AUSTRALIAN MEAT PROCESSOR CORPORATION

Optimised Water Reduction Through Steam Sanitation Technology

Project code:	A.ENV.0136
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Date Published:	March 2015
Published by:	Australian Meat Processor Corporation

Abstract

The extended drought and climate variability has focused the need to continue to drive down water consumption at red meat processing plants. The use of 82°C water for organoleptic sanitation contributes greatly to plant operating costs. Cleaning equipment with pressurised steam enables impact temperatures >100°C. This study aims to investigate the use of steam sanitation of viscera tray surfaces as a way of optimising water reduction. Food contact grade steam was generated via Simon's electric steam boiler VS300 with a steam capacity of 47.7kg/h and VS610 with a steam capacity of 159.1kg/h. Both boilers had a maximum design pressure of 750kPa. The initial study comprised of three 1/8-CD3 (one-piece nozzle to use with steam) nozzles ranging in size (0.5, 1.0 and 2.0) attached to a bar, connected to the boilers. Using triangular spray pattern calculations, the required amount of nozzles needed to adequately cover each tray was calculated for both small stock and beef. This trial was run on the small stock evisceration table where the maximum tray width and depth was 600mm and 100mm respectively. A minimum distance of 120mm from nozzle release to tray surface was achieved. The secondary study incorporated a steam bath and tunnel. Pipes were connected from the boilers and attached to a coil which would be super-heated from the steam and therefore boil the water in the bath. The steam bath sat 140mm below tray surface. Current conditions (82˚C water sanitation) were found to perform sanitising methods to satisfactory organoleptic standards. All three designs of the steam injection bars used in the first study produced steam at a temperature of approximately 30°C at the distance of 120mm. Further research into steam physics and trial performance indicated that the aforementioned steam injection design lacks the ability to produce steam at the required pressure, ensuring that at a distance of 120mm the mandatory temperature of 82°C was met. Microbiological post sampling and the visual assessments were unable to be conducted. At this time, due to the operational facilities available, the design of the initial study was unable to produce steam at the desired pressure, and therefore temperature, which would enable the trays to be sanitised.

The idea has potential, however, further study into boiler capacity and steam injection technology is required. The steam bath in the second study produced temperatures of 82.8˚C at a distance of 140mm. The required temperature is 82°C and therefore results are satisfactory for organoleptic sanitising. Microbiological post sampling and the visual assessments were conducted with the results showing almost 100% elimination of bacteria. However, the second study indicated that the replacement of the hot wash on the evisceration tables with a steam bath generates temperatures necessary for acceptable organoleptic sanitation while optimising water reduction. Further study into steam bath design should incorporate a professionally designed system to improve contact time and the use of recycled steam and water to further water savings.

Executive Summary

This trial has indicated the efficacy of the application of steam technology to achieve a viable alternative to 82°C water and that the alternative had the potential to save energy, water and waste water discharge costs across the industry.

This project aims to significantly reduce water consumption and energy use required to achieve standards necessary when sanitising viscera trays. To avoid contamination, the trays must be cleaned and sanitised between each series. The configuration of the viscera tray cleaning and sanitation step incorporates three separate water sprays. The initial rinse removes fats and solids, preparing the tray for sanitation. The second rinse is the 82°C sanitation step ensuring suitable organoleptic cleanliness. The final cooling rinse then occurs ensuring the tray is cooled to an appropriate ambient temperature before product contact.

Cleaning equipment with pressurised steam enables impact temperatures >100°C. Through design and development of steam sanitation technologies within the Australian red meat processing industry, this study aimed to investigate the use of steam sanitation of viscera tray surfaces as a way of optimising water reduction.

Using an ultrasonic flow meter, flow conditions were calculated at all four evisceration tables. In order to determine accurate conclusions as to current water usage (kL/hr.), flow measurements were taken at all four tables, six times a day, over a period of two days. Once average hourly usage was calculated, daily, monthly and yearly costing's were able to be determined. Microbiological and visual cleanliness of evisceration trays were monitored to ensure required sanitation is currently being met. Microbial assessment was achieved by testing two trays three times daily over five days using Petrifilm. Samples were tested for total viable count of E. coli and coliforms. Visual analysis was conducted in terms of presence or absence of soil types including stain, blood, tissue, and fat.

Food contact grade steam was generated via Simon's electric steam boiler VS300 and VS610 currently employed for steam generation. Both boilers had a maximum design pressure of 750kPa.

The initial study employed a spray bar design employing flat fan nozzles with an overlapping triangular spray pattern was designed to ensure total cover of tray surfaces. A required temperature of 82°C is required for sanitation. The tray surface is 120mm away from the nozzle, therefore, the temperature was measured at a distance of 120mm from nozzle. All nozzles were wide deflected flat spray. The generated pressure from the boiler produced steam at 550kPa that was then delivered to the spray nozzles. A direct correlation between steam pressure and temperature can be derived using steam tables.

