Milestone 1 Report

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Cost benefit analysis of spray chilling intervention

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1 Introduction

1.1 Background

It is a mandatory requirement to test for seven Shiga toxin-producing *Escherichia coli* (STEC) in all lots of manufacturing beef exported to the USA and Canada (North America). These seven serotypes of *E. coli* are O157:H7, O26, O45, O103, O111, O121 and O145. Both the US and Canada undertake port-of-entry testing. Other major export markets (including Japan, South Korea and European Union) also undertake port-of-entry testing, with Australian beef abattoirs undertaking routine O157:H7 testing of lots destined for these markets.

The current practice of the Australian beef industry has resulted in a low prevalence of STECs in Australian manufacturing beef lots, which has decreased since 2013 (Figure 3 and Figure 4). This has been due, in part, to the successful holistic management of beef carcases, from handling of livestock pre-slaughter all the way to delivery of product to destination market.

Due to the existing STEC screening and confirmation testing program in place, there have been no port-of-entry rejections of STEC in Australian product or subsequent rejections, from any export markets in the past few years. The current testing procedure involves a screening test. Any samples that are positive from this test (potential positives) are submitted to a secondary confirmatory test.

There are large differences in both STEC prevalence rates, and the antimicrobial interventions used, between Australian abattoirs. A recent trial undertaken by University of Tasmania (UTas), trialled a new antimicrobial intervention as a potential way to reduce *E. coli* and subsequently STEC prevalence.

2 Objective

The objective of this milestone was to undertake a cost benefit analysis for applying chlorine dioxide (ClO_2) or peroxyacetic acid (PAA), to the beef carcase, via a spray chilling system, in regards to reduction in STEC prevalence and resultant savings.

3 Methodology

3.1 Costs related to STECs

The three major areas of cost considered in this report are the testing of presumptive positives (confirmation testing), the downgrade of lots that are confirmed positive and the costs associated with storage of product whilst awaiting results of confirmation testing.

In brief the process for STEC testing is as follows:

- For manufacturing beef being sent to US or Canada, testing of each lot (350 or 700 cartons) are tested for all 7 STECs using a screening test method. If this test gives a positive (presumptive positive) then sample is submitted for a confirmation test (all 7 STECs).
- For manufacturing beef sent to other export markets, testing of the majority of lots (not mandatory) are tested for O157:H7 using screening test method. If this test gives a positive (presumptive positive) then sample is submitted for a confirmation test (O157:H7 only).
- If any lots are confirmed positive for any STEC (O157:H7 or any of other 6) then they are heat treated and sold to a market in which price is approximately 50% of non-heat treated product.

The ratio of prevalence for O157:H7 and non-O157 STECs is similar (Figure 3).

The source numbers used for the calculation of STEC costs are summarised in Table 1. In regards to offloading confirmed positive lots, an increase in the number of approved heat treatment plants has increased over the past five years, which has made it easier for abattoirs (particularly smaller companies) to sell this.

