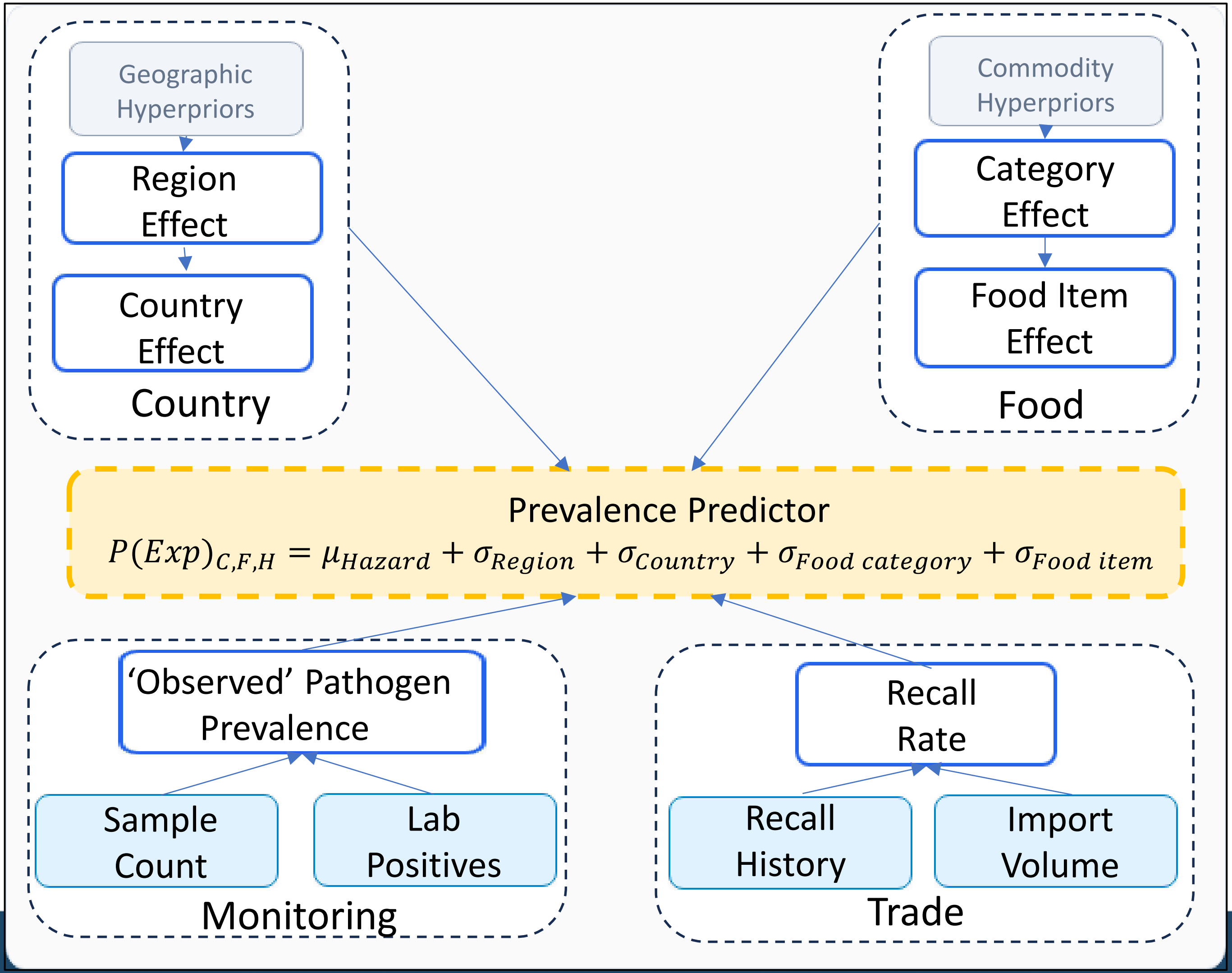
$\frac{Trade_{C,F}}{SS_F}$ - Number of servings of the specified food from the specified country.

$P(Exp)_{C,F,H}$ - Probability the food from the given country is contaminated with the hazard (i.e., prevalence).

$P(Ill|Exp)_{C,F,H}$ - Probability of a becoming ill after exposure to a contaminated serving (by country, food and hazard). This value is affected by dose (i.e. dose-response relationship), and incudes consideration of cooking and/or growth.

$DALYs_H$ - DALYs per case for the specified hazard.

