

Risk-based meat inspection and integrated meat safety assurance

RIBMINS WG2/WG3 Training school: Farm and abattoir interventions in a risk-based meat safety assurance system

Dragan Antic | 29-Jun-22 | virtual, UK



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WG3 Abattoir level: controls + risk categorization

- Results from ongoing work -



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WG3 Specific objectives

Controls:

 3.1 Assessment of effectiveness of new tools | methods for detection of carcass contamination

3.2 Assessment of the significant intervention strategies and alternative methods for the slaughtering | the carcass dressing

Risk categorisation:

- 3.3 Assessment of the performance of food safety management systems
 3.4 Harmonised Epidemiological Indicators in risk categorisation of 3 & 4
- 3.4 Harmonised Epidemiological Indicators in risk categorisation of abattoirs

Years

1 & 2

WG3 Prevalence of the main foodborne pathogens at abattoir (mean prevalence from selected studies)



WG3 ongoing activities

performing systematic literature reviews coupled with meta-analysis on:

interventions for the reduction of bacterial load on
 pig | beef | sheep | chicken carcasses at abattoirs



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Article

Systematic review and meta-analysis of the efficacy of interventions applied during primary processing to reduce microbiological contamination on pig carcasses

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LTTC burgers (FSA Board, March 2020)

- "it can be expected that the 4 logs performance criterion can be achieved in the minced beef production chain, at the FBOs which supply meat for LTTC burgers"
- "most promising interventions to reduce microbial load on beef: cattle hide interventions (including FSA's `clean livestock policy`), carcass pasteurisation treatments and organic acid washes ... multiple interventions reduce microbiological load by up to 3 log (99.9%)"
- recommendations: the sequential use of general hygiene practice and hazardbased interventions at the pre-slaughter, slaughter and post-slaughter stages, as an integral part of intervention-based HACCP



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WG3 Interventions

- Interventions are actions taken during slaughter and processing to reduce microbial contamination of carcasses
- Hazard based interventions:
 - Any intervention that has a significant and persistent effect in reducing carcass microbial contamination
 - Cattle hide interventions: chemical washes with vacuuming and immobilisation treatments
 - Carcass interventions: thermal interventions (hot water washes, pasteurisation treatments), organic acid washes

GHP-based control measures:

- Iack of evidence (e.g. cattle hide removal practices, bunging/rodding);
- have shown inconsistent results in reducing microbial contamination (particularly in respect to pathogens, e.g. hide cleanliness assessment, hide clipping, chilling);
- no processing parameters can be clearly established (e.g. environment sanitation, equipment and tools sanitation, and trimming)
- Steam vacuuming ? rely on due diligence, manual application



WG3 Interventions - legislation

EU (Regulation (EC) No. 853/2004: Interventions with substances other than potable water are permissible but subject to regulatory authorisation and following a risk assessment by the EFSA

Regulation 101/2013 allows the use of <u>lactic acid</u> to reduce microbiological surface contamination on bovine carcases

However,

Good Hygiene Practice must be implemented first, as interventions must not be a substitute for GHP, only an additional measure





¹grouping in high or low risk categories based on food chain information/epidemiological indicators (e.g. high risk are those with high *Salmonella* and/or VTEC prevalence) ²grouping in high or low risk categories based on process hygiene criteria/epidemiological indicators (e.g. high risk are those with poor process hygiene, i.e. GMP/GHP and HACCPbased procedures not sufficient to meet PHC or other targets)

³ aimed at preventing carcass microbial contamination: help to "lower" abattoir risk category at the same time

⁴ aimed at removing/eliminating hazards from carcasses: applied only in "high risk scenario" (high risk farm + high risk abattoir), i.e. when targets cannot otherwise be met



WG3 Interventions – reducing the food safety risks

- Average probability of illness per serving of ground beef, non-intact beef cuts, and intact beef cuts for each beef intervention scenario as determined using Monte Carlo simulation
- Public health risks, expressed as average probability of illness per serving, were reduced by:
 - 31%-72% for single pre-harvest interventions (on farm)
 - 44%-96%, for single processing interventions (at slaughter)
 - 95%-99.9% for combinations of interventions (both on farm and at slaughter)

relative to a worst-case scenario where no interventions were applied

		Intervention	Scenario	Description	Average probabili	ty of illness	
		type None Single	(Sc.)		Ground beef	Non-intact beef cuts	Intact beef cuts
		Intervention type None Single	1	No Interventions	1.78×10^{-4}	6.97×10^{-7}	6.00×10^{-8}
		Single	2	Probiotics	9.62×10^{-5}	4.31×10^{-7}	3.71×10^{-8}
			3	SRP vaccine	1.23×10^{-4}	4.39×10^{-7}	3.88×10^{-8}
			4	Type III protein vaccine	6.77 × 10 ⁻⁵	2.69×10^{-7}	1.67×10^{-8}
			5	Carcass wash (≤50 °C)	9.71×10^{-5}	3.88×10^{-7}	3.36×10^{-8}
	Food Control 20 (2012) 264 - 281		6	Hot water wash (\geq 85 °C)	4.13×10^{-5}	1.29×10^{-7}	1.12×10^{-8}
	1000 Control 29 (2013) 304-381		7	Pre-wash intervention followed by wash	5.74×10^{-5}	2.08×10^{-7}	1.83×10^{-8}
	CONTROL		8	Steam pasteurization	4.37×10^{-5}	1.55×10^{-7}	1.28×10^{-8}
and states and the	Contents lists available at SciVerse ScienceDirect CONTROL FOOD CONTROL		9	Acid spray chill	1.36×10^{-5}	3.13×10^{-8}	2.08×10^{-9}
Date and Arrest and			10	Dry-aged chill	5.37×10^{-5}	1.70×10^{-7}	1.45×10^{-8}
2000	Food Control		11	Water spray chill	1.90×10^{-4}	8.84×10^{-7}	6.68×10^{-8}
En Seller	CONTROL	Combination	12	Current Practices	8.66×10^{-6}	3.29×10^{-8}	2.92×10^{-9}
ELSEVIER	journal homepage: www.elsevier.com/locate/foodcont		13	Sc. 12 + Probiotics	3.75×10^{-6}	2.39×10^{-8}	2.76×10^{-9}
			14	Sc. 12 + SRP vaccine	3.81 × 10 ⁻⁶	1.52×10^{-8}	1.15×10^{-9}
			15	Sc. 12 + Type III protein vaccine	1.90×10^{-6}	1.14×10^{-8}	4.62×10^{-10}
			16	Pre-evis, Hot water wash + post-evis, Hot water	5.15×10^{-6}	4.67×10^{-9}	5.64×10^{-10}
A risk asses	ment model for <i>Escherichia coli</i> O157:H7 in ground beef and beef cuts			wash + Acid spray chill			
in Canada:	Evaluating the effects of interventions		17	Pre-evis. Hot water wash + post-evis. Hot water	3.99×10^{-6}	2.59×10^{-9}	3.22 × 10 ⁻¹⁰
III Callaua.	Evaluating the effects of interventions			wash + post-evis. Steam pasteurization + Acid			
Ben A Smith*	Aamir Fazil Anna M. Lammerding			spray chill			
Den n. Shinen ,			18	Sc. 17 + Probiotics	2.09×10^{-6}	1.20×10^{-9}	1.61×10^{-10}
Science to Policy Division,	taboratory jor rooaborne zoonoses, Public Health Agency of Canada, 206-160 Research Lane, Guelph, Ontario, Canada NIG 582		19	Sc. 17 + SRP vaccine	2.09×10^{-6}	1.14×10^{-9}	1.32×10^{-10}
			20	Sc. 17 + Type III protein vaccine	6.71×10^{-7}	8.06×10^{-10}	6.33 × 10 ⁻¹¹

WG3 Methodology

- Systematic reviews:
 - PICO framework,
 - From lairage to chilled carcasses
 - Scopus & CAB Direct (1990-2021), SciELO (2002-2021)
 - All stages, two reviewers, third to resolve discrepancies
 - Risk of bias performed to see which studies are suitable for meta-analysis
- Meta-analysis:
 - Data stratified by study design/conditions, intervention (sub)category, outcomes and measures (prevalence, concentration: mean log CFU)
 - Meta-analysis performed when an intervention group had three or more trials with a low risk of bias
 - A mixed-effects model was used to create pooled summary statistics and then presented as Forest plots.
 - Tests for heterogeneity of study groups were performed.



