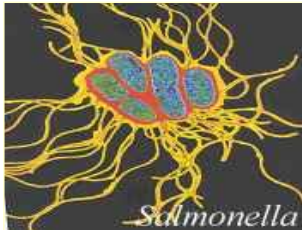




***Salmonella* control in food-animals: Focus on chicken and pork**

Andrijana Rajić

PHAC/University of Guelph

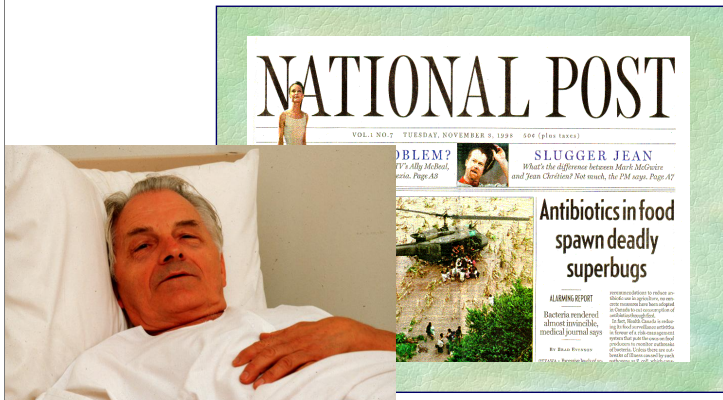


Story

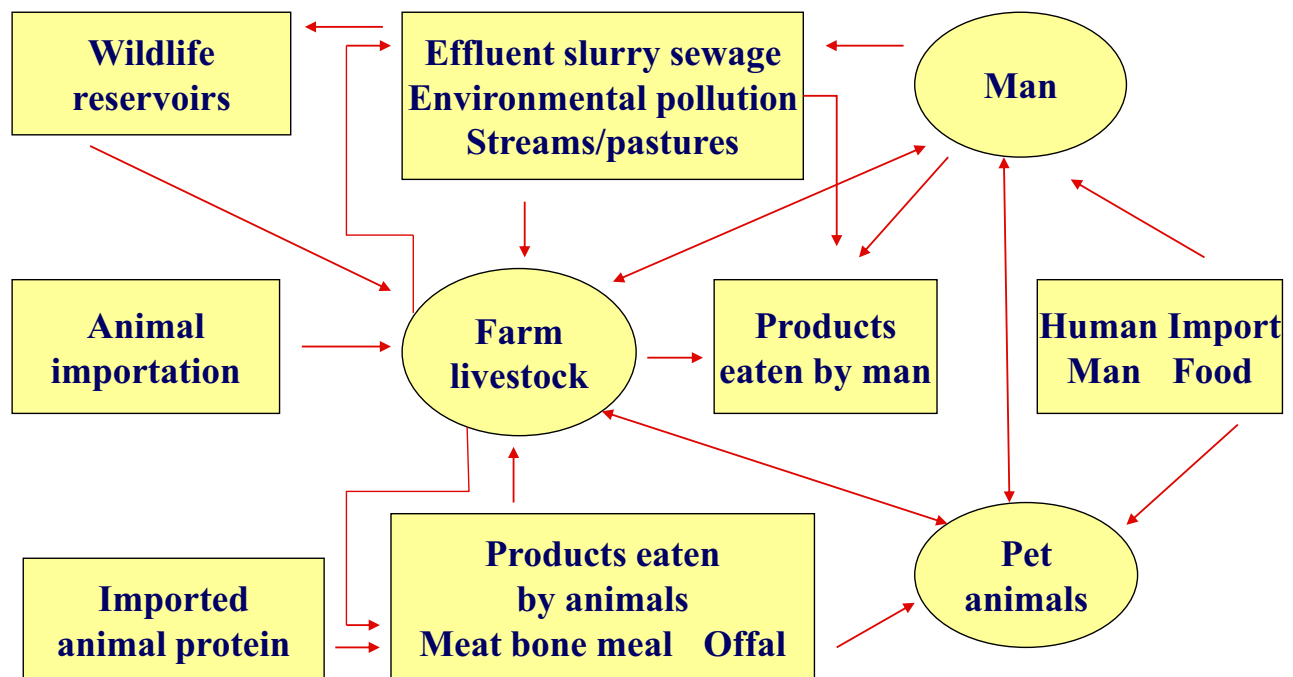
- Epidemiology and ecology of *Salmonella*
 - Food animal chain
- *Salmonella* control
 - Conventional wisdom
 - International approaches
- Evidence-informed approach
 - Case study: Efficacy of farm-to-processing interventions for *Salmonella* in broiler chicken
- Summary/Canadian context/

Salmonella in food-animals

- Common foodborne illness
- 11 million food-borne illness each year in Canada (Thomas, 2009)
- Costs US \$2.9 billion annually (USDA)
- Disease in food animals
- Common infection
- Serovar distribution / overlap
- Food safety/public health
 - Disease in humans
 - Vulnerable populations
 - AMR
- Economic impact
 - Production, trade