Estimating Prevalence



- Prevalence is estimated using a Bayesian hierarchical model.
- Uses observed laboratory results and recall history.
- Adjusts estimates using similarities between regions, countries and foods.
- Improves estimates when observations are limited by using related data.
- For combinations lacking direct surveillance data, the model uses a tiered surrogacy sequence.

Bottom-up Example
Salmonella in Fresh Herbs from Country X

Step 1: Calculate the number of servings of imported food consumed.

$$\boldsymbol{DALYs_{CFH} = \underbrace{\frac{Trade_{CF}}{SS_F}} \times P(Exp)_{CFH} \times P(Ill|Exp)_{CFH} \times DALYs_H}$$

Amount of Fresh Herbs imported from Country X[1]:
$Trade_{CF}$ = 146,057 kg

Serving size of Fresh Herbs[2]:
$SS_F = 41\ \mathrm{g}$

[1] Data retrieved from Statistics Canada - Canadian International Merchandise Trade Database.
[2] Lyons, J (2013). *The Irish Food Portion Sizes Database.* Available at: https://www.iuna.net/

Bottom-up Example

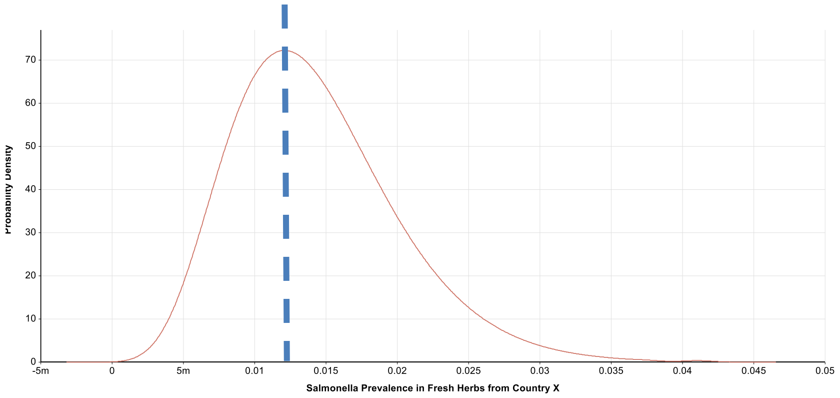
Salmonella in Fresh Herbs from Country X

Step 2: Calculate the probability that food from a given country is contaminated by the hazard.

$$DALYs_{CFH} = \frac{Trade_{CF}}{SS_F} \times P(Exp)_{CFH} \times P(Ill|Exp)_{CFH} \times DALYs_H$$

Uses the Bayesian hierarchical model

Taking the mean estimate (blue dashed line), the prevalence is about 1.43%



[1] Data from CFIA food surveillance programs.

Bottom-up Example

Salmonella in Fresh Herbs from Country X

Step 3: Calculate the probability that a person will become ill after exposure to the hazard.

$$\boxed{\boldsymbol{DALYs_{CFH} = \frac{Trade_{CF}}{SS_F} \times P(Exp)_{CFH} \times \underbrace{P(Ill|Exp)_{CFH}} \times DALYs_H}}$$

$$\begin{aligned} P(Ill|Exp)_{CFH} &= f_H(dose_{CFH}) \\ &= 1 - (1 + (dose_{CFH}/51.45))^{-0.1324} \\ &= 1 - \left(1 + \left(\frac{2.46\ CFU/serving}{51.45}\right)\right)^{-0.1324} \\ P(Ill|Exp)_{CFH} &= 0.0062 \end{aligned}$$

Where,

$$\begin{aligned} dose_{CFH} &= SS_F \times 10^{C_{CFH}+G_{FH}-LR_{FH}} \\ &= 41\ g \times 10^{\log(0.06\frac{CFU}{g})+0-0} \\ dose_{CFH} &= 2.46\ CFU/serving \end{aligned}$$

$f_H(d)$ - Hazard specific dose-response model dependent upon the ingested dose d
C_{CFH} - Concentration of hazard ($\log_{10}$) by country, food, hazard
G_{FH} - Growth of hazard ($\log_{10}$) by food and hazard; 0 for *Salmonella* on Fresh Herbs
LR_{FH} - Reductions in hazard concentration ($\log_{10}$) post sampling, and prior to consumption (e.g., cooking); 0 for Fresh Herbs

[1] World Health Organization. *Risk assessments of Salmonella in eggs and broiler chickens*. Vol. 2. Food & Agriculture Org., 2002.