Table 1: Industry wide and generic abattoir information related to STEC costs

	Parameter	Value	Source	Assumptions/comments
Industry wide	Average annual kgs sent to North America for manufacturing (mandatory STEC testing) - 2014-2016	256,496,618	MLA statistics download	
	Average annual kgs sent to other export markets for manufacturing - 2014-2016	131,578,794	MLA statistics download	
	Average cattle slaughter in export plants - 2014-2016	8,091,195	DAWR	
	Estimated % of trim sent to North America for manufacturing to total trim	34.7%		300kg HCW; 30% of HCW is trim. Volume sent to North America for manufacturing divided by estimated total trim produced from export plants.
	Average price ($/kg) of manufacturing beef sent to North America - 2014-2016	5.21	MLA statistics download	
	Estimated % of trim sent to other export countires for manufacturing to total trim	18.4%		300kg HCW; 30% of HCW is trim. Volume sent to other export markets for manufacturing divided by estimated total trim produced from export plants.
	% 350 carton lots to North America	84.0%		Based on number of all 7 STEC testing and volumes of manufacturing beef sent to North America
	% 700 carton lots to North America	16.0%		Based on number of all 7 STEC testing and volumes of manufacturing beef sent to North America
	Screening test cost ($/test)	100	Commercial laboratory	
	Confirmation testing cost - all 7 STECs ($/test)	1900	Commercial laboratory	average price
	Storage time required awaiting confirmation test - days	3.5	Commercial laboratory	2-5 days (average of 3) for test; 0-1 day to transport sample to laboratory (average of 0.5)
	Storage cost whilst awaiting confirmation test results ($/carton/day)	0.065	Abattoirs/processing companies	35% of industry have no storage cost due to their lot transport system; 65% of industry have storage cost of $0.10
	O157:H7 confirmation testing cost ($/test)	300	Commercial laboratory	
Generic Beef abattoir	# head processed annually	200,000		
	kg per carton	27.4		industry average
	kgs per 350 lot	9,590		27.4 kg x 350
	kgs per 700 lot	19,180		27.4 kg x 700
	annual kgs of trim produced	18,000,000		300kg HCW; 30% of HCW is trim
	#350 carton lots	1,577		84% of 350 carton lots
	#700 carton lots	150		16% of 700 carton lots
	$/kg of trim	5.21		Based on industry average
	% of product requiring mandatory STEC screening test	34.7%		Product going to North American market
	% downgrade in product value following heat treatment	50%	MLA; abattoirs	

3.2 Review of current practice of carcase management and benefits/costs of interventions

Interviews were undertaken with five specific beef abattoirs regarding their current practice in regards to antimicrobial interventions and their rates of STEC prevalence. The specific situation of four abattoirs has been used as the basis of the data in Table 5 (as data could be sourced from these abattoirs and they represented diversity of operation and STEC prevalence). Further discussions were undertaken with two major beef processing companies.

A generic abattoir scenario was compiled based on industry averages (Table 1) and used as the basis of the data in Table 8.

The "Processor's Guide to Improving Microbiological Quality and Shelf Life of Meat 3rd Edition"[1] was reviewed and relevant data was analysed to determine potential benefits of interventions in regards to STEC prevalence and costs. The data from three abattoirs was used (based on three case studies from Processor's Guide - #22 pages 60-63, #23 pages 64-65, #24 pages 66-69; achieved reductions in STEC and *E. Coli* are detailed in 4.3.1, 4.3.2 and 4.3.3) to compare what was achieved with hot water spray wash or lactic acid spray wash, with the spray chilling interventions. Table 2 lists the operational cost per carcase for each spray wash treatment. The values used for capital cost of installing hot water or lactic acid spray wash system were $400,000[2] and $200,000[3], respectively (costed to have a life of 10 years and discount rate of 7%). Both ClO_2 and PAA are also used currently, in certain abattoirs, as a spray wash. It is important to note that the way spray wash treatments are applied varies considerably between abattoirs and spray wash systems are used for application to whole carcase sides or broken down carcase components. Spray wash systems can be either made in house or provided by external suppliers. As a result, the capital costs may vary significantly from those quoted.

Table 2: Operational cost of hot water and lactic acid spray wash treatments

Cost of hot water	**19.25 L of ~82°C/side**	**Source/assumptions**
cold water - $/kL	3.77	Council rates
82°C water - $/kL (heating)	5.20	P.PIP.0334
19.25 L of 82°C water - $	0.17	7-14 s* of 110 L/min spray** per side
total - $/head	**0.35**	38.5 L/head
Cost of lactic acid	**1.6 L of 2.5%/side**	**Source/assumptions**
cold water - $/kL	3.77	Council rates
lactic acid - 88% - $/ton	1300	Commercial provider
lactic acid - 88% - $/litre	1.57	Based on density
1.6 litres of 2.5% lactic acid - $	0.08	28.75 mls lactic acid/litre
total - $/head	**0.16**	3.2 L/head

P.PIP.0334 - Data collection, base calculations, design and monitoring/SCADA implementation associated with hot water production and distribution upgrade, May 2014. *Pages 60 and 64 of "Processor's Guide to Improving Microbiological Quality and Shelf Life of Meat 3rd Edition". **Page 32 of A.ENV.0090-Environmental data analysis (MLA, July 2011).