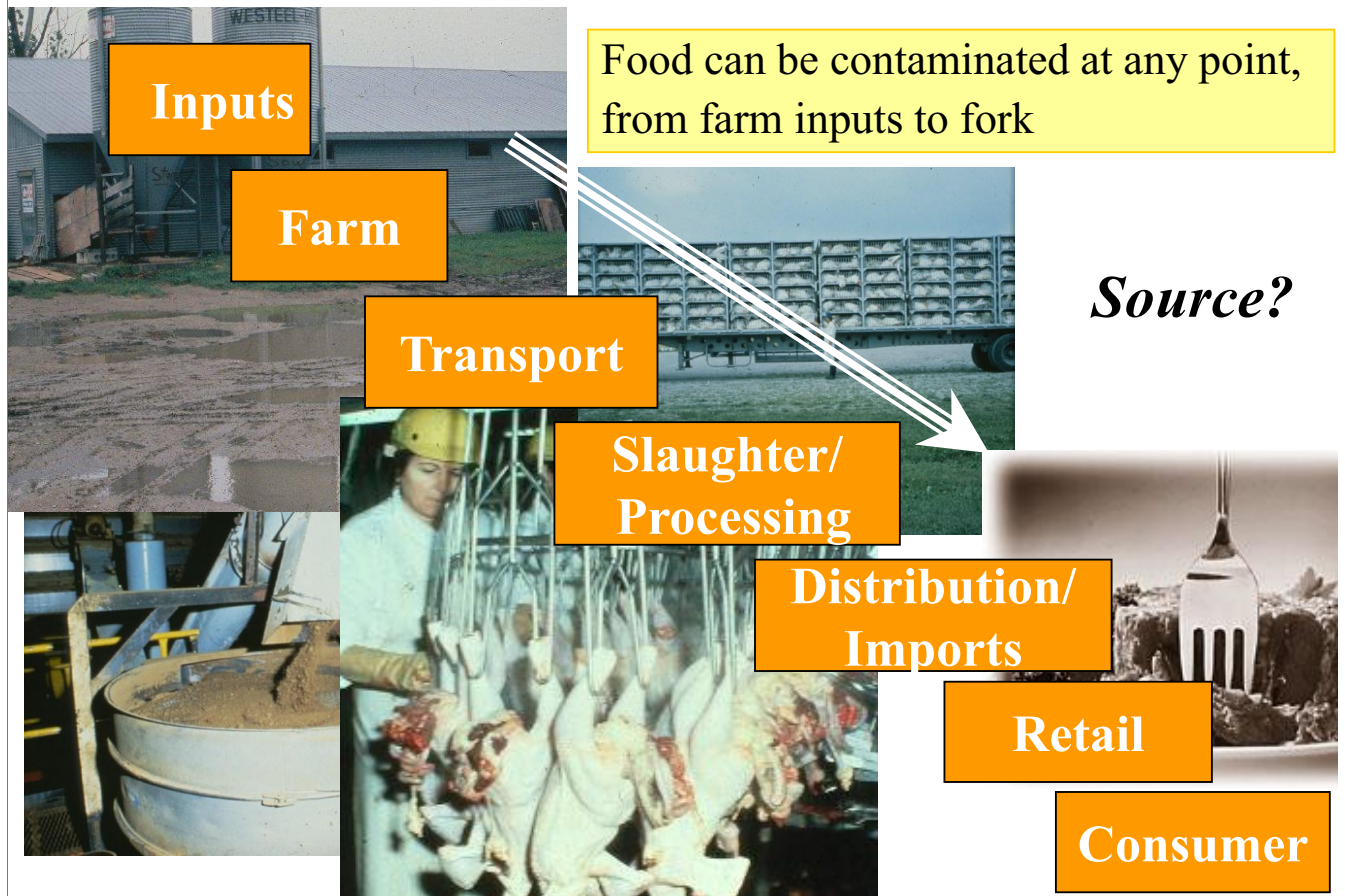


Complexity of Salmonella ecology



From Ray and Davies

Complexity of food-animal chain



Farm/Transport



- **Risk Factors**
 - Feed, breeding, hatching
 - Production practices
 - Replacement animals, mixing, transport stress
 - Animals as reservoirs
 - Environment
 - Litter, feed, water, dust, rodents, wildlife, ...
 - Equipment
 - Humans
 - Visitors, workers ...
 - **Recommended practices**
 - Feed control/dietary interventions
 - Quarantine/testing
 - Good hygiene & bio-security programs, training
 - Transport in separate containers
 - Sanitation
 - Integrated control programs
- Key aspects: persistence, unique farm/production system ecology?**

Slaughter/Processing



• Risk factors

- Lairage/holding pens
- Contaminated feathers/hides
- Carcass contamination
 - Pre-post evisceration
- Plant building, equipment and environment
- Human carriers
- Initial contamination of raw materials
- Production, processing, food handling, distribution and preparation
- Level of sanitation

• Interventions

- HACCP/Microbial testing
- Holding in pens separated by concrete
- Facility design, production flow
- Covering the bungs with a plastic bag
- Various decontamination procedures
- Large scale monitoring and surveillance
- Personnel training
- Logistic slaughter

Key aspects: pathogen/food matrix /plant ecology?

International approaches

- Scandinavia
 - Sweden, Denmark
- EU Zoonoses legislation
 - Farm level
 - Main Targets: Typhimurium, Enteritidis
- US
 - HACCP/PR at processing
- Canada
 - HACCP/PR at processing
 - OFFS programs
 - No pathogen targeted monitoring/control



Denmark success

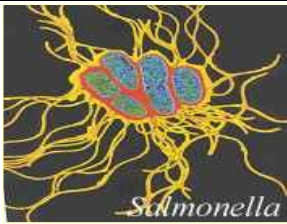
- *Salmonella* program in broiler chicken chain
 - Number of positive flocks reduced considerably
- *Salmonella* program in pork chain
 - Considerable incremental reduction reported along with the program modification
- *Salmonella* reduction in humans
 - Domestic human cases reduced
 - Import/travel-related cases
- Cost-effectiveness? Applicability to other countries?



Contextual factors

- History of major outbreaks
- Regulatory aspects
- Trust in government
- Consumer preferences
- Industry size and organization
- Trade aspects
- Overall food safety/public health priorities
- Resources, cost-effectiveness
- Long-term sustainability
- Transparency, accountability
 - Risk and science-based approach to food safety
- Partnership
 - Multi-stakeholder approach, partnership
- Health, nutrition trends
 - Food safety objectives part of public health objectives
- Long-term sustainability