Bottom-up Example
Salmonella in Fresh Herbs from Country X

Step 4: Multiply by the number of DALYs per case for the specified hazard

$$\boldsymbol{DALYs_{CFH}} = \frac{\boldsymbol{Trade_{CF}}}{\boldsymbol{SS_F}} \times \boldsymbol{P(Exp)_{CFH}} \times \boldsymbol{P(Ill|Exp)_{CFH}} \times \underbrace{\boldsymbol{DALYs_H}}$$

Number of DALYs per case of illness for *Salmonella* (non-typhoidal)[1]: 0.049

Table 4
Overall disease burden, disease burden per 100.000 inhabitants and mean disease burden per case of illness in the Netherlands, 2009.

Pathogen	DALY per year		DALY per 100,000 inhabitants		DALY per 1000 cases of illness	
Discount rate	0%	1.5%	0%	1.5%	0%	1.5%
Bacteria – infectious						
Campylobacter spp.	3250	2890	19.8	17.5	41	36
STEC O157	125	98	0.7	0.6	143	113
Salmonella spp.	1270	1100	7.7	6.7	49	41
Listeria monocytogenes (perinatal)	27	16	0.16	0.09	9190	5460
Listeria monocytogenes (acquired)	87	80	0.53	0.49	1140	1050
Listeria monocytogenes (total)	114	96	0.69	0.58	1450	1220
Bacteria-toxin-producing						
Bacillus cereus	112	112	0.7	0.7	2.3	2.3
Clostridium perfringens	536	531	3.3	3.2	3.2	3.2
Staphylococcus aureus	770	761	4.7	4.6	2.6	2.6
Viruses						
Norovirus	1480	1310	8.9	7.9	2.4	2.1
Rotavirus	1820	1630	11.0	9.9	4.9	4.4
Hepatitis A virus	142	123	0.86	0.75	167	145
Hepatitis E virus	24	20	0.15	0.12	460	380
Protozoa						
Cryptosporidium spp.	69	67	0.4	0.4	2.9	2.8
Giardia spp.	162	159	1.0	1.0	2.1	2.1
Toxoplasma gondii (congenital)	2270	1330	13.8	8.1	6360	3730
Toxoplasma gondii (acquired)	1350	1020	8.2	6.2	3170	2400
Toxoplasma gondii (total)	3620	2350	23.0	14.3	4610	2990

[1] Havelaar, Arie H., et al. "Disease burden of foodborne pathogens in the Netherlands, 2009." International journal of food microbiology 156.3 (2012): 231-238.

Bottom-up Example

Salmonella in Fresh Herbs from Country X

Putting it all together…

$$\boldsymbol{DALYs_{CFH} = \frac{Trade_{CF}}{SS_F} \times P(Exp)_{CFH} \times P(Ill|Exp)_{CFH} \times DALYs_H}$$

$$= \frac{146{,}057\ kg}{41\ g} \times 0.0143 \times 0.0062 \times 0.049 \frac{DALYs}{case}$$