3.3 Cost benefit analysis of spray chilling intervention

The two spray chilling interventions trialled previously by UTas were:

- 50 ppm ClO_2
- 200 ppm PAA.

The effectiveness of the interventions (Table 3) was determined by calculating the reduction (versus water) in the average of the percentage of sites that had ≥10 *E. coli* cells. The data for each site was received from UTas. In calculating the benefit of these interventions the %

[1] Publication compiled by South Australian Government (PIRSA and SARDI) in collaboration with MLA and AMPC
[2] Hot Water Rinse intervention summary. Downloaded from MLA website, https://www.mla.com.au/research-and-development/food-safety/food-safety-interventions/
[3] Organic Acids intervention summary. Downloaded from MLA website, https://www.mla.com.au/research-and-development/food-safety/food-safety-interventions/

reduction in *E. coli* was assumed to be equal with reduction in STEC prevalence (34.7% for PAA and 58.7% for ClO_2).

Table 3: *E. coli* prevalence and % reduction with spray chilling treatment

Treatment	Percentage of sites showing to contain ≥10 E. coli cells						% Reduction
	Leg	Bung	Flank	Brisket	Neck	Average	
Water	12	52	64	80	92	60	0
PAA	4	52	36	48	56	39.2	34.7%
ClO2	0	12	16	20	76	24.8	58.7%

The estimated operational costs of the spray chill interventions are $0.37/carcase, ClO_2, and $0.20/carcase, PAA (Table 4). These costs are based on the cost of chemicals only and do not include the cost of the water used for spray chilling. Interestingly another commercial provider of ClO_2 quoted a price of $3.50/litre of 3000 ppm stock, which would give an operational cost of $1.30/carcase and make ClO_2 treatment unaffordable.

Table 4: Cost of spray chill interventions

Cost of ClO_2 spray chill	**50 ppm ClO_2**	**Source/assumptions**
3000 ppm stock - $/litre	1	Commercial provider
litres per head 50 ppm	22.3	P.PIP.0175
$/head	0.37	
Cost of PAA spray chill	**200 ppm PAA**	**Source/assumptions**
PAA stock - $/litre	7.5	Commercial provider
litres per carcase - 200 ppm	22.3	P.PIP.0175
$/head	0.20	1.2 ml PAA stock/litre

P.PIP.0175 – Verification of the effect of spray chilling in preventing chiller yield loss. May 2011.

The UTas-led spray chill trial was undertaken at Longford abattoir. The trial was prompted by a customer request for an antimicrobial intervention to be put in place at this plant.

The capital cost of installing a spray chiller was not considered. The reason for this was that the context of this project was abattoirs who already had an existing spray chiller would be the only plants interested in the interventions (i.e. an abattoir would not be installing a spray chiller for the reason of implementing an antimicrobial intervention with ClO_2 or PAA).

It is important to note that ClO_2 or PAA are not approved for use on beef carcases being exported to several export markets including South Korea and the European Union. However, market access is being sought for these treatments. As a result, a net benefit is presented for two scenarios:

- Only carcases going to North American market being treated, which is 90% of the current STEC cost (4.1)
- All export carcases being treated (no market access or customer restrictions).

The number of head treated for each scenario have been estimated based on the % of manufacturing trim being sent to each market (Table 1). Thus, the assumption of the model is that animals with trim going to North American market have 4.8 times higher STEC cost than those going to other export markets (90% cost [4.1] amongst 65% animals [North

American market; 65% based on trim volumes = 34.7%/(34.7%+18.4%)] vs 10% cost [4.1] shared amongst 35% animals [other export markets; 35% based on trim volumes 18.4%/(34.7%+18.4%)]). This is helpful as an initial comparison. However, it is important to note that this is an oversimplification of what most abattoirs would face in treating whole carcases with ClO_2 or PAA (based on the many markets and customers that may be supplied product from a single carcase and the differences between export country market access restrictions and customer requirements). Further commentary regarding this is provided in 4.4.