Evidence-informed policy/decision making in food safety

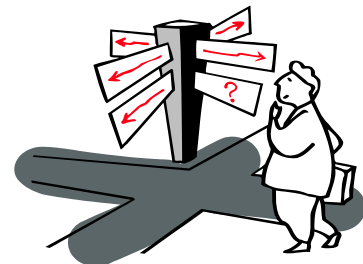


Evidence-informed approach: Systematic review-meta-analysis

Case study: Salmonella in chicken

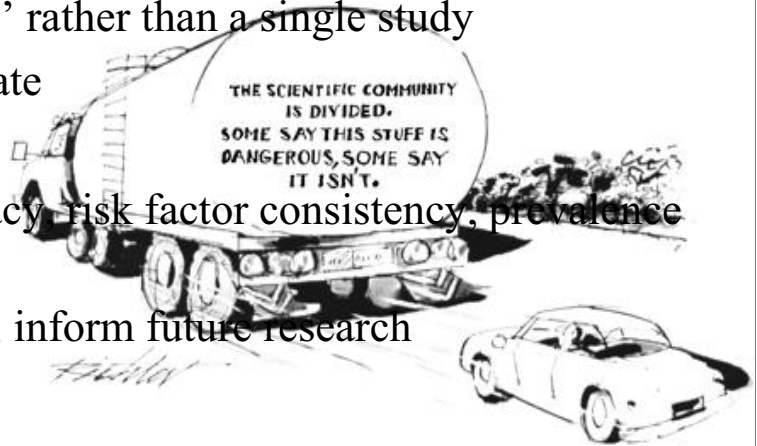
Study rationale

- **Chicken: main source of *Salmonella***
- **Canada/Ontario (CIPARS, 08)**
 - **Serovar overlap?**
 - **Humans**
 - Typhimurium, Enteritidis, Heidelberg
 - **Chicken (abattoir)**
 - Kentucky, Enteritidis, Typhimurium
 - **Chicken (retail):**
 - Kentucky, Enteritidis, Typhimurium
- **Control options**
 - Different
 - Experts disagree
- **International risk management guidelines**
 - WHO/FAO/Codex Committee for Food Hygiene
- **Need to assess intervention effectiveness (farm to processing)**
 - Optimal combination of interventions?



Evidence-informed approach

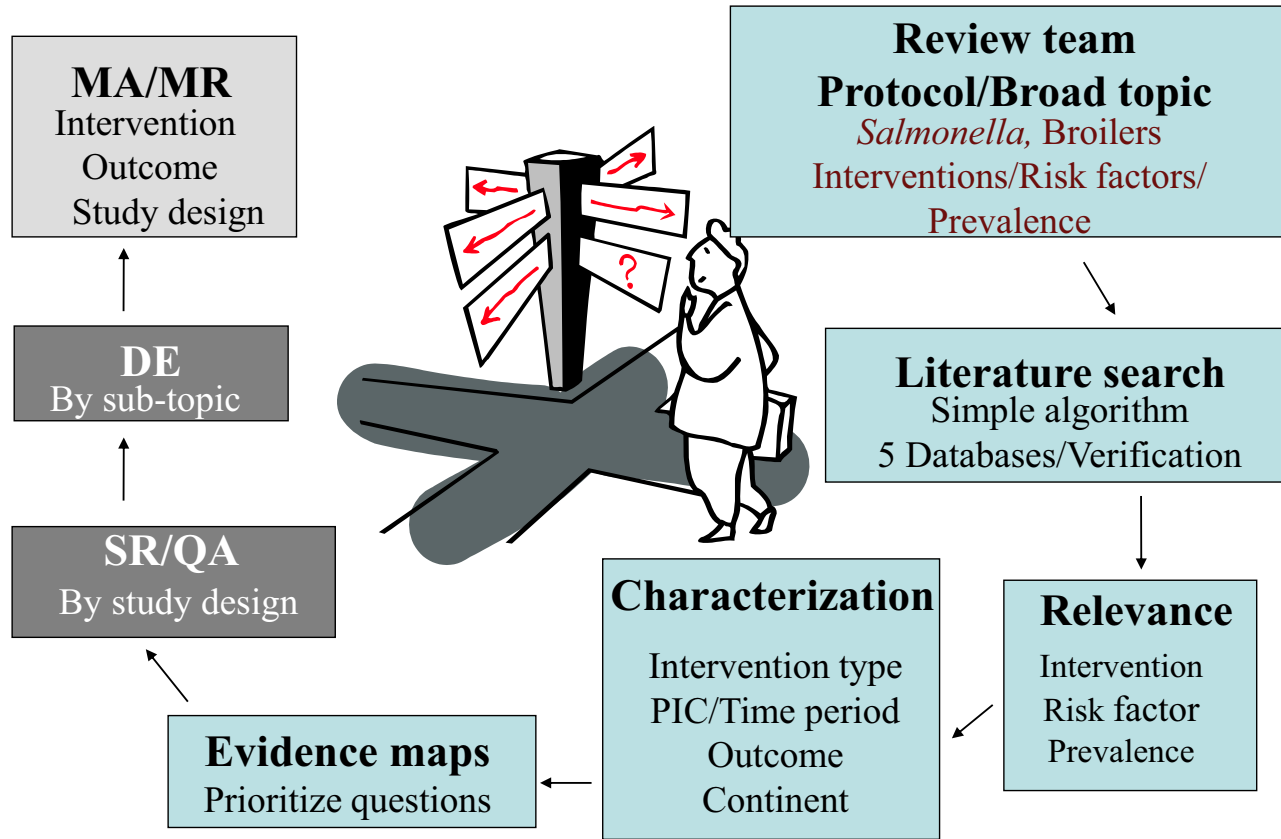
- Knowledge synthesis and translation science
- Long tradition in health sector
- Systematic review-meta-analysis
 - Transparent and replicable methodology
 - ‘All available knowledge’ rather than a single study
 - Frequently used to evaluate
 - Intervention efficacy
 - Diagnostic test accuracy, risk factor consistency, prevalence extent
 - Identify knowledge gaps, inform future research