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WG3 Results – Risk of Bias and MA grade

- Relevant studies were identified, and then
 - Iow risk of bias' studies selected for meta-analysis.
- Three or more trials forest plots generated:
 - with meta-analysis summary effects
- Test for heterogeneity:
 - homogenous (p>0.05 on the test for heterogeneity),
 - moderately heterogeneous (p<0.05, I²<=60%),
 - highly heterogeneous (p<0.05, *I*²>60%).
- Meta-analysis grade:
 - Significant positive effect
 - No effect
 - Significantly homogenous studies



Bias arising from the randomization process Bias due to deviations from intended interventions Bias due to missing outcome data Bias in measurement of the outcome Bias in selection of the reported result Overall risk of bias





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WG3 Beef interventions (progressed to meta-analysis)

Lairage interventions

- Lairage cleaning
- Cattle handling in lairage
- Hide cleanliness assessment
- Pre-slaughter cattle hide interventions (washing, clipping, bacteriophage spray)

Cattle hide interventions

- Water wash
- Chemical wash (organic acids, chlorine, sanitiser)
- Chemical dehairing, thermal
- Shellac hide coating



- Beef carcass interventions
- SPP & GHP:
 - knives sanitation; hide removal; bung bagging
- Pre-chill carcass treatments:
 - Water wash
 - Knife trimming
 - Hot water wash
 - Steam pasteurisation
 - Steam vacuuming
 - Lactic acid wash
 - Other organic acids wash
 - Other chemicals
- Chilling
 - Dry chilling
 - Dry aging
 - Water spray chilling
 - Spray chilling with chemicals
- Multiple interventions
 - Pasteurisation and acid washes

WG3 Results – overall beef carcass interventions for **generic** *E. coli*



A comparison of meta-analyses of cattle hide and beef carcass processing interventions on generic *E.coli* counts (pooled log change) on beef carcasses under commercial abattoir conditions

Green: Homogenous trials **Red:** Heterogeneous trials

Numbers in bar chart: Top number = Number of studies, Bottom number = Number of trials

WG3 Results – overall beef carcass interventions for **generic** *E. coli*



A comparison of meta-analyses of beef carcass processing interventions on **generic** *E.coli* **prevalence** (pooled **risk ratios**) on beef carcasses under **commercial abattoir** conditions

Green: Homogenous trials **Red:** Heterogeneous trials

Numbers in bar chart: Top number = Number of studies, Bottom number = Number of trials

WG3 Results – overall beef carcass interventions for ACC



A comparison of meta-analyses of cattle hide and beef carcass processing interventions on **aerobic colony counts** (pooled **log** change) on beef carcasses under **commercial abattoir** conditions

Green: Homogenous trials **Red:** Heterogeneous trials

Numbers in bar chart: Top number = Number of studies, Bottom number = Number of trials

WG3 Beef abattoir interventions – Hide cleanliness assessments

• Using hide cleanliness scores led to:



- Aerobic colony count (ACC) reduction:
 - **0.90** log CFU/cm², 95%CI 0.54-1.26, *I*²=88.4%

Enterobacteriaceae count (EBC) reduction:

• **0.71** log CFU/cm², 95%CI 0.36-1.05, *I*²=88.4%

• 0.75 log CFU/cm², 95%CI 0.65-0.85, *I*²=0%

Study	Intervention	Description	Mean Difference	MD	95%-CI	Weight
Serraino (2012)	UK scoring system	Clean hide cat. 1 vs Dirty hide cat 5		-2.80	[-3.35; -2.25]	5.0%
Serraino (2012)	UK scoring system	Clean hide cat. 2 vs Dirty hide cat 5		-2.20	[-2.78; -1.62]	5.0%
Serraino (2012)	UK scoring system	Clean hide cat. 1 vs Dirty hide cat 4		-2.10	[-2.50; -1.70]	5.4%
Serraino (2012)	UK scoring system	Clean hide cat. 1 vs Dirty hide cat 3		-1.50	[-2.32; -0.68]	4.3%
Serraino (2012)	UK scoring system	Clean hide cat. 2 vs Dirty hide cat 4	- 	-1.50	[-1.94; -1.06]	5.3%
Blagojevic (2012)	UK scoring system	Clean hide cat. 1 vs Dirty hide cat 4	<u> </u>	-1.13	[-1.65; -0.61]	5.1%
Hauge (2012)	Norwegian scoring system	Clean hide cat. 0 vs Dirty hide cat 1	*	-0.90	[-1.30; -0.50]	5.4%
Serraino (2012)	UK scoring system	Clean hide cat. 2 vs Dirty hide cat 3		-0.90	[-1.74; -0.06]	4.3%
Blagojevic (2012)	UK scoring system	Clean hide cat. 2 vs Dirty hide cat 4		-0.76	[-1.29; -0.23]	5.1%
McEvoy (2000)	Irish scoring system	Clean hide cat. 2 vs Dirty hide cat 3		-0.62	[-1.06; -0.18]	5.3%
McEvoy (2000)	Irish scoring system	Clean hide cat. 2 vs Dirty hide cat 5	֥ -	-0.54	[-1.04; -0.04]	5.2%
McEvoy (2000)	Irish scoring system	Clean hide cat. 2 vs Dirty hide cat 5	÷ • -	-0.53	[-0.96; -0.10]	5.3%
McEvoy (2000)	Irish scoring system	Clean hide cat. 2 vs Dirty hide cat 5		-0.53	[-1.13; 0.07]	4.9%
McEvoy (2000)	Irish scoring system	Clean hide cat. 2 vs Dirty hide cat 3		-0.49	[-1.09; 0.11]	4.9%
Hauge (2012)	Norwegian scoring system	Clean hide cat. 0 vs Dirty hide cat 2		-0.48	[-1.16; 0.20]	4.7%
McEvoy (2000)	Irish scoring system	Clean hide cat. 2 vs Dirty hide cat 3		-0.34	[-0.87; 0.19]	5.1%
Blagojevic (2012)	UK scoring system	Clean hide cat. 1 vs Dirty hide cat 3		-0.34	[-0.73; 0.05]	5.4%
McEvoy (2000)	Irish scoring system	Clean hide cat. 2 vs Dirty hide cat 5		-0.15	[-0.93; 0.63]	4.5%
McEvoy (2000)	Irish scoring system	Clean hide cat. 2 vs Dirty hide cat 3		-0.02	[-0.81; 0.77]	4.4%
Blagojevic (2012)	UK scoring system	Clean hide cat. 2 vs Dirty hide cat 3	+	0.03	[-0.38; 0.44]	5.4%
Heterogeneity: I ² =8	8.4%, t ² =0.515, p<0.0001			-0.90	[-1.26; -0.54]	100.0%
			-3 -2 -1 0 1 2 3			