3.4 Other benefits

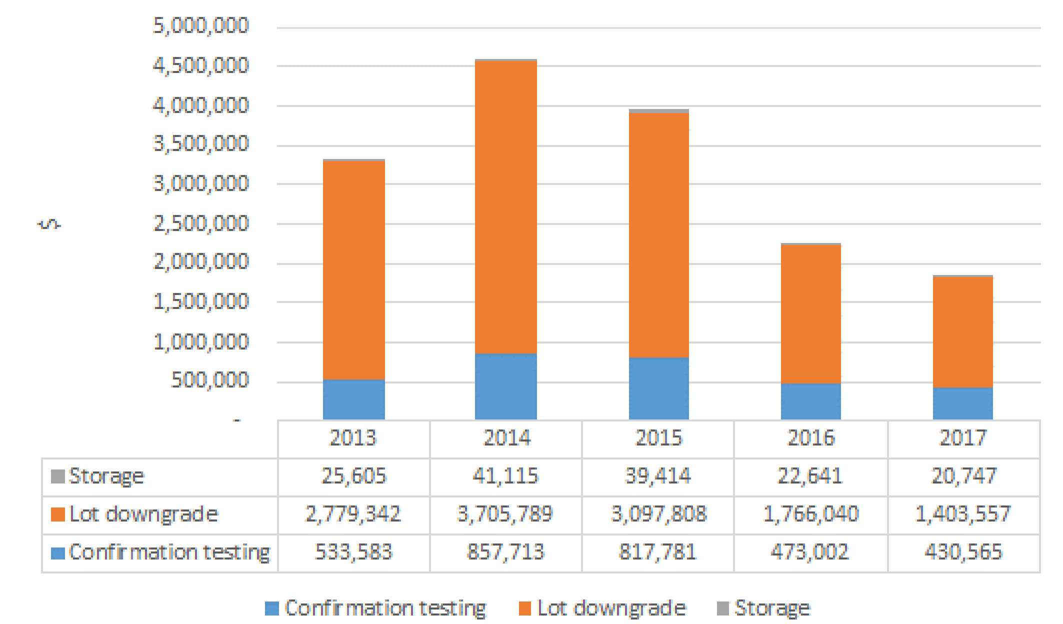
It is important to note that there are other benefits apart from STEC reduction from antimicrobial interventions. This includes removal of faeces and other physical contaminants from carcase (as a result of hot water spray washing), as well as reduction to suitable levels (as necessary) of aerobic plate counts, (other) *E. Coli* and Salmonella (as detailed in documents such as “Processor’s Guide to Improving Microbiological Quality and Shelf Life of Meat 3rd Edition”). The consideration of these other benefits were not part of the scope of this project and thus have not been considered in this report.

4 Results & Discussion

4.1 Whole of industry costs related to STECs

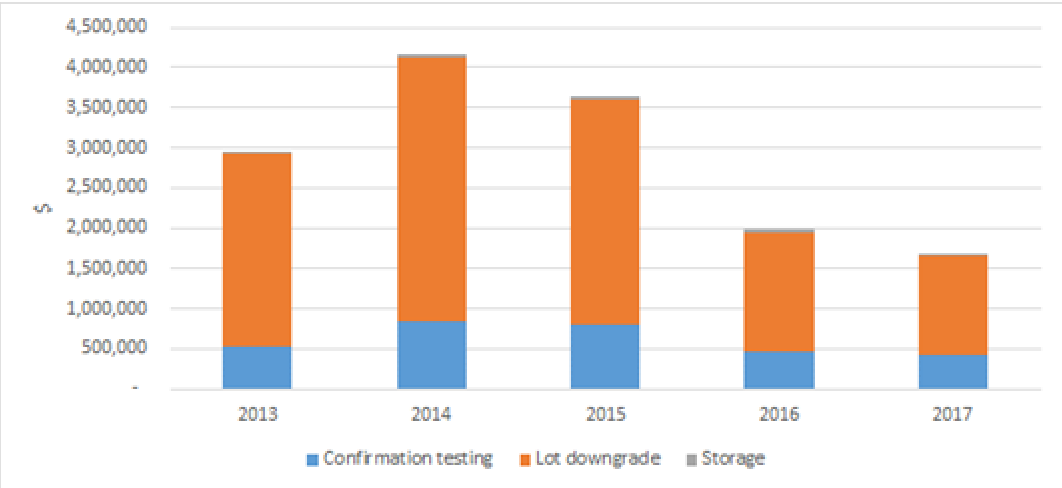
The annual cost of STECs for the Australian beef industry (Figure 1), apart from mandatory and pre-emptive STEC screening (pre-confirmation testing), has been calculated to range from $1.85 (2017; current results adjusted to estimate entire year) to $4.6 million (2014). The majority of the cost (80%) is from confirmed positive lots being downgraded in value. Confirmation testing is 19% of the cost with storage costs being less than 1%. An average of 90% (2013-2017) of the cost is for manufacturing beef being exported to North America (US and Canada; Figure 2).