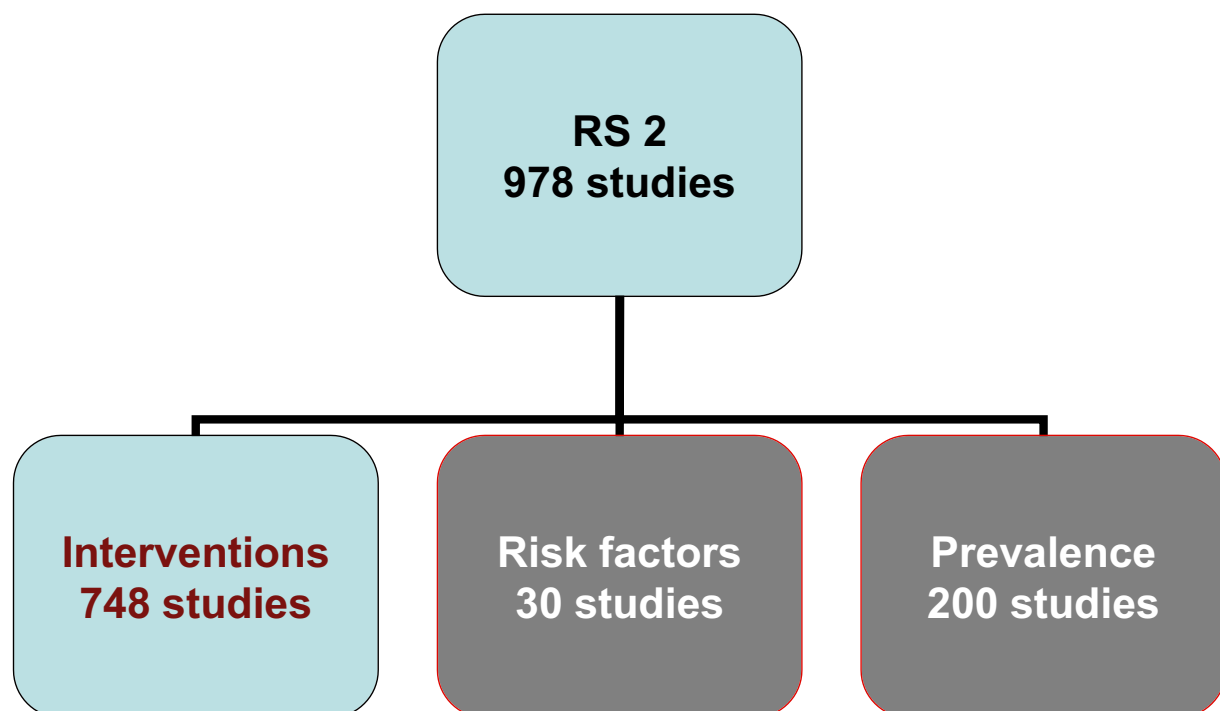
Study objective

- Evaluate all publicly available primary research investigating the efficacy of various interventions, from farm to processing, for *Salmonella* in broiler chicken
 - Using evidence mapping, systematic review and meta-analysis methodology (SR-MA)
 - Which specific interventions are effective or more promising?
 - Overall quality and relevance of publicly available intervention research knowledge

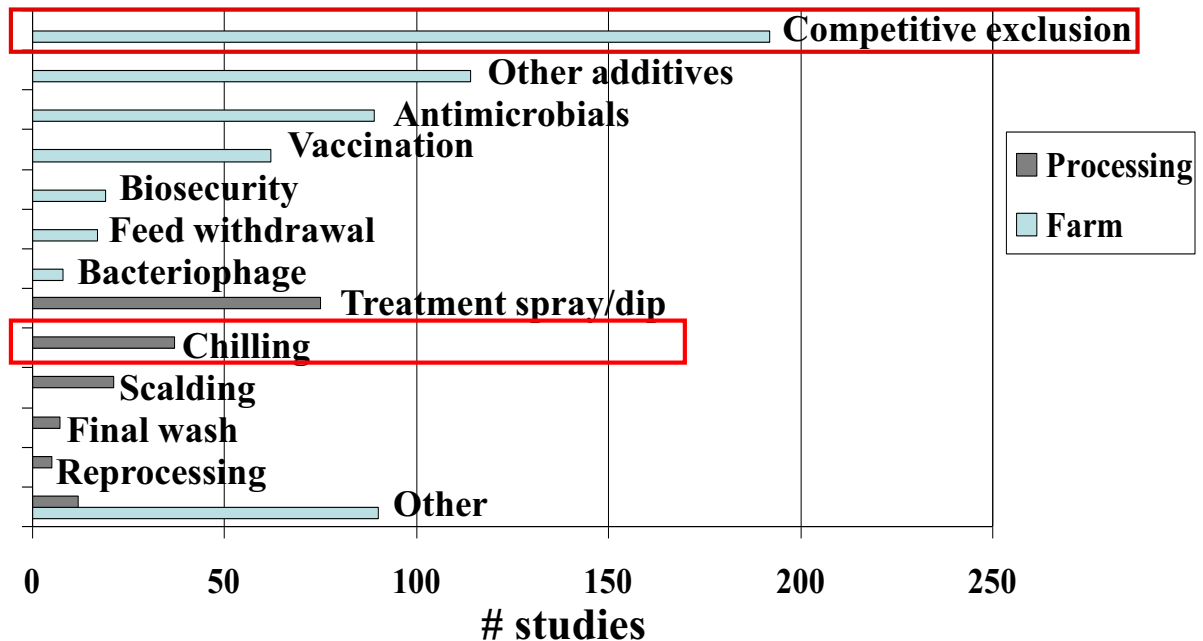
Evidence-informed approach



Evidence summary



Intervention evidence summary



Study distribution by type of intervention / point in chain

CE evidence summary

- 18% published after 2000
- 69% conducted in Canada/USA
- 96% used day old chicks
- 78% CE administered one time only
- 72% only received CE treatment
- 28% in combination with:
 - Other additives (66%)
 - Vaccination (15%)
 - Antimicrobials (11%)
 - Feed withdrawal (7%)
 - Bacteriophages (1%)
- 15 unique products
- 9 routes of administration
 - Oral gavage (65%)
- 16 sample types
 - Cecal contents (28%)
- Time outcome measured
 - Range 1-13 weeks
 - 8-14 days post-treatment (28%)
- Serovar
 - Typhimurium (47%)
 - Enteritidis (29%)
 - Infantis (13%)