E. coli reduction:

Study	Intervention	Description	Mean Difference	MD	95%-CI	Weight	
Serraino (2012) Serraino (2012) Serraino (2012) Serraino (2012) Blagojevic (2012) Serraino (2012) Blagojevic (2012) Blagojevic (2012) Blagojevic (2012)	UK scoring system UK scoring system	Clean hide cat. 1 vs Dirty hide cat 3 Clean hide cat. 2 vs Dirty hide cat 3 Clean hide cat. 2 vs Dirty hide cat 5 Clean hide cat. 2 vs Dirty hide cat 5 Clean hide cat. 2 vs Dirty hide cat 4 Clean hide cat. 1 vs Dirty hide cat 4 Clean hide cat. 1 vs Dirty hide cat 4 Clean hide cat. 2 vs Dirty hide cat 4 Clean hide cat. 2 vs Dirty hide cat 4 Clean hide cat. 2 vs Dirty hide cat 3 Clean hide cat. 2 vs Dirty hide cat 3		-1.50 -1.50 -1.10 -1.10 -0.71 -0.70 -0.70 -0.68 -0.05 -0.02	[-2.61; -0.39] [-2.61; -0.39] [-1.56; -0.64] [-1.10; -0.32] [-1.21; -0.19] [-1.21; -0.19] [-1.17; -0.19] [-0.36; 0.26] [-0.44; 0.40]	5.1% 5.1% 11.1% 11.1% 11.8% 10.5% 10.5% 10.7% 12.7% 11.5%	
Heterogeneity: I ² =74	4.0%, t ² =0.175, p<0.0	0001		-0.71	[-1.05; -0.36]	100.0%	
			-2 -1 0 1 2				

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WG3 Beef abattoir interventions – Cattle hide interventions overall

- Under commercial abattoir conditions:
 - Shellac spray hide coating
 - Cetylpyridinium chloride spray wash
 - Sanitizer spray wash
 - Sodium hydroxide spray wash
- Together these studies showed:
 - ACC reduction:
 - 1.09 log CFU/cm², 95%CI 0.65-1.53, I²=100% ⁶

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tudy	Intervention	Description	Mean Difference	MD	95%-CI	Weight	
ntic (2011) osilevac (2004) ntic (2011) ntic (2018) osilevac (2005a) ntic (2018)	Shellac (23%) spray in ethanol hide coating Cetylpyridinium chloride 1% spray wash Proprietary QAC sanitiser wash with vacuum Aqueous shellac (35%) hide spray coating Sodium hydroxide 1.5% spray wash/chlorine rinse with vacuum Aqueous shellac (35%) hide spray coating	20°C, 8min 20°C, 3+1min, 500 lb/in² 50°C, 6min 20°C, 3min 65°C, 700 lb/in² 20°C, 3min	*	-1.70 -1.50 -1.00 -0.96 -0.80 -0.61	[-2.17; -1.23] [-1.50; -1.50] [-1.61; -0.39] [-1.27; -0.65] [-0.80; -0.80] [-0.93; -0.29]	14.3% 19.9% 12.0% 17.0% 19.9% 16.8%	
eterogeneity: I ² =10	00%, t ² =0.14, p<0.0001			-1.09	[-1.53; -0.65]	100.0%	
			2 1 0 1 2				

EBC reduction:

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0.81 log CFU/cm², 95%CI 0.28-1.35, I²=9

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Study	Intervention	Description	Mean Difference	MD	95%-CI	Weight	
Antic (2011) Antic (2011) Bosilevac (2004) Bosilevac (2005a) Antic (2018)	Shellac (23%) spray in ethanol hide coating Proprietary QAC sanitiser wash with vacuum Cetylpyridinium chloride 1% spray wash Sodium hydroxide 1.5% spray wash/chlorine rinse with vacuum Acueous shellac (15%) lide spray roash/chlorine rinse with vacuum	20°C, 8min 50°C, 6min 20°C, 3+1min, 500 lb/in131 65°C, 700 lb/in ² 20°C, 3min	*	-1.40 -1.30 -1.10 -0.80 0.33	[-1.99; -0.81] [-1.85; -0.75] [-1.20; -1.00] [-1.00; -0.60]	13.6% 14.2% 18.9% 18.3% 18.3%	
Antic (2018)	Aqueous shellac (35%) hide spray coating	20°C, 3min		-0.14	[-0.50; 0.22]	16.6%	
Heterogeneity: I ² =93	3.0%, t ² =0.22, p<0.0001			-0.81	[-1.35; -0.28]	100.0%	
			-1 0 1				



WG3 Results – standard processing procedures: pig scalding



Forest plot of the results of before-and-after trials performed under commercial abattoir conditions to investigate the efficacy of scalding in reducing *Enterobacteriaceae* prevalence on pig carcasses

Study	Intervention	Description	Mean Difference	MD	95%-CI	Weight
Pearce (2004)	Scalding	8 min at 61°C, a linear scald tank	+ !	-3.76 [-	4.07; -3.45]	7.1%
Pearce (2004)	Scalding	8 min at 61°C, a linear scald tank		-3.81 [-	4.12; -3.50]	7.1%
Pearce (2004)	Scalding	8 min at 61°C, a linear scald tank	-	-3.72 [-	4.03; -3.41]	7.1%
Rivas (2000)	Scalding		•	-2.14 [-	2.22; -2.06]	7.2%
Rahkio (1992)	Scalding			0.07 [-	0.15; 0.29]	7.1%
Rahkio (1992)	Scalding			-0.78 [-	1.02; -0.54]	7.1%
Spescha (2006)	Scalding	5 min immersion at 59°C-62°C	•	-3.05 [-	3.16; -2.94]	7.2%
Spescha (2006)	Scalding	5 min immersion at 59°C-62°C	+	-3.21 [-	3.32; -3.10]	7.2%
Spescha (2006)	Scalding	5 min immersion at 59°C-62°C	+	-3.19 [-	3.32; -3.06]	7.2%
Spescha (2006)	Scalding	5 min immersion at 59°C-62°C	•	-3.37 [-	3.48; -3.26]	7.2%
Spescha (2006)	Scalding	8.5 min immersion at 59°C-62°C	+	-3.23 [-	3.35; -3.11]	7.2%
Spescha (2006)	Scalding	8.5 min immersion at 59°C-62°C	+	-3.25 [-	3.38; -3.12]	7.2%
Spescha (2006)	Scalding	8.5 min immersion at 59°C-62°C	+	-3.16 [-	3.30; -3.02]	7.2%
Spescha (2006)	Scalding	8.5 min immersion at 59°C-62°C	+	-3.16 [-	3.30; -3.02]	7.2%
Random effects mode Heterogeneity: $I^2 = 99\%$,	Ι τ ² = 1.2829, <i>p</i> =	0		2.84 [-:	3.50; -2.18]	100.0%