Figure 1: Cost of STEC for Australian beef industry



	2013	2014	2015	2016	2017
Storage	25,605	41,115	39,414	22,641	20,747
Lot downgrade	2,779,342	3,705,789	3,097,808	1,766,040	1,403,557
Confirmation testing	533,583	857,713	817,781	473,002	430,565

Figure 2: Cost of STEC for product going to North American market



The relative decrease in STEC costs since 2014 are a result of lower cattle numbers and reduced STEC prevalence (Figure 3 and Figure 4).

Figure 3: Prevalence of STECs and cattle slaughtered in export abattoirs (data sourced from DAWR)

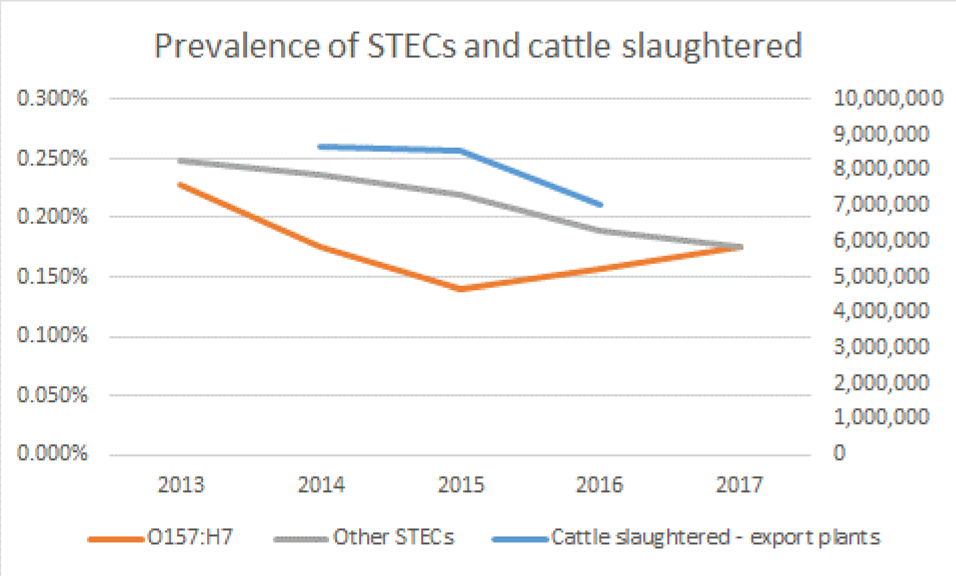
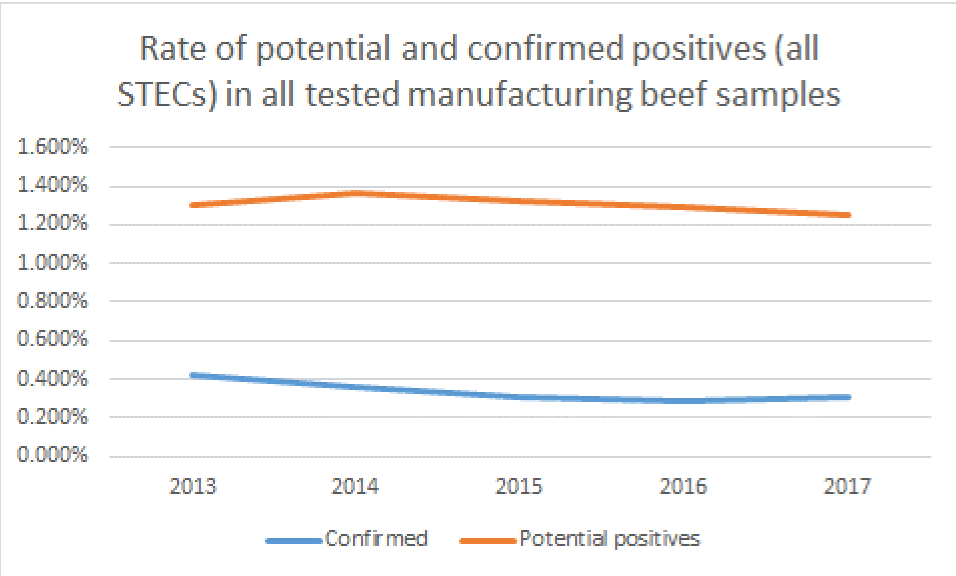