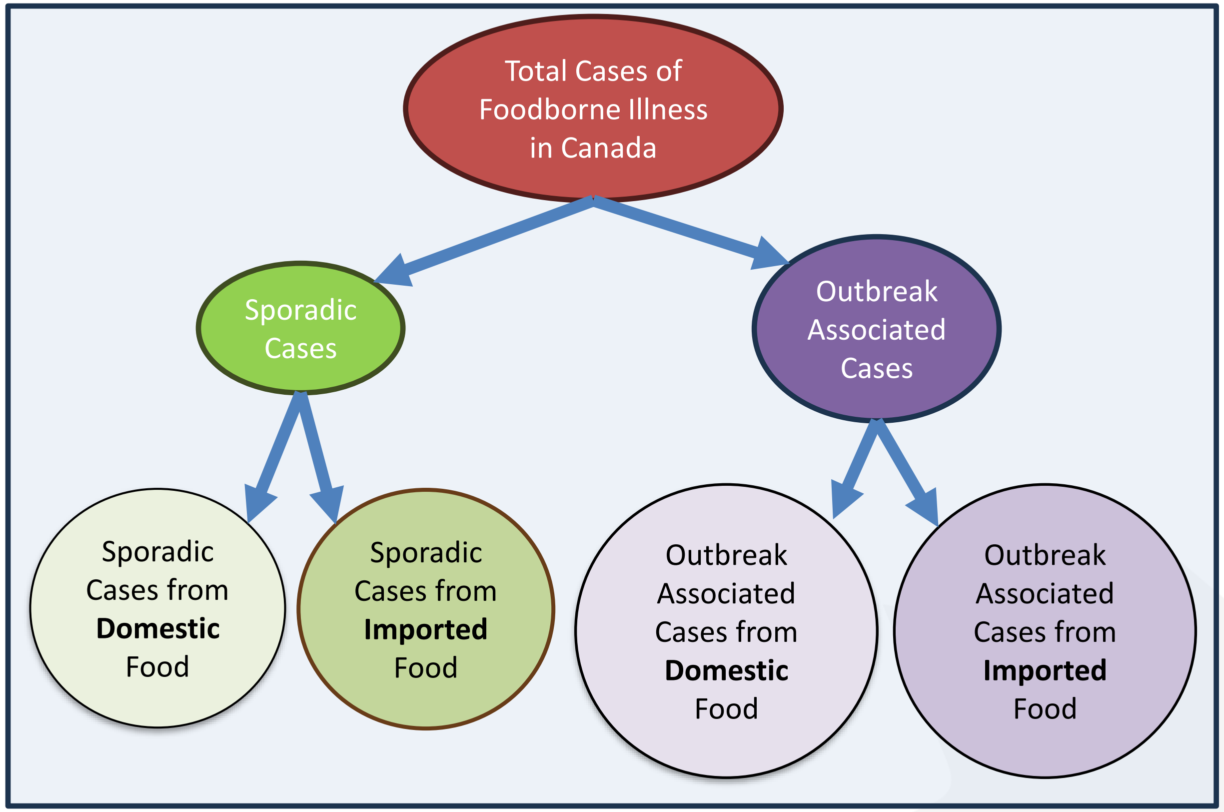
$$\boldsymbol{DALYs_{CFH} = 15\ DALYs}$$

Result is 15 DALYs for *Salmonella* in Fresh Herbs from Country X.

FIRE Top-down Methodology

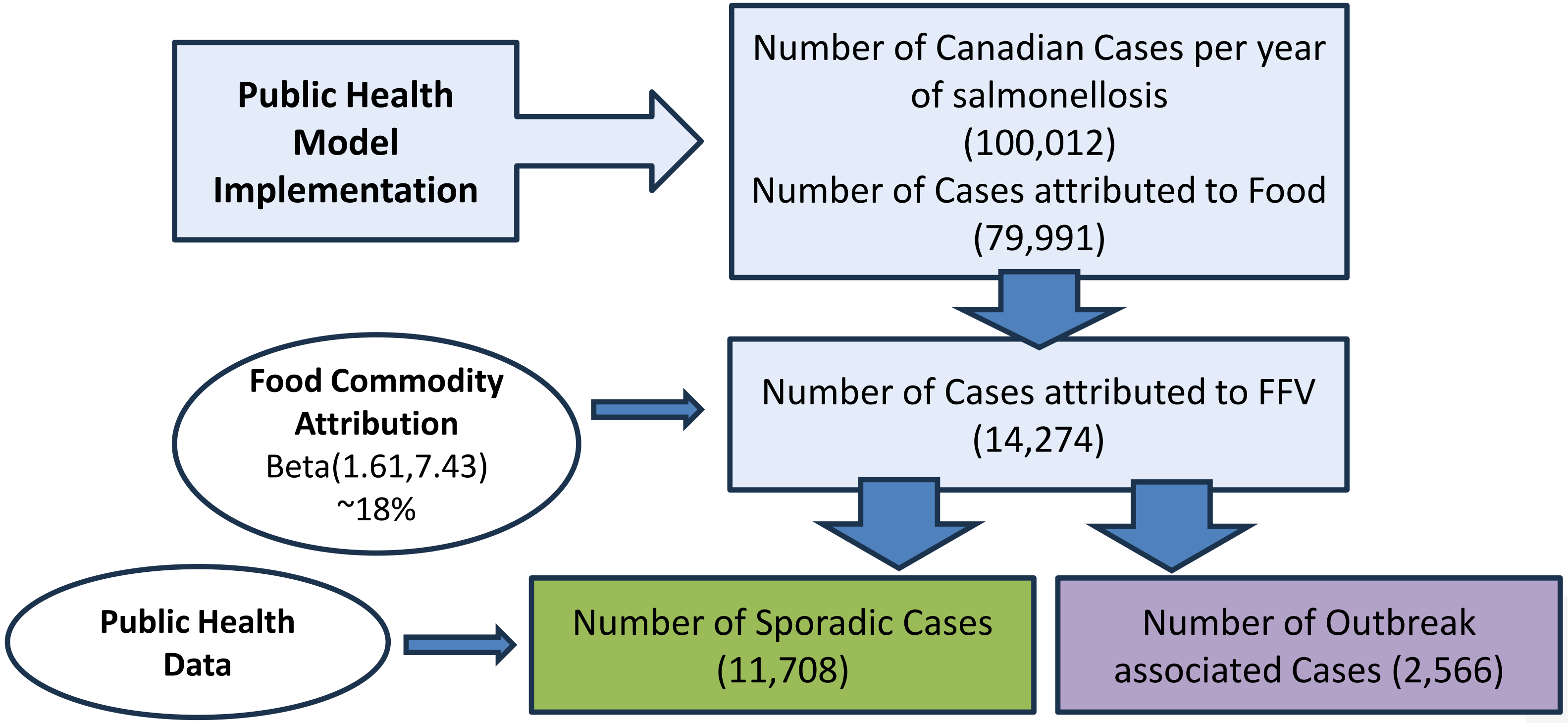
- Divides Canadian foodborne illness estimates into sporadic and outbreak-associated cases, then into those from foods of domestic and imported origin.