Forest plot of the results of before-and-after trials performed under commercial abattoir conditions to investigate the efficacy of scalding in reducing aerobic colony count (log₁₀ CFU) on pig carcasses

WG3 Results – standard processing procedures: pig singeing



Forest plot of the results of before-and-after trials performed under commercial abattoir conditions to investigate the efficacy of singeing in reducing *Enterobacteriaceae* prevalence on pig carcasses



Forest plot of the results of before-and-after trials performed under commercial abattoir conditions to investigate the efficacy of singeing in reducing aerobic colony count (log₁₀ CFU) on pig carcasses





WG3 Pre-chill beef carcass SPPs: water wash

Study	Intervention	Description		Risk	Ratio		RR	9	5%-CI	Weight	
Gill & Landers (2003b) Gill & Landers (2003b) Gill & Landers (2003b) Gill & Landers (2003b) Gill & Landers (2003b)	Water wash Water wash Water wash Water wash Water wash	Post-evisceration cabinet, 40°C, 280 psi, 25 s Post-evisceration cabinet, 40°C, 280 psi, 25 s Post-evisceration cabinet, 40°C, 280 psi, 12 s Post-evisceration cabinet, 40°C, 280 psi, 25 s Cold water at 2°C, 140 psi					0.53 0.88 1.00 1.00 31.00	[0.28; [0.58; [0.59; [0.85; [0.06; 164	1.03] 1.34] 1.70] 1.18] 28.28]	22.8% 25.1% 24.0% 26.6% 1.5%	
Heterogeneity: I ² =14.7%	ot ² =0.61, p=0.32	2			↓ ↓]	0.88	[0.44;	1.79]	100.0%	\sum
			0.001	0.1	1 10	1000					

Forest plot of the results of before-and-after trials performed under **commercial abattoir** conditions to investigate the efficacy of water wash in reducing **generic** *E. coli* **prevalence** on beef carcasses (low heterogeneity, no effect)



WG3 Results – SPPs: pig carcass water wash

Study	Interventio	n Ri	sk Ratio		RR	95%-0	CI Weight	
Gill (2000)	Water was	h	<u> </u>		1.33	[1.03: 1.7]	20.9%	
Gill (2000)	Water was	h	<u> </u>		1 25	0.88 1.7	3] 13.5%	
Gill (2000)	Water was	h	-+		1.00	[0.89: 1.1	0 41 1%	
Gill (2000)	Water was	h	<u> </u>		1 1/	[0.03, 1.12 [0.72: 1.8	0.1%	
Gill (2000)	Water was	n h —	- E		0.70	[0.72, 1.0]	21 63%	
Gill (2000)	Water was	n			0.19	[0.45, 1.5	0.370	
Gill (2000)	Water was	li —	· .		2.00	[0.21, 2.0	DJ 1.770	
GIII (2000)	water was	n	<u> </u>		3.00	[0.67, 13.4	0] 1.0%	
Gill (2000)	Water was	h –	1		0.92	[0.53; 1.6	1] 6.5%	
Random effects mod	el				1.09	[0.94; 1.2]	7] 100.0%	
Heterogeneity: $I^2 = 26\%$,	$\tau^2 = 0.0110, p$	= 0.22		1				
		0.1 0.5	1 2	10				Weight
Rivas (2000)	Water wash 2	25 s. high pressure	e			-0.3	0 [-0.49: -0.11	1 5.2%
Gill (2000)	Water wash	, 31			_	0.1	3 [-0.14; 0.40	5.0%
Gill (2000)	Water wash				_	-0.0	1 [-0.43; 0.41	j 4.5%
Gill (2000)	Water wash					-0.2	5 [-0.59; 0.09	4.8%
Gill (2000)	Water wash		_			-0.5	3 [-0.95; -0.21] 4.7%
Gill (2000)	Water wash		_			-0.0	5 [-0.27; 0.1 5	5.2%
Gill (2000)	Water wash			- :	_	-0.7	4 [-1.07; -0.41] 4.8%
Gill (2000)	Water wash		_	-		0.5	2 [0.17; 0.87] 4.8%
Gill (2000)	Water wash		•			-1.1	6 [-1.55; -0.77] 4.6%
Yu (1999)	Water wash	Final wash					3 [0.91; 1.65	4.7%
Yu (1999)	Water wash	Final wash				- 0.5	2 [0.05; 0.99	4.3%
Yu (1999)	water wash	Pre-evisceration				-0.5	J [-0.92; -0.08	4.5%
Spescha (2006)	water wash	10°C 10r 15 S				-0.3	3 [-0.49, -0.17	J 5.3%
Spescha (2006)	Water wash	10°C for 15 S				-0.0	3 [-0.15, 0.09] 0.4% 1 5.2%
Spescha (2006)	Water wash	10 C 101 15 S				0.0	J [-0.14, 0.14 2 [0.05: 0.21	J 5.3%
Spescha (2000)	Water wash	10 C 101 15 S		i i i		0.0	5 [-0.05, 0.21 5 [0.27: 0.11	J 5.3%
Spescha (2000)	Water wash	10°C for 15 s				-0.1	9 [-0.27, -0.11]	J 5.4%
Spescha (2000)	Water wash	10°C for 15 c				-0.3	S [0.28 0.28	J 5.4%
Spescha (2006)	Water wash	10°C for 15 s				-0.1) [_0.30 [·] _0.10	1 5.4%
	water wash	10 0 10 10 5				-0.2	. [-0.00, -0.10	1 0.470
Random effects model				_ 🔶		-0.1	2 [-0.35; 0.11] 100.0%
Heterogeneity: $I^- = 90\%$, τ^-	r = 0.2260, p < 0.	01	-1.5 -1	-050	0.5	1 1.5		

Forest plot of the results of before-and-after trials performed under commercial abattoir conditions to investigate the efficacy of singeing in reducing generic *E. coli* prevalence on pig carcasses

 $\blacktriangleright \quad \bigstar$

Forest plot of the results of before-and-after trials performed under commercial abattoir conditions to investigate the efficacy of water wash in reducing aerobic colony count (log₁₀ CFU) on pig carcasses

WG3 Results – SPP: pig carcass rectum sealing



Forest plot of the results of controlled trials performed under commercial abattoir conditions to investigate the efficacy of rectum sealing in reducing *Yersinia enterocolitica* prevalence on pig carcasses



WG3 | Dragan Antic

WG3 Beef pre-chill carcass interventions: hot water wash

Study	Intervention	Description		Mean	Differe	ence		MD	95%-CI	Weight
Gill (2000) Gill (2000) Gill (2000) Gill (1999) Gill (1999) Gill (1999)	Hot water wash Hot water wash Hot water wash Hot water wash Hot water wash Hot water wash	Post-evisceration cabinet, 85°C, 8 s Post-evisceration cabinet, 85°C, 9 s Post-evisceration cabinet, 85°C, 10 s Post-evisceration cabinet, 85°C, 10 s Post-evisceration cabinet, 85°C, 10 s Post-evisceration cabinet, 85°C, 15 s			-			-0.78 -0.71 -0.62 -0.52 -0.49 -0.36	[-1.07; -0.49] [-1.04; -0.38] [-1.03; -0.21] [-0.89; -0.15] [-0.82; -0.16] [-0.72; 0.00]	21.7% 17.7% 12.7% 14.7% 17.4% 15.7%
Heterogene	eity: 1 =0% t =0.01,	p=0.51	Γ	$\dot{\frown}$				-0.59	[-0.76; -0.42]	100.0%
			-1	-0.5	0	0.5	1			