Figure 4: Rate of potential and confirmed positives (O157:H7 or all 7 STECs, depending on confirmation test/market) in manufacturing beef lots (data sourced from DAWR)



4.2 Comparison of current abattoir practice and STEC prevalence, and spray chill intervention opportunity

Table 5 shows the comparison for four abattoirs in regards to STEC prevalence. Abattoir A and B have low STEC prevalence (24% and 31% of industry average of confirmed positives) and because of this there is no net benefit for either spray chill intervention. Abattoir C has high prevalence (393% of industry average) and thus has a net benefit for both ClO_2 ($32,006/annum) and PAA intervention ($19,351/annum). Abattoir D has higher STEC prevalence (175% industry average) and thus also has net benefit for both treatments. In terms of net benefit per head, for abattoirs C and D, Table 6 details the current situation in which there is market restrictions on usage. Table 7 shows a future situation in which there were no market access limitation for ClO_2 or PAA, with net benefit/annum estimated to increase by 20-40%.

This information highlights several key points:

- there are large differences in abattoir practice in regards to antimicrobial interventions
- there are large differences in STEC prevalence between abattoirs
- for abattoirs that have low STEC prevalence there is no net benefit for spray chill treatments.

Table 5: Comparison of four abattoirs – STEC prevalence and costs and net benefit for spray chill interventions

Abattoir	Antimicrobial interventions	Spray chill	STEC prevalence	Prevalence relative to industry average	Current costs of STECs - $/annum	ClO2 treatment - net benefit/annum	PAA treatment - net benefit/annum
A	hot water spray	yes	0.07%	24%	$24,986	-$18,979	-$2,757
B	pre-slaughter wash	yes	0.09%	31%	$15,339	-$11,802	-$1,774
C	none	yes	1.14%	393%	$86,544	$32,006	$19,351
D	pre-slaughter wash	no	0.51%	175%	$343,498	$125,041	$74,799

Table 6: Net benefit per head for abattoirs C and D

Abattoir	ClO2 treatment - net benefit/head	PAA treatment - net benefit/head
C	$1.44	$0.87
D	$2.70	$1.61

Table 7: Net benefit per annum for abattoirs C and D in situation with no market access restrictions for use of ClO_2 or PAA

Abattoir	ClO2 treatment - net benefit/annum	PAA treatment - net benefit/annum
C	$38,584	$23,471
D	$175,120	$104,876

Table 8 shows the scenario for a generic abattoir (which may or may not have antimicrobial intervention in place) that processes 200,000 head/annum and has average STEC prevalence. For the current situation (spray chill would be used for carcases destined for North American market) both ClO_2 and PAA would provide a small net benefit ($0.10/head and $0.08/head). In a future situation where market access restriction of usage was removed, the net benefit per head would decrease to -$0.02 ($ClO_2$) and $0.01 (PAA), based on the fact that the trim for the North American market is responsible for 90% of STEC costs (4.1) but only 65% of export manufacturing beef (Table 2, 3.3).