(n=2,789 trials)

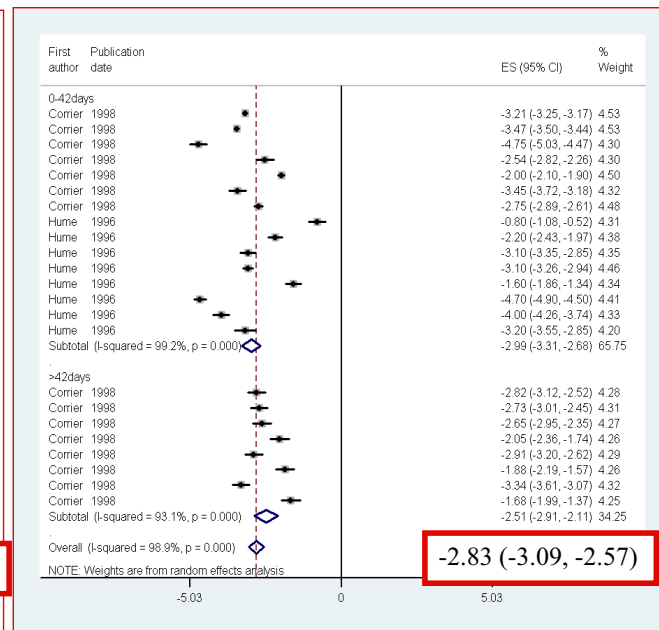
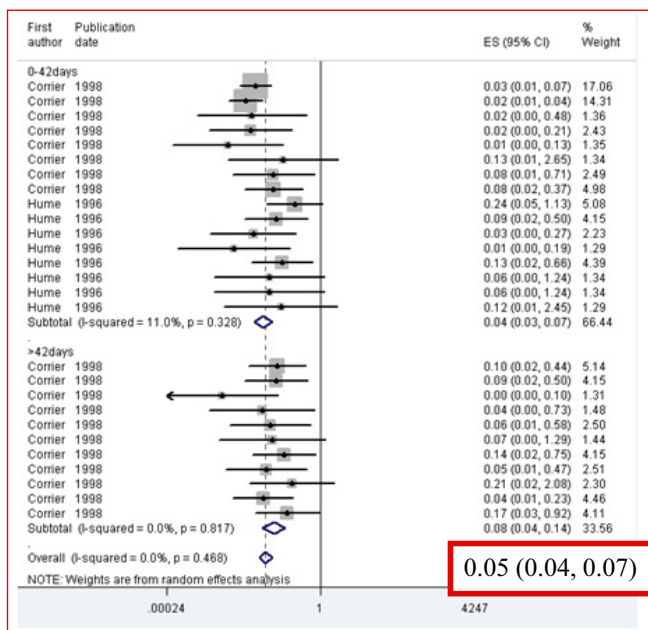
Studied CE products

CE TYPE	FREQUENCY	%
Undefined, chicken source	1743	62.5
Other	304	10.9
Containing lactobacillus	200	7.17
Undefined, unknown source	95	3.41
Aviguard	76	2.72
Vermicompost	69	2.47
FM-B11	67	2.40
Broilact	66	2.37
Primilac	47	1.69
CF3	43	1.54
Avian Pac Plus	30	1.08
Preempt	24	0.86
MSC	11	0.39
Simbiotico	8	0.29
Avifree	6	0.22
TOTAL	2789	100

Efficacy of CE: Meta-Analysis

Prevalence Outcome

Concentration Outcome



Favours treatment

Favours control

Favours treatment

Favours control

More intuitive knowledge translation

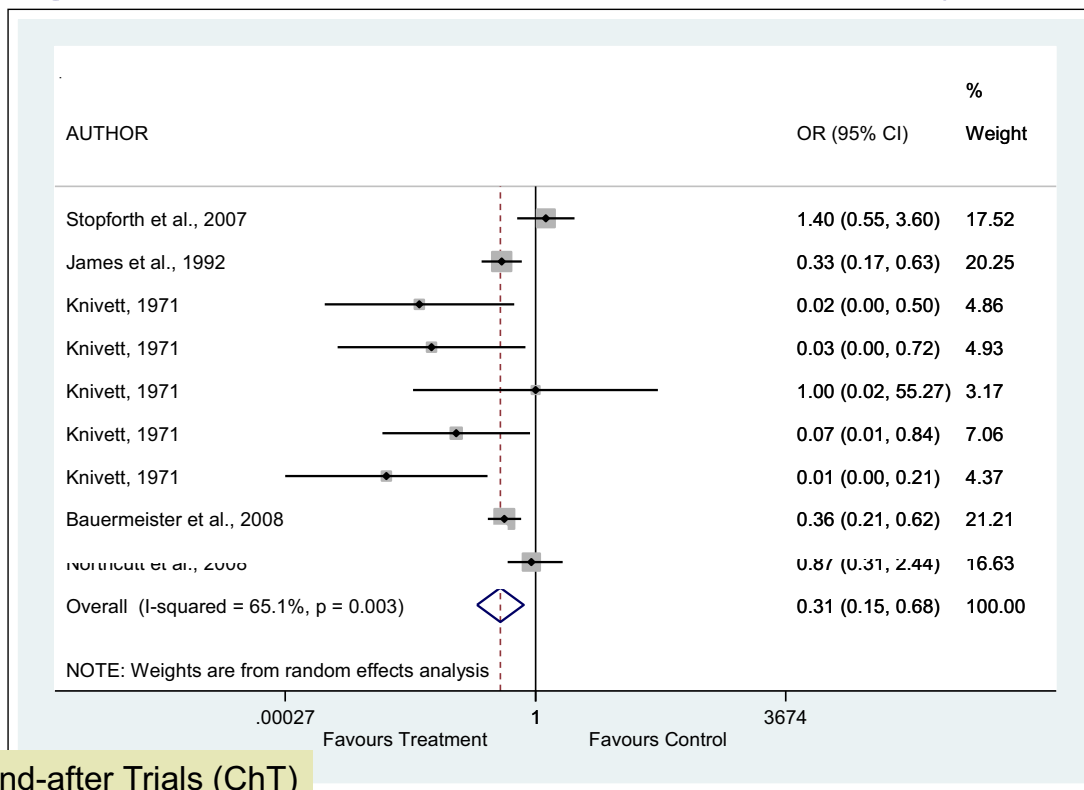
- *CF3 reduced the risk of Salmonella colonization by 47% out of 100 chickens treated with CE when compared to the control group*
- *On average CF3 reduced Salmonella in treated broiler groups by 2.83 log₁₀ cfu/g of cecal material when compared to the control group*