Forest plot of the results of before-and-after trials performed under **commercial abattoir** conditions to investigate the efficacy of hot water wash in reducing **generic** *E. coli* **counts** (log₁₀ CFU) on beef carcasses (low heterogeneity, positive effect)

 $\oslash \bigstar$

Study	Intervention	Description		Risk Ratio)	RR	95%-CI	Weight	
Gill (1999)	Hot water wash	Post-evisceration cabinet, 85°C, 10 s		<u> </u>		0.05	[0.01; 0.36]	5.5%	
Gill (2000)	Hot water wash	Post-evisceration cabinet, 85°C, 10 s	_			0.15	[0.05; 0.44]	10.5%	
Gill (2000)	Hot water wash	Post-evisceration cabinet, 85°C, 12 s	_			0.16	[0.05; 0.47]	10.5%	
Gill (1999)	Hot water wash	Post-evisceration cabinet, 85°C, 10 s				0.28	[0.12; 0.63]	12.8%	
Gill (1999)	Hot water wash	Post-evisceration cabinet, 85°C, 15 s				0.29	[0.13; 0.67]	12.7%	
Gill (2000)	Hot water wash	Post-evisceration cabinet, 85°C, 11 s		<u> </u>		0.42	[0.23; 0.78]	14.7%	
Gill (2000)	Hot water wash	Post-evisceration cabinet, 85°C, 9 s				0.62	[0.41; 0.94]	16.3%	
Gill (2000)	Hot water wash	Post-evisceration cabinet, 85°C, 8 s				0.67	[0.49; 0.90]	17.0%	
Heterogenei	ty: I ² =69.0% t ² =0.4	3, p=0.002	[0.32	[0.17; 0.58]	100.0%	
			0.01 0	.1 1	10 100)			

29-Jun-22

Forest plot of the results of before-and-after trials performed under **commercial abattoir** conditions to investigate the efficacy of hot water wash in reducing **generic** *E. coli* **prevalence** on beef carcasses (high heterogeneity, positive effect)



WG3 Pig abattoir interventions – Hot water washing

Hot water washing effect:

- E. coli prevalence reduced (RR 0.31, 95% CI 0.15-0.64) and counts (1.2 log CFU/cm²; 95% CI 0.34-0.73)
- ACC reduced by 1.32 log CFU/cm² (95% CI 0.71-1.93)

Study	Intervention	Description	Risk Ratio	RR	95%-CI	Weigh
Hamilton, D (2010)	Hot water wash	83.5°C, 15 s		0.11	[0.04; 0.27]	16.79
Hamilton, D (2010)	Hot water wash	83.5°C, 15 s	÷.	0.32	[0.23; 0.44]	21.9%
Gill (1997)	Hot water wash Post-	polishing, pre-evisceration, 85°C, 15 s		0.70	0.51; 0.95]	22.09
Gill (1997)	Hot water wash Post-	polishing, pre-evisceration, 85°C, 15 s		0.81	[0.59; 1.11]	21.9%
Gill (1998)	Hot water wash	85°C, 10 s, carcass split before		0.09	[0.01; 0.65]	8.79
Gill (1998)	Hot water wash	85°C, 10 s, carcass split after		0.08	[0.01; 0.59]	8.7%
Random effects mod	del $r^2 = 0.6180, p < 0.01$			0.31	[0.15; 0.64]	100.0%
neterogeneity. 7 = 9170	$p_{1} = 0.0100, p < 0.01$		0.1 0.51 2 10			

Study	Intervention	Description	Mean Difference	MD	95%-CI	Weight
Hamilton (2010)	Hot water wash	83.5°C, 15 s		-2.25	[-3.61; -0.89]	7.4%
Hamilton (2010)	Hot water wash Dest poliching	83.5°C, 15 S	—	-0.90	[-2.60; 0.80]	5.7% 14.0%
Gill (1997)	Hot water wash Post-polishing	, pre-evisceration, 85°C, 15 s	-	-1.94	[-2.20, -1.00]	14.8%
Gill (1997)	Hot water wash Post-polishing	, pre-evisceration, 85°C, 15 s	_ 	-0.09	[-0.45; 0.27]	14.4%
Gill (1997)	Hot water wash Post-polishing	, pre-evisceration, 85°C, 15 s	<u>i</u>	-0.65	[-1.01; -0.29]	14.4%
Gill (1998)	Hot water wash 85°C, 1	0 s, carcass split before		-1.38	[-1.83; -0.93]	13.8%
Gill (1998)	Hot water wash 85°C,	10 s, carcass split after		-1.70	[-2.01; -1.39]	14.7%
Random effects model Heterogeneity: $I^2 = 93\%$, τ	 ² = 0.4338, <i>p</i> < 0.01			-1.32	[-1.93; -0.71]	100.0%
			-3 -2 -1 0 1 2 3			







29-Jun-22

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WG3 Beef abattoir interventions – Carcass steam pasteurisation

Steam pasteurisation effect:

- *E. coli* prevalence (**RR 0.15**, 95% CI 0.09-0.26) and counts (**0.54 log** CFU/cm²; 95% CI 0.34-0.73)
- Enterobacteriaceae prevalence (RR 0.17, 95% CI 0.07-0.43) and counts 1.04 log CFU/cm² (95% CI 0.60-1.48)
- ACC reduced by 1.14 log CFU/cm² (95% CI 0.93-1.35)

Study	Intervention	Description	Risk Ratio	RR	95%-CI	Weight
Nutsch (1997) Nutsch (1997) Retzlaff (2005) Nutsch (1997) Retzlaff (2005) Retzlaff (2005) Corantin (2005) Gill & Bryant (1997b) Retzlaff (2005) Retzlaff (2005) Heterogeneity: l ² =0% t	Steam pasteurisation Steam pasteurisation	82.2°C, pressurised, 8 s; then cold water spray (4.4°C) at 40 lb/in2, 10 s 82.2°C, pressurised, 8 s; then cold water spray (4.4°C) at 40 lb/in2, 10 s 85.0°C, pressurised, 11 s; then cold water spray (1°C), 12 s 82.2°C, pressurised, 11 s; then cold water spray (1°C), 12 s 82.2°C, pressurised, 6 s; then cold water spray (1°C), 12 s 82.2°C, pressurised, 6 s; then cold water spray (4.4°C) at 40 lb/in2, 10 s 87.6°C, pressurised, 11 s; then cold water spray (1°C), 12 s 87.8°C, pressurised, 11 s; then cold water spray (1°C), 12 s 87.8°C, pressurised, 11 s; then cold water spray (1°C), 12 s 74.5°C, 95 to 100 psi, 5 s 105°C, pressurised, 11 s; then cold water spray (1°C), 12 s 79.4°C, pressurised, 11 s; then cold water spray (1°C), 12 s		0.01 0.02 0.05 0.09 0.09 0.13 0.14 0.33 0.50 0.15	[0.00; 3.81] [0.00; 4.98] [0.00; 8.22] [0.00; 25.34] [0.00; 26.29] [0.00; 55.81] [0.00; 57.17] [0.00; 57.17] [0.00; 57.17] [0.00; 7.17] [0.07; 0.31] [0.04; 2.94] [0.10; 2.43] [0.09; 0.26]	1.6% 1.6% 1.5% 1.5% 1.5% 1.5% 1.5% 34.1% 28.7% 9.9% 15.3%