Table 8: Estimated net benefit for generic beef abattoir (200,000 head/annum)

Scenario	STEC prevalence	ClO2 treatment - net benefit		PAA treatment - net benefit	
		per annum	per head	per annum	per head
Spray chill used for North American market	0.30%	$7,135	$0.10	$5,579	$0.08
Spray chill used for all export markets	0.30%	-$1,686	-$0.02	$1,092	$0.01

4.3 Case studies for actual improvements with spray wash interventions versus spray chill interventions

4.3.1 Abattoir 1 – Installed hot water spray wash

Brief summary of abattoir:

- Process 143,000 head/annum (estimated)
- Had higher rates of STEC prevalence than industry average
    - 1.50% confirmed positives
    - Estimated cost was $239,003/annum
- Installed hot water spray system and saw 75% reduction in STEC prevalence
    - 0.38% confirmed positives
- Capital cost of spray wash system estimated to be $0.53/head.

The benefit from hot water system is $10,179 - $52,547/annum greater than the potential opportunity for ClO_2 or PAA spray chill treatment, when considering the scenario where the spray chill treatments are only used for product to North American market (Table 9). However, if spray chill treatments were allowed by all export markets then the ClO_2 treatment ($1.48/head) would have a net benefit equal to the hot water spray wash ($1.49/head), but net benefit from PAA ($0.89/head) would be $0.60/head less than hot water.

Table 9: Comparison of hot water spray wash with spray chill interventions (Ab 1)

		Hot water spray wash	ClO_2 spray chill	PAA spray chill
Spray chill used for North American market	Net benefit/annum	$116,129	$105,950	$63,582
	Net benefit/head	$1.53	$4.02	$2.41
Spray chill used for all export markets	Net benefit/annum	$116,129	$114,602	$69,213
	Net benefit/head	$1.53	$1.51	$0.91

4.3.2 Abattoir 2 – Installed hot water spray wash

Brief summary of abattoir:

- Process 200,000 head/annum (estimated)
- Had average STEC prevalence
    - 1.29% potential positives
    - 0.29% confirmed positives
- Installed hot water spray wash system and reduced *E. Coli* prevalence by 87%
- Extrapolated STEC prevalence to reduce by same factor
- Capital cost of spray wash system estimated to be $0.38/head.

Both spray chill treatments have improved net benefit over hot water spray wash (Table 10).

Table 10: Comparison of hot water spray wash with spray chill interventions (Ab 2)

		Hot water spray wash	ClO2 spray chill	PAA spray chill
Spray chill used for North American market	Net benefit/annum	-$20,775.36	$7,134.55	$5,579.03
	Net benefit/head	-$0.20	$0.10	$0.08
Spray chill used for all export markets	Net benefit/annum	-$20,775.36	$4,522.65	$4,760.44
	Net benefit/head	-$0.20	$0.04	$0.04

4.3.3 Abattoir 3 – Installed lactic acid spray wash

Brief summary of abattoir:

- Process 100,000 head/annum (estimated)
- Had slightly higher rates of STEC prevalence than industry average
    - 1.51% potential positives
    - 0.34% confirmed positives
- Installed lactic acid spray wash system and reduced STEC prevalence by 82%
    - 0.06% confirmed positives
- Capital cost of spray wash system estimated to be $0.38/head.

In the scenario where spray chill treatments were only used for carcases for product to North American market, the net benefit is $1,821 to $3,772 greater than lactic acid spray wash (Table 11). However, if used for all export markets the benefits become similar for all treatments ($0.05/head, Table 11).