Chilling evidence summary

Variable	Category	# studies	# trials
Study design	Controlled trials	6	16
	Challenge trials	8	105
	Before-and-after (no challenge)	7	45
	Before-and-after (challenge)	9	46
Setting	Laboratory	7	152
	Pilot	9	45
	Commercial	8	15
Chilling types	Immersion with agitation	17	62
	Immersion no agitation	6	24
	Air	2	3
	Simulated / Other	3	123
Disinfectants	Chlorine	10	46
	Acetic acid	4	16
	Lactic acid	4	15
	Potable water	6	36
	Other	20	99

Only some data shown

Efficacy of immersion chilling with agitation-chlorine: Meta-analysis



Before-and-after Trials (ChT)

Summary: some on-farm practices

Intervention	Promising practices	Efficacy est./CI	CGR	PTR	GR
Competitive exclusion	Preempt	OR=0.05 (0.04, 0.07) / MD range -0.12, 6.43	72%	11%	**
		OR=0.13 (0.1, 0.18)† / MD range 0.05, 3.19	3.82	n/a	**
	Broilact	OR=0.06 (0.02, 0.17)†	81%	36%	**
			2.78	n/a	***
		33%	3%	*	
Feed/water additives	Organic acids	OR range 0.00, 7.67	28%	1-26%	***
	Lactose	OR=0.22 (0.13, 0.37)	94%	77%	**
		MD range -0.53, 6.60	6.10	n/a	*
Vaccination	Live <i>ST</i>	OR 0.21 (0.06, 0.77)	21%	1%	***
	Killed <i>SE</i>	OR range 0.09, 1.75	50%	8-64%	**
	Killed <i>SE</i> + <i>ST</i>	OR range 0.15, 0.87	78%	35-76%	**
Bio-security	H ₂ O ₂ /eggs	OR=0.13 (0.06-0.30)†	75%	28%	**
	PHMB/eggs	OR=0.07 (0.02-0.30)†	68%	12%	**

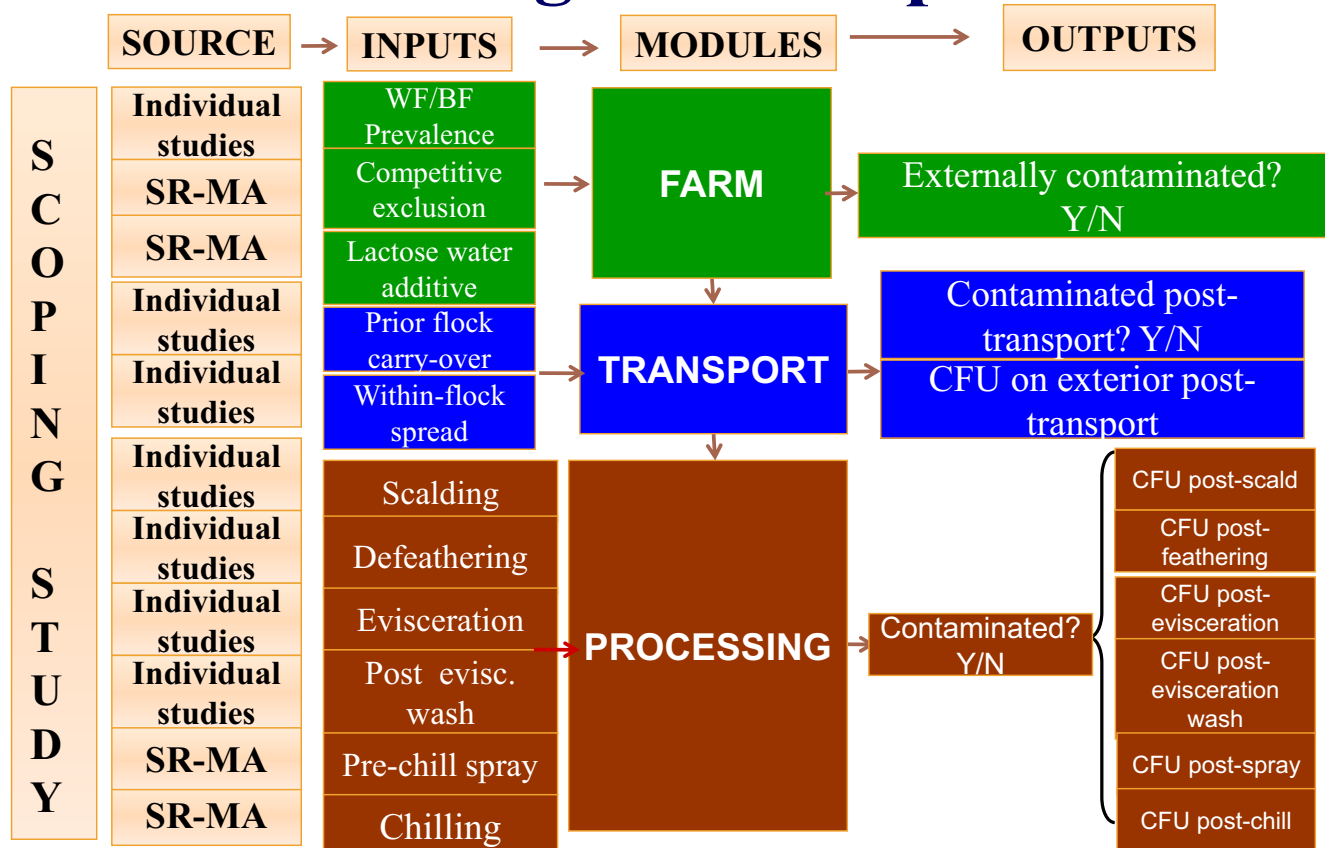
OR=odds ratio; MD=mean difference; †=significant heterogeneity; GR=GRADE=* very low quality to **** high quality evidence; CGR=control group risk; PTR=predicted treated risk; n/a= not applicable