Sludy	Intervention	Description	RISK RAUO	RR	95%-CI	weight
Retzlaff (2005) Steam pasteurisation	85.0°C, pressurised, 11 s; then cold water spray (1°C), 12 s		0.01	[0.00; 5.42]	2.4%
Nutsch (1997) Steam pasteurisation	82.2°C, pressurised, 6 s; then cold water spray (4.4°C) at 40 lb/in2, 10 s		0.02	[0.00; 12.23]	2.4%
Nutsch (1997) Steam pasteurisation	82.2°C, pressurised, 6 s; then cold water spray (4.4°C) at 40 lb/in2, 10 s		0.02	[0.00; 12.08]	2.4%
Nutsch (1997) Steam pasteurisation	82.2°C, pressurised, 8 s; then cold water spray (4.4°C) at 40 lb/in2, 10 s		0.03	[0.00; 0.20]	13.3%
Retzlaff (2005) Steam pasteurisation	87.8°C, pressurised, 11 s; then cold water spray (1°C), 12 s		0.03	[0.00; 16.99]	2.4%
Nutsch (1997) Steam pasteurisation	82.2°C, pressurised, 8 s; then cold water spray (4.4°C) at 40 lb/in2, 10 s		0.10	[0.03; 0.32]	19.8%
Retzlaff (2005) Steam pasteurisation	73.9°C, pressurised, 11 s; then cold water spray (1°C), 12 s		0.20	[0.03; 1.56]	12.6%
Retzlaff (2005) Steam pasteurisation	79.4°C, pressurised, 11 s; then cold water spray (1°C), 12 s		0.33	[0.08; 1.46]	17.0%
Retzlaff (2005) Steam pasteurisation	76.7°C, pressurised, 11 s; then cold water spray (1°C), 12 s		0.60	[0.17; 2.18]	18.5%
Retzlaff (2005) Steam pasteurisation	82.2°C, pressurised, 11 s; then cold water spray (1°C), 12 s		1.00	[0.07; 14.90]	9.2%
Hotorogo	neity: 1 ² -23.8% t ² -1.00 n-0.22					
neteroge	100, p 0.22			0.17	[0.07; 0.43]	100.0%
			0.001 0.1 1 10 1000			



WG3 Results – hazard-based, pre-chill carcass interventions: **lactic acid wash**



Forest plot of the results of **challenge trials** performed under **laboratory** conditions to investigate the efficacy of lactic acid wash in reducing *Enterobacteriaceae* count (log₁₀ CFU) on pig carcass meat

Study	Intervention	Description	Mean Difference	MD	95%-CI	Weight	
Van Netten (1997)	Lactic acid 1% wash	55°C for 90 s	: -	-0.40	[-0.58: -0.22]	9.0%	
Van Netten (1997)	Lactic acid 2% wash	55°C for 90 s		-1.20	[-1.38; -1.02]	9.0%	
Van Netten (1997)	Lactic acid 5% wash	55°C for 90 s	-	-1.20	[-1.38; -1.02]	9.0%	
Van Netten (1997)	Lactic acid 1% wash	55°C for 90 s	-	-0.70	[-0.88; -0.52]	9.0%	
Van Netten (1997)	Lactic acid 2% wash	55°C for 90 s		-1.40	[-1.58; -1.22]	9.0%	
Van Netten (1997)	Lactic acid 5% wash	55°C for 90 s	-	-1.70	[-1.88; -1.52]	9.0%	
Van Netten (1997)	Lactic acid 1% wash	55°C for 120 s		-1.10	[-1.51; -0.69]	7.3%	
Van Netten (1997)	Lactic acid 2% wash	55°C for 120 s		-1.20	[-1.61; -0.79]	7.3%	
Van Netten (1997)	Lactic acid 5% wash	55°C for 120 s		-1.50	[-1.91; -1.09]	7.3%	
Van Netten (1997)	Lactic acid 1% wash	55°C for 120 s		-0.40	[-0.72; -0.08]	8.0%	
Van Netten (1997)	Lactic acid 2% wash	55°C for 120 s		-1.10	[-1.42; -0.78]	8.0%	
Van Netten (1997)	Lactic acid 5% wash	55°C for 120 s		-1.00	[-1.32; -0.68]	8.0%	
Random effects mode	el		<u> </u>	-1.07	[-1.33; -0.81]	100.0%	
Heterogeneity: $I^2 = 93\%$,	τ ² = 0.1464, <i>p</i> < 0.01						
			-1.5 -1 -0.5 0 0.5 1 1.5				

Forest plot of the results of **challenge trials** and performed under **laboratory** conditions to investigate the efficacy of hot water wash in reducing **aerobic colony count** (log₁₀ CFU) on pig carcasses

WG3 Results – hazard-based, pre-chill carcass interventions: **lactic acid wash**



Forest plot of the results of before-and-after trials performed under **commercial abattoir** conditions to investigate the efficacy of lactic acid spray wash in reducing **generic** *E. coli* **prevalence** on beef carcasses (high heterogeneity, no effect)

Study	Intervention	Description		Mean	Differ	rence		MD	95%-CI	Weight	
Signorini (2018) Signorini (2018) Signorini (2018)	Lactic acid 3% wash Lactic acid 2% wash Lactic acid 2% wash	45-50°C, 11 s, 1.5-3 bar, automated cabinet 20-25°C, 10 s, 1.5-3 bar, automated cabinet 20-25°C, 10-15 s, manual		H.				-1.03 -0.82 -0.07	[-1.26; -0.80] [-1.00; -0.64] [-0.21; 0.07]	32.8% 33.4% 33.8%	
Heterogeneity: I ² =	97.1% t ² =0.24, p<0.00	1	====				_	-0.63	[-1.89; 0.62]	100.0%	
			-1	-0.5	0	0.5	1				

Forest plot of the results of before-and-after trials performed under **commercial abattoir** conditions to investigate the efficacy of lactic acid spray wash in reducing **generic** *E. coli* counts (log₁₀ CFU) on beef carcasses (high heterogeneity, no effect)

IRMINS

WG3 Results – hazard-based, pre-chill beef carcass interventions: **pasteurization & acid**



Forest plot of the results of before-and-after trials performed under **commercial abattoir** conditions to investigate the efficacy of pasteurisation and subsequent acid spray washes in reducing **generic** *E. coli* **prevalence** on beef carcasses (low heterogeneity, positive effect)



WG3 Results – chilling: beef carcass water spray chilling



Forest plot of the results of before-and-after trials performed under **commercial abattoir** conditions to investigate the efficacy of water spray chilling in reducing **generic** *E. coli* **prevalence** on beef carcasses (high heterogeneity, no effect)