Table 11: Comparison of lactic acid spray wash with spray chill interventions (Ab 3)

		Lactic acid spray wash	ClO2 spray chill	PAA spray chill
Spray chill used for North American market	Net benefit/annum	$2,661.76	$6,433.57	$4,483.24
	Net benefit/head	$0.05	$0.19	$0.13
Spray chill used for all export markets	Net benefit/annum	$2,661.76	$2,448.49	$2,490.82
	Net benefit/head	$0.05	$0.05	$0.05

4.4 Comments from abattoirs

A summary of the statements made by abattoirs and commercial providers of equipment, in discussing the spray chill interventions with them, are provided in Table 12 together with directly related consideration.

Table 12: Comments regarding spray chill interventions and related considerations

Comment	Consideration
We think the chemicals may have a negative impact on our equipment and rooms. We build our infrastructure to last for 50 years and are concerned that routine use (of the chemicals) may result in compromising this lifetime.	Suitability of chemicals in spray chillers needs to be confirmed by previous studies (if data is available), or needs to be tested to determine if there are negative impacts on room/equipment (as a result of long term use).
Interventions need to be trialled in a specific plant setting to know the actual benefit (log reduction; prevalence reduction). We would always want to trial an intervention before deciding on whether it was worth committing to.	The data set for the spray chill interventions is small and from one plant. Larger trial at specific plant would be required for abattoir to know actual effectiveness of the system.
I am very surprised to see efficacy of ClO_2 at levels <200 ppm.	Industry information[4] suggests that ClO_2 does not significantly reduce STECs below <200 ppm. Larger trials are required to validate the efficacy of ClO_2 at 50 ppm.

[4] Chlorine Dioxide intervention summary. Downloaded from MLA website, https://www.mla.com.au/research-and-development/food-safety/food-safety-interventions/

The lack of market approval for use of ClO_2 and/or PAA, by certain non-North American export markets, is a major limitation of the treatment.	For abattoirs that process carcases destined to many markets the use of ClO_2 or PAA in spray chilling would be complex. There would be a percentage of carcases that wouldn't be treated and changing spray chilling solution (water vs ClO_2 or PAA) between markets may lead to increased costs. If market access is achieved in all export markets then this problem would be removed.
With the diversity of markets and customers that we supply, we see use of ClO_2 or PAA as a market or customer specific treatment. It would therefore need to applied post chilling via a production line in boning room.	Abattoirs that are needing to implement an intervention (higher rates of STECs and/or customer request for intervention) are currently looking at treatments that can be targeted for specific customers. Certain US customers have requested an antimicrobial intervention be put in place. However, many other customers would not want ClO_2 or PAA treated product, regardless of whether their market access jurisdiction allows it. It is anticipated that more and more customers will want to have 'chemical' free product.

5 Summary and recommendations

For abattoirs that have a spray chiller in place those who could benefit from implementing either ClO_2 or PAA in spray chill, as an antimicrobial intervention, is limited to those with rates of STEC prevalence (at or above industry average). In making an initial decision as to the potential suitability of these interventions, there are two broad considerations as outlined below:

1. STEC prevalence
    a. If >0.29% - there is potential benefit
    b. If <0.29% - there will be little to no net benefit
2. Market to which products from carcases are going
    a. High proportion to North American and other export markets for which ClO_2 or PAA are approved
        i. Potential opportunity
    b. High proportion to other export markets for which ClO_2 or PAA is not approved
        i. Little benefit (currently)

The initial comparison of spray chill treatments with currently used spray wash treatments (hot water or lactic acid), showed a generally similar or improved net benefit for the spray chill treatments. Plants similar to the Longford abattoir (~100,000 head/annum; spray chiller in place) would be most likely to adopt the spray chill treatments, due to:

- having spray chill system in place
- not having antimicrobial intervention in place

- lower head/annum throughput making the relative capital cost of hot water spray wash treatments higher.

Further in-plant trials are required to determine the actual effectiveness (in long term commercial use) of the spray chill treatments. Ideally, if an abattoir is found that fits the criteria described above, then a long term trial that evaluated STEC prevalence over 12 months before and after intervention installation (similar to certain case studies recorded in "Processor's Guide to Improving Microbiological Quality and Shelf Life of Meat 3rd Edition") should be undertaken.

6 Appendix

6.1 List of Tables

6.2 List of figures