Summary: some processing practices

Intervention	Promising practice	Efficacy est./CI	CGR	PTR	GR
Carcass sprays	Potable water	MD range 0.01, 1.59	6.55	n/a	*
	Trisod. phosphate 10%	MD=1.31 (0.7, 1.92)†	5.94	n/a	*
	Cetylpyrid. chloride 0.1%	MD=0.85 (0.51, 1.18)†	6.10	n/a	*
	Lactic acid 1%	MD=0.91 (0.55, 1.27)†	5.80	n/a	*
	Sodium bisulfate	MD range 0.97, 2.58	5.01	n/a	*
Carcass dips	Lactic acid	OR range 0.001, 0.51	59%	4%	**
	Trisodium phosphate	OR 1.16 (0.59, 2.26)	20%	22%	***
Chilling	Air chilling	OR=0.7 (<i>single trial</i>)	25%	18%	***
	Immersion/agitation + H ₂ O	OR=0.08 (0.04, 0.17)	84%	29%	***
	Immersion/agitation + Cl	OR range 0.02, 49.63	52%	2-98%	***
	Immersion + cl	OR range 0.02, 1.5	61%	3-70%	***
	Immersion + LA acid	OR range 0.004, 0.05	79%	2-16%	***

OR=odds ratio; MD=mean difference; †=significant heterogeneity; GR=GRADE=* very low quality to **** high quality evidence; CGR=control group risk; PTR=predicted treated risk; n/a= not applicable