WG3Results – chilling: pig carcass **conventional dry chilling**



Study	Intervention	Description	Mean Difference	MD	95%-CI	Weight
Langkabel (2014)	Dry chilling	Conventional chiller	- -	-0.20	[-0.48; 0.08]	6.6%
Langkabel (2014)	Dry chilling	Mobile chilling unit		-0.10	[-0.35; 0.15]	6.7%
Langkabel (2014)	Dry chilling	Conventional chiller		-0.20	[-0.49; 0.09]	6.5%
Langkabel (2014)	Dry chilling	Mobile chilling unit		-0.10	[-0.29; 0.09]	7.0%
Langkabel (2014)	Dry chilling	Conventional chiller		-0.40	[-0.63; -0.17]	6.8%
Langkabel (2014)	Dry chilling	Mobile chilling unit	— • — I	-0.70	[-0.96; -0.44]	6.7%
Pearce (2004)	Dry chilling	2°C - 4°C, 24 h		0.14	[-0.17; 0.45]	6.4%
Pearce (2004)	Dry chilling	2°C - 4°C, 24 h		-0.01	[-0.32; 0.30]	6.4%
Pearce (2004)	Dry chilling	2°C - 4°C, 24 h		0.33	[0.02; 0.64]	6.4%
Gill (2000)	Dry chilling	Dry chilling		-0.38	[-0.83; 0.07]	5.7%
Gill (2000)	Dry chilling	Dry chilling		0.05	[-0.31; 0.41]	6.2%
Spescha (2006)	Dry chilling	4.0 m/s at 2°C		-0.65	[-0.78; -0.52]	7.2%
Spescha (2006)	Dry chilling	4.0 m/s at 2°C		-0.96	[-1.11; -0.81]	7.1%
Spescha (2006)	Dry chilling	4.0 m/s at 2°C		-1.17	[-1.32; -1.02]	7.1%
Spescha (2006)	Dry chilling	4.0 m/s at 2°C	-	-0.89	[-1.03; -0.75]	7.1%
Random effects mo	del			-0.36	[-0.61; -0.12]	100.0%
Heterogeneity: $I^2 = 94\%$	6, τ ⁻ = 0.1789, <i>p</i> <	0.01				
			-1 -0.5 0 0.5 1			

Forest plot of the results of before-and-after trials performed under commercial abattoir conditions to investigate the efficacy of dry chilling in reducing *Enterobacteriaceae* prevalence on pig carcasses

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Forest plot of the results of before-and-after trials performed under commercial abattoir conditions to investigate the efficacy of dry chilling in reducing aerobic colony count (log₁₀ CFU) on pig carcasses

WG3 Results – chilling: blast chilling

Study	Intervention	Description	Risk Ratio	RR	95%-CI Weight
Spescha (2006) Spescha (2006) Spescha (2006) Spescha (2006)	Blast and conventional chilling Blast and conventional chilling Blast and conventional chilling Blast and conventional chilling	Blast for 45 min (8.0 m/s at -8° C) then dry chill 1.0 m/s at 2° C Blast for 45 min (8.0 m/s at -8° C) then dry chill 1.0 m/s at 2° C Blast for 45 min (8.0 m/s at -8° C) then dry chill 1.0 m/s at 2° C Blast for 45 min (8.0 m/s at -8° C) then dry chill 1.0 m/s at 2° C -		0.39 0.04 0.08 0.03	[0.22; 0.68] 33.5% [0.01; 0.32] 22.5% [0.02; 0.32] 27.3% [0.00; 0.42] 16.6%
Random effects model Heterogeneity: $I^2 = 78\%$, τ^2	² = 1.8444, <i>p</i> < 0.01		0.01 0.1 1 10 100	0.10	[0.02; 0.47] 100.0%

Forest plot of the results of before-and-after trials performed under commercial abattoir conditions to investigate the efficacy of blast and conventional chilling in reducing *Enterobacteriaceae* prevalence on pig carcasses

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Study	Intervention	Description	Mean Difference	MD	95%-CI	Weight
Gill (2000)	Blast and conventional chilling	Blast chilling at -20°C for 1h, then dry chill	÷	0.08	[-0.18; 0.34]	9.9%
Gill (2000)	Blast and conventional chilling	Blast chilling at -20°C for 1h, then dry chill	· · · ·	0.29	[-0.03; 0.61]	9.4%
Gill (2000)	Blast and conventional chilling	Blast chilling at -20°C for 1h, then dry chill		-0.26	[-0.60; 0.08]	9.2%
Gill (2000)	Blast and conventional chilling	Blast chilling at -20°C for 1h, then dry chill		- 0.61	[0.11; 1.11]	7.7%
Rahkio (1992)	Blast chilling	Blast at -22°C for 1 h	<u> </u>	-0.04	[-0.24; 0.16]	10.4%
Rahkio (1992)	Blast chilling	Blast at -22°C for 1 h		-0.05	[-0.20; 0.10]	10.6%
Spescha (2006)	Blast and conventional chilling Blas	t for 45 min (8.0 m/s at -8°C) then dry chill 1.0 m/s at 2°C		-0.20	[-0.38; -0.02]	10.5%
Spescha (2006)	Blast and conventional chilling Blas	t for 45 min (8.0 m/s at -8°C) then dry chill 1.0 m/s at 2°C		-0.79	[-0.93; -0.65]	10.7%
Spescha (2006)	Blast and conventional chilling Blas	t for 45 min (8.0 m/s at -8°C) then dry chill 1.0 m/s at 2°C	-+-	-0.59	[-0.73; -0.45]	10.7%
Spescha (2006)	Blast and conventional chilling Blas	t for 45 min (8.0 m/s at -8°C) then dry chill 1.0 m/s at 2°C	-	-0.51	[-0.64; -0.38]	10.8%
Random effects mo	del 6 τ ² = 0 1515 ρ < 0.01			-0.17	[-0.47; 0.12]	100.0%
	-,, p		-1 -0.5 0 0.5	1		

Forest plot of the results of before-and-after trials performed under commercial abattoir conditions to investigate the efficacy of blast and conventional chilling in reducing aerobic colony count (log₁₀ CFU) on pig carcasses.

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WG3 Results – beef carcass multiple pasteurization and acid interventions

Study	Intervention	Description
Gill & Landers (2003b)	Pasteurisation and acid treatment system G	
Gill & Landers (2003b)	Pasteurisation and acid treatment system F	
Gill (2003) Gill (2003)	Pasteurisation and acid treatment system F	
Bacon (2000b)	Pasteurisation and acid treatment system C	
Gill & Landers (2003b)	Pasteurisation and acid treatment system H	
Bacon (2000b)	Pasteurisation and acid treatment system C	
Bacon (2000b)	Pasteurisation and acid treatment system A	
Bacon (2000b)	Pasteurisation and acid treatment system C	
Bacon (2000b)	Pasteurisation and acid treatment system A	
Bacon (2000b)	Pasteurisation and acid treatment system A	

Heterogeneity: I²=92.4% t²=1.05, p=0.002



RR	95%-CI	weight
0.01	[0.00; 3.24]	1.1%
0.02	[0.00; 10.00]	1.1%
0.05	[0.01; 0.33]	6.0%
0.06	[0.01; 0.41]	5.9%
0.13	[0.06; 0.29]	9.9%
0.25	[0.08; 0.78]	8.7%
0.33	[0.21; 0.51]	11.0%
0.43	[0.30; 0.61]	11.1%
0.45	[0.32; 0.63]	11.2%
0.59	[0.45; 0.77]	11.3%
0.63	[0.49; 0.80]	11.3%
1.00	[0.98; 1.02]	11.5%
0.30	[0.16; 0.59]	100.0%

Forest plot of the results of before-and-after trials performed under **commercial abattoir** conditions to investigate the efficacy of multiple pasteurisation and acid interventions in reducing **generic** *E. coli* **prevalence** on beef carcass sides (high heterogeneity, positive effect)