- Output from the Core FIRE model can then be used to attribute these illnesses to food-country pairs.



Top-down Example: *Salmonella* in Fresh Fruits and Vegetables

Step 1: Separation of Cases into Sporadic and Outbreak



Note: All examples are fictitious and do not reflect actual values.

Top-down Example: *Salmonella* in Fresh Fruits and Vegetables

Step 2a: Separation of Sporadic Cases into Domestic & Imported

Sporadic Cases
(11,708)

Number of Sporadic Cases attributed to FFV **Food Items**

Leeks Chives and Similar	0
Cantaloupe	2,828
Fresh Herbs	159
Mangoes Guava	4,885
Spinach	2,010
Peppers	1,825
Other Vegetables	1
Totals	11,708

Imported Cases
(10,531)

Import Trade/ Domestic Production Data

Domestic Cases
(1,177)

Number of Imported Cases by FFV Food and Country

	Brazil	Colombia	Costa Rica	Dominican Republic
Leeks Chives and Similar	0	0	0	0
Cantaloupe	139	13	61	35
Fresh Herbs	8	1	4	2
Mangoes Guava	294	28	128	74
Spinach	110	11	48	28
Peppers	85	8	37	21
Other Vegetables	0	0	0	0
Totals	636	61	278	160

Number of Domestic Cases by FFV Food Item

Leeks Chives and Similar	0.0284
Cantaloupe	416.2
Fresh Herbs	23.24
Mangoes Guava	0
Spinach	470.5
Peppers	266.7
Other Vegetables	0
Totals	1177

FIRE predictive attribution

Note: All examples are fictitious and do not reflect actual values.

Top-down Example: *Salmonella* in Fresh Fruits and Vegetables

Step 2b: Separation of Outbreak Cases into Domestic and Imported

Canadian Foodborne Outbreak Data

- Number of outbreaks
- Number of cases
- Foods involved

Outbreak Cases
(2,566)

Domestic Cases
(641)

Imported Cases
(1,925)

Leeks Chives and Similar	0
Cantaloupe	0
Fresh Herbs	0
Mangoes Guava	0
Spinach	641.2
Peppers	0
Other Vegetables	0

	Leeks Chiv...	Cantaloupe	Fresh Herbs	Mangoes Guava	Spinach	Peppers
Brazil	0	0	0	0	107	0
Canada	0	0	0	0	0	0
Colombia	0	0	0	0	9.65	0
Costa Rica	0	0	0	0	52.98	0
Dominican Republic	0	0	0	0	30.48	0
Guatemala	0	0	0	0	360.2	0
Guyana	0	0	0	0	3.856	0
Mexico	0	0	0	0	1240	0
Peru	0	0	0	0	111.9	0
Viet Nam	0	0	0	0	8.815	0
Unknown	0	0	0	0	0	0
Totals	0	0	0	0	1925	0

FIRE predictive attribution

Note: All examples are fictitious and do not reflect actual values.