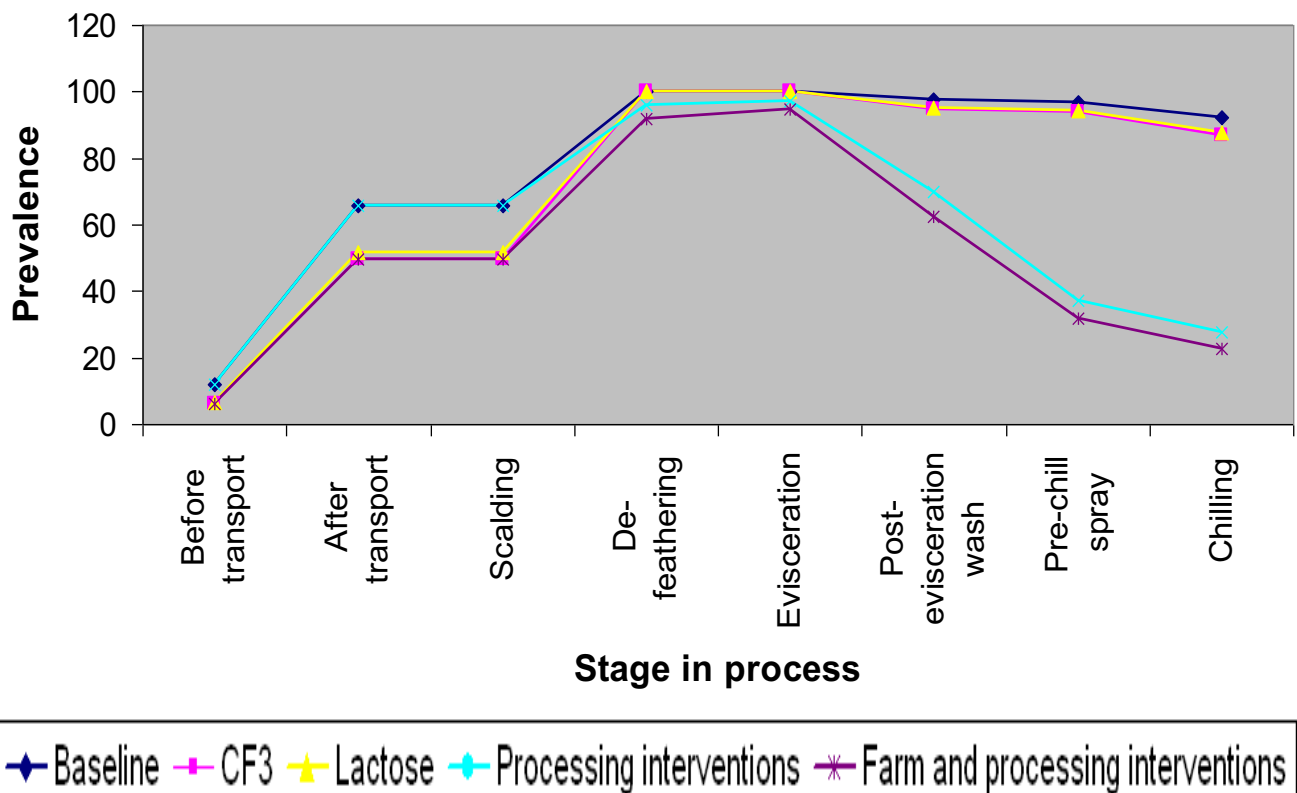
Modelling control options



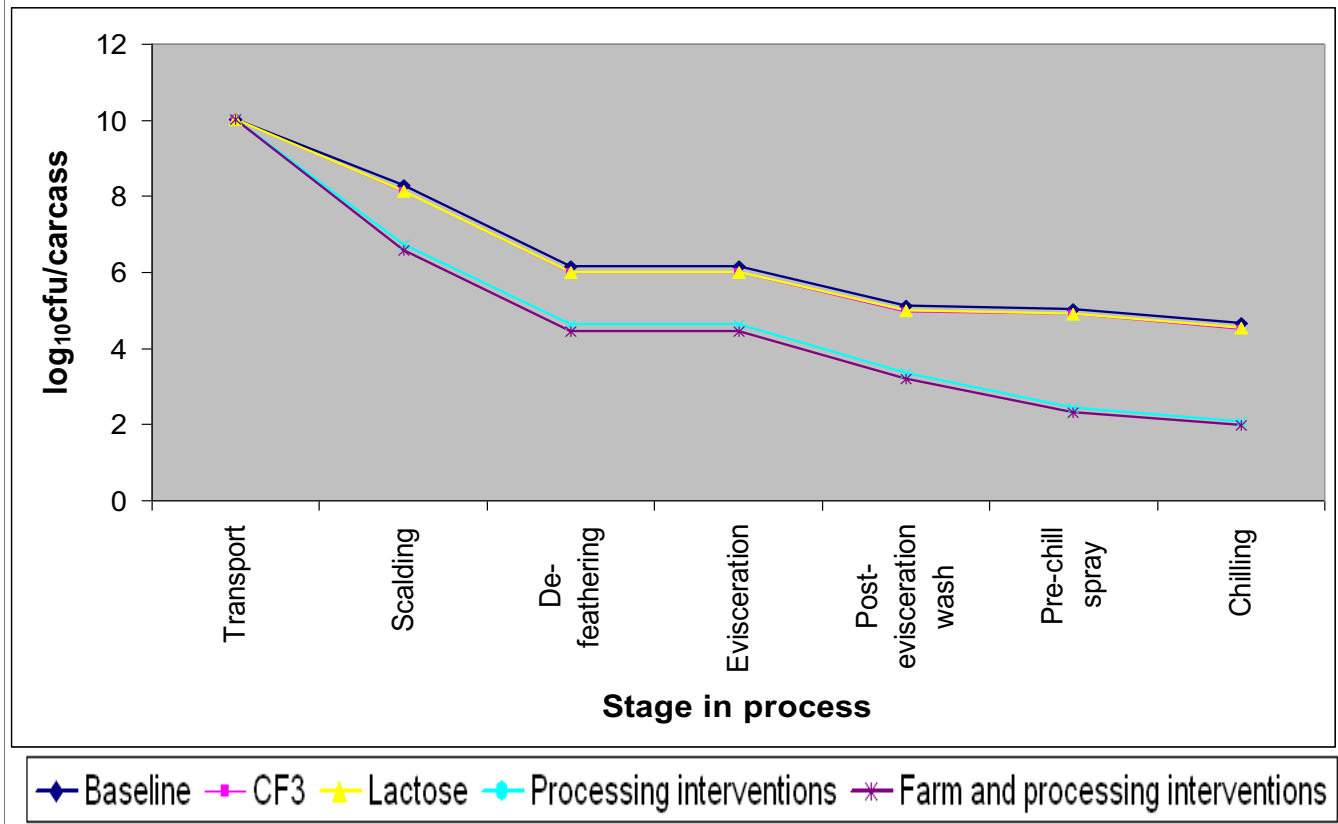
Model scenarios

- Two baseline populations/fresh & frozen product market
- Farm interventions (WFP)
 - CE culture CF3, 2-2.5% lactose water additive
- Processing intervention package (CFU/carcass)
 - 1% NaOH scald water additive, 500ppm Cl₂ post-evisceration spray, 10% TSP pre-chill spray, 20ppm Cl₂ chilling or air chilling
- Single farm + processing intervention package
 - CF3 + scalding, post-evisceration spray + pre-chill spray + chilling
- Hypothetical reductions
 - 50% reduction in flock-level prevalence
 - 50% reduction in *Salmonella* cfu/carcass post-transport
- Sensitivity analysis: relative impact/model parameters

Intervention impact/*Salmonella* prevalence (Broiler carcasses/fresh product market/+ve flocks)



Intervention impact/*Salmonella* concentration (Broiler carcasses/fresh product market/+ve flocks)



Food safety intervention research

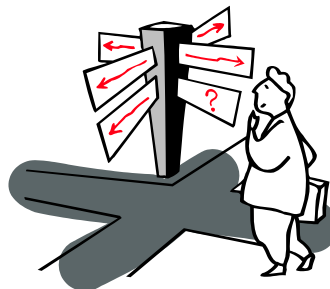
- Overall, globally and within Canada:
- Lack of robust, powerful research
 - Both at the farm and processing level
 - This applies to other priority food safety pathogens
 - Lack of large, well-designed and reported field trials for all interventions
 - Lack of specific bio-security intervention protocols
 - Lack of strong contextual research
- Food safety research: Priority?
 - Verbal priority vs. really funded research priority
 - Funding multi-disciplinary teams?
- Empirical evidence, proprietary data?
- Importance of multi-stakeholder partnership, multi-disciplinary knowledge sharing approach

Future of *Salmonella* control

- ***International trends* indicate:**
- **Burden of salmonellosis can be reduced in humans**
- **Pathogen reduction plans**
 - multi-faceted control options at the most critical stages in the food chain/importance of contextual relevance
- **Incremental risk reduction is possible**
 - with continuous modification of surveillance approaches
 - sustainability?
- **Public health objectives**
 - **Food safety objectives (FSO)**
 - Tolerable levels of the pathogens and regular review of FSO

Impact on Canada

- | | |
|--|--|
| <ul style="list-style-type: none">• International trends<ul style="list-style-type: none">– EU, USA<ul style="list-style-type: none">• Stringent standards– Market demands– Consumer pressures | <ul style="list-style-type: none">• Options<ul style="list-style-type: none">– Do nothing?– React if/when necessary<ul style="list-style-type: none">• Adopt / modify approaches from others– Pro-active<ul style="list-style-type: none">• Develop own policy? |
|--|--|



Acknowledgements

**All reviewers, collaborators,
OMAFRA, PIC and PHAC
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