Study	Intervention	Description
Bacon (2000b) Bacon (2000b) Bacon (2000b) Bacon (2000b) Bacon (2000a)	Pasteurisation and acid treatment system C Pasteurisation and acid treatment system A Pasteurisation and acid treatment system C Pasteurisation and acid treatment system A Pasteurisation and acid treatment system A	
Bacon (2000b) Bacon (2000b) Bacon (2000b) Gill (2003)	Pasteurisation and acid treatment system C Pasteurisation and acid treatment system A Pasteurisation and acid treatment system A Pasteurisation and acid treatment system F	

Heterogeneity: I²=97.5% t²=1.37, p<0.0001

n	Mean Dif	ference		MD	95%-CI	Weight
	—			-4.10	[-4.57; -3.63]	11.0%
	+			-3.80	[-4.20; -3.40]	11.1%
				-3.00	[-3.38; -2.62]	11.1%
	-+			-2.80	[-3.17; -2.43]	11.2%
				-2.70	[-3.24; -2.16]	10.8%
	÷-			-2.30	[-2.62; -1.98]	11.2%
				-1.20	[-1.57; -0.83]	11.2%
	-+-			-1.00	[-1.26; -0.74]	11.3%
	-			-0.83	[-1.21; -0.45]	11.1%
	\sim			-2.41	[-3.32; -1.49]	100.0%
			7			
	-4 -2 0	2	4			

Forest plot of the results of before-and-after trials performed under **commercial abattoir** conditions to investigate the efficacy of multiple pasteurisation and acid interventions in reducing **generic** *E. coli* counts (log₁₀ CFU) on beef carcass sides (high heterogeneity, positive effect)

WG3 Results – pig carcass multiple interventions

-4 -2 0 2 4

Study	Intervention	Description	Risk Ratio	RR	95%-CI	Weight
Spescha (2006) Spescha (2006) Spescha (2006) Spescha (2006) Spescha (2006) Spescha (2006) Spescha (2006) Spescha (2006)	Multiple interventions S Multiple interventions S Multiple interventions S Multiple interventions S Multiple interventions Multiple interventions Multiple interventions Multiple interventions	calding, dehairing, singeing, polishing, trimming, water wash, blast chill, dry chill calding, dehairing, singeing, polishing, trimming, water wash, blast chill, dry chill calding, dehairing, singeing, polishing, trimming, water wash, blast chill, dry chill calding, dehairing, singeing, polishing, trimming, water wash, blast chill, dry chill Scalding, dehairing, singeing, polishing, trimming, water wash, dry chill	*	0.14 0.01 0.02 0.00 0.43 0.18 0.17 0.21	[0.09; 0.23] [0.00; 0.07] [0.01; 0.08] [0.00; 0.08] [0.35; 0.54] [0.12; 0.28] [0.11; 0.26] [0.15; 0.31]	14.7% 9.0% 10.9% 4.8% 15.5% 15.0% 14.9% 15.1%
Random effects mod Heterogeneity: $I^2 = 94\%$	del 6, τ ² = 0.8798, <i>ρ</i> < 0.01		0.001 0.1 1 10	0.11	[0.05; 0.23]	100.0%

Forest plot of the results of before-and-after trials performed under commercial abattoir conditions to investigate the efficacy of multiple interventions in reducing *Enterobacteriaceae* prevalence on pig carcasses

Study	Intervention	Description	Mean Difference	MD	95%-CI	Weight
Pearce (2004)	Multiple interventions	Scalding, dehairing, singeing, polishing, water wash, dry chill 24 h, 2°C		-3.22	[-3.55; -2.89]	6.6%
Pearce (2004)	Multiple interventions	Scalding, dehairing, singeing, polishing, water wash, dry chill 24 h, 2°C		-2.70	[-3.03; -2.37]	6.6%
Pearce (2004)	Multiple interventions	Scalding, dehairing, singeing, polishing, water wash, dry chill 24 h, 2°C		-2.60	[-2.93; -2.27]	6.6%
Van Ba (2019)	Multiple interventions	Scalding, dehairing, singeing, water wash, lactic acid 2% spray, dry chill 24 h, 2°C		-4.25	[-4.86; -3.64]	6.1%
Van Ba (2019)	Multiple interventions	Scalding, dehairing, singeing, water wash, lactic acid 4% spray, dry chill 24 h, 2°C +	•	-4.81	[-5.42; -4.20]	6.1%
Rahkio (1992)	Multiple interventions	Scalding, dehairing, singeing, blast chill -22°C for 1 h		-1.34	[-1.61; -1.07]	6.7%
Rahkio (1992)	Multiple interventions	Scalding, dehairing, singeing, blast chill -22°C for 1 h	+	-1.38	[-1.63; -1.13]	6.7%
Spescha (2006)	Multiple interventions	Scalding, dehairing, singeing, polishing, trimming, water wash, blast chill, dry chill	+	-2.32	[-2.47; -2.17]	6.8%
Spescha (2006)	Multiple interventions	Scalding, dehairing, singeing, polishing, trimming, water wash, blast chill, dry chill		-3.08	[-3.20; -2.96]	6.8%
Spescha (2006)	Multiple interventions	Scalding, dehairing, singeing, polishing, trimming, water wash, blast chill, dry chill	+	-2.84	[-2.97; -2.71]	6.8%
Spescha (2006)	Multiple interventions	Scalding, dehairing, singeing, polishing, trimming, water wash, blast chill, dry chill	+	-2.76	[-2.89; -2.63]	6.8%
Spescha (2006)	Multiple interventions	Scalding, dehairing, singeing, polishing, trimming, water wash, dry chill	+	-2.51	[-2.64; -2.38]	6.8%
Spescha (2006)	Multiple interventions	Scalding, dehairing, singeing, polishing, trimming, water wash, dry chill		-3.06	[-3.21; -2.91]	6.8%
Spescha (2006)	Multiple interventions	Scalding, dehairing, singeing, polishing, trimming, water wash, dry chill	+	-3.23	[-3.38; -3.08]	6.8%
Spescha (2006)	Multiple interventions	Scalding, dehairing, singeing, polishing, trimming, water wash, dry chill	+	-2.95	[-3.10; -2.80]	6.8%
Random effects model Heterogeneity: $I^2 = 97\%$, $\tau^2 = 0.7383$, $p < 0.01$				-2.85	[-3.33; -2.37]	100.0%

Forest plot of the results of before-and-after trials performed under commercial abattoir conditions to investigate the efficacy of multiple interventions in reducing aerobic colony count (log₁₀ CFU) on pig carcasses.



WG3 Conclusions

- Beef interventions can control microbial contamination on beef carcasses
 - cattle hide interventions including cleanliness assessments (can produce ~1 log₁₀ reduction in microbial transfer each)
 - carcass steam pasteurisation, hot water washing, multiple (up to 2.5 log₁₀ reduction)
- Pig interventions can control microbial contamination on beef carcasses
 - scalding, singeing, rectum sealing, hot water washing and dry chilling are effective
- Interventions integrated in RB-MSAS:
 - used to prevent carcass microbial contamination: help to "lower" abattoir risk category at the same time
 - used to remove/eliminate hazards from carcasses: applied only in "high risk scenario" (high risk farm + high risk abattoir), i.e. when targets cannot otherwise be met



Systematic review and Meta-analysis of beef, pig, sheep WG3 and poultry interventions

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Thank you for the attention. Please join us at **RIBMINS**



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