Merging top-down & bottom-up models: *Salmonella* in Fresh Fruits and Vegetables

Calibrating bottom-up DALYs to match top-down DALYs

Sporadic Domestic Cases (1,177)

Sporadic Imported Cases (10,531)

Outbreak Domestic Cases (641)

Outbreak Imported Cases (1,925)

Salmonella DALY (0.049)[b]

DALYs (699)

	Leeks C...	Cantalo...	Fresh H...	Mangoe...	Spinach	Peppers	Other V...	Totals
Brazil	0	5.86	0.418	14.3	9.96	3.97	0.00375	34.5
Canada	0.00139	20.4	1.14	0	54.5	13.1	0	89.1
Colombia	0	0.576	0.0412	1.37	0.95	0.396	0.000353	3.33
Costa Rica	9.8e-06	3.72	0.209	5.58	4.95	1.98	0.00204	16.4
Dominican Republic	0	1.6	0.115	3.58	2.82	1.18	0.00096	9.3
Guatemala	0	26.9	1.4	37.5	33.4	13.3	0.012	112
Guyana	0	0.221	0.0159	0.506	0.376	0.151	0.000167	1.27
Mexico	3.92e-05	68.6	4.89	149	121	51	0.042	395
Peru	0	6.14	0.439	15	10.5	4.18	0.00381	36.2
Viet Nam	0	0.343	0.0268	0.731	0.716	0.248	0.000255	2.06
Unknown	0	0	0	0	0	0	0	0
Totals	0.00144	134	8.69	228	239	89.4	0.0653	699

[b]Havelaar, Arie H., et al. "Disease burden of foodborne pathogens in the Netherlands, 2009." International journal of food microbiology 156.3 (2012): 231-238.

Note: All examples are fictitious and do not reflect actual values.

Comparative Risks using FIRE Model Results in Fresh Fruits and Vegetables (demo-not real results)

Country	Food	Hazard	Risk (DALYs)
A	Lettuce	*E. coli* O157	820
G	Lettuce	*Salmonella*	658
G	Fresh Herbs	*Salmonella*	262
A	Blackberries	Norovirus	136
A	Blackberries	E. coli O157	59
M	Blackberries	*Salmonella*	51
A	Fresh Herbs	*Salmonella*	39
G	Fresh Herbs	*E. coli* O157	27
A	Lettuce	*Salmonella*	21
A	Fresh Herbs	*Salmonella*	16
G	Blackberries	Norovirus	11
M	Lettuce	*E. coli* O157	8
M	Fresh Herbs	*Salmonella*	6
M	Blackberries	Norovirus	4

Total DALYs: 2118

Country

Country	Risk (DALYs)
A	1091
G	958
M	69

Country A has a higher relative risk than Country G or M.

Food

Food	Risk (DALYs)
Lettuce	1507
Fresh Herbs	350
Blackberries	261

Lettuce has a higher relative risk than Fresh Herbs or Blackberries.

Hazard

Hazard	Risk (DALYs)
Salmonella	1053
E. coli O157	914
Norovirus	151

Salmonella has a higher relative risk than *E. coli* O157 or Norovirus.

Applications: Putting the FIRE model to work

FIRE is helping CFIA's food program to	
1	Estimate relative risks at the F/H/COO level and prioritize food safety risk reviews of imported products, which can trigger changes to the program design (i.e. risk control measures)
2	Identify offshore workplan priorities (i.e. countries/commodities/products/systems that could be subject to CFIA activities)
3	Identify if importers of certain foods from a specific country/region require a targeted inspection and/or communication
4	Identify areas for further sampling
5	Access, manipulate and visualize data related to imported foods (using FIRE as a data hub)
6	Identify recent changes in risk / trends
7	Forecast changes in risk / emerging issues (near future)

CFIA's food program is developing business processes that will embed FIRE results into its risk-informed work planning process for program design and implementation

Road ahead

- Continue to onboard more hazards (including chemical hazards & Allergens)
  - Wider scope

- Continue to add new data elements to enhance the food safety story from other countries (incident/recall, outbreak, other government department data)
  - More proactive

- Explore advanced methods such as Meta analysis and Bayesian network analysis
  - Improve precision of FIRE results

- Continue to use Machine Learning/AI/IT tools for automation
  - Trend analysis and Forecasting for more sooner detection of high risk and quick response

Continue to collaborate with internal, external and international partners….

Questions ?

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We are the CFIA.

The Canadian Food Inspection Agency (CFIA) touches the lives of all Canadians in so many positive ways.

Each day, hard-working CFIA employees—including inspectors, veterinarians and scientists—inspect food for safety risks, protect plants from pests and invasive species, and respond to animal diseases that could threaten Canada's national herd and human health.

Guided by science-based decision-making and modern regulations, the Agency works tirelessly to ensure access to safe and healthy food in Canada, and support access to international markets for our high-quality agricultural products.

To learn more, visit inspection.canada.ca.

Canada