The secondary study incorporated food contact grade steam which was again generated via a Simon's electric steam boiler with a maximum design pressure of 750kPa. Excess steam from the boiler would be redirected into a coil placed within a tray of 600mm wide x 400mm long (steam bath) that would then heat water to boiling point and produce steam. The steam would then sanitise the trays passing over it. The tray surface is approx. 140mm away from the steam bath, therefore, the temperature was measured at a distance of 140mm from the source to see if the steam reached the required temperature of 82˚C. The pressure generated from the boiler produced steam at approx. 550kPa that was then delivered to the steam bath.

Both studies were run on the small stock evisceration table where the maximum tray width was 600mm and the tray height was 100mm being the highest of all four tables.

During the first study, each bar containing the different sized nozzle and required nozzle numbers were tested in order to determine which devise produced the desired pressure/temperature. Flows and steam pressures where monitored to determine water use and ensure temperature control for optimum sanitation.

Microbiological and visual cleanliness of evisceration trays were monitored to ensure required sanitation was met. Using Petrifilm, swabs were to be taken pre steam rinse/bath and post to ensure microbes were present and therefore eliminated. Samples were tested for total viable count of E. coli and coliforms. Visual analysis of cleanliness were recorded in terms of high, medium and low soil. Soil types included stain, blood, tissue, and fat.

Current flow condition on the small stock evisceration tables were recorded using an ultrasonic flow meter. Six random recordings were taken each day over a period of two days, totalling 12 samples. Average daily consumption were found to be 10.378kL. Through further calculation daily cost per head, on the assumption of an average of approximately 4000 sheep processed on this table, was determined to be $0.004.

Microbial assessment of current conditions were determined to be within the parameters required for organoleptic standards, as was visual cleanliness.

All three trials of the steam injection bars (study one) were found to produce steam at a temperature of approximately 30°C at the distance of 120mm. The required temperature is 82°C and therefore results are unsatisfactory for sanitising. Further research into steam physics and trial performance indicated that the aforementioned steam injection design lacks the ability to produce steam at the required pressure, ensuring that at a distance of 120mm the mandatory temperature of 82°C was met. At this time, due to the operational facilities available, the design was unable to produce steam at the desired pressure, and therefore temperature, which would enable the trays to be sanitised. The idea has potential, however, further study into boiler capacity and steam injection technology is required.

The steam bath design (study two) was found to produce steam at a temperature of approximately 82.8°C at the distance of 140mm. This exceeds the required temperature of 82°C and therefore results are satisfactory for sanitising trays to produce acceptable organoleptic conditions. Further study into steam bath design (length, application time, steam enclosure efficiency) would again improve organoleptic conditions.

Currently, 82˚C sanitation water use across all four evisceration tables (2x small stock, 2x beef) is approximately 4.868kL/hr. When using geothermal bore water the energy required to heat 4.868kL of water from 40˚C to 82˚C is 19.24GJ when not using a cogen plant. Midfield is currently using a cogen plant which heats the water to 75˚C and therefore the joules needed to heat the water a further 7˚C is approximately 3.47GJ. If using town water the energy required would be greater due to the fact that Geothermal bore water is 40˚C whereas town water is around 13˚C. With the potential of recycling water from sterilisers and steam through the boilers the implementation of a steam bath could potentially wipe out all current energy and water costs.

Capital costs of both studies came to approximately $47,000. $7,000 was spent of design and development. $36,000 installation costs which include the Simon's VS610 boiler, piping and nozzles, microbiological testing and labour. A further $4,000 was used to retrofit both devises to the tables and conclude the study.

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1.0 Background

The extended drought and probability of climate change bringing more frequent drought periods has focused the need to continue to drive down water consumption at meat processing plants (MLA 2008). Currently, the usage of 82°C sterilisation water equates to >60% of total water use at the Australian red meat industry sites (MLA 2011). As part of an industry initiative to investigate possible areas where water use reduction can occur the sterilisation of viscera tray tables has been identified as a considerable water use point where opportunities may occur which will significantly reduce water consumption.

The cost of utility supply to the Australian red meat industry has increased dramatically over the past decade (MLA 2011). The use of 82°C water for organoleptic sterilisation contributes to plant operation costs through water supply, heating and wastewater treatment and disposal costs. This project aims to significantly reduce water consumption and energy use required to achieve standards necessary when sterilising viscera trays.

Following slaughter cattle and sheep are eviscerated; their internal organs and intestines are placed on stainless steel trays. To avoid contamination the trays must be cleaned and sanitised between each series. The configuration of the viscera tray cleaning and sanitation step incorporates three separate water sprays. The initial rinse removes fats and solids, preparing the tray for sanitation. The second rinse is the 82°C sanitation step ensuring suitable organoleptic cleanliness. The final cooling rinse then cools the tray to an appropriate ambient temperature before product contact. The tray operates as a rotating conveyor with separate trays to avoid cross contamination between the carcase viscera. In the case of small stock, the system runs continually throughout the shift whereas in the case of the beef, the system is linked to the splitting of the carcase.

Steam has been used as a cleaning agent in the meat industry for over fifty years (AQIS Meat Notice 2008/01). Cleaning equipment with pressurised steam enables impact temperatures >100°C. The disadvantage of steam is the aerosol formation produced that may affect equipment and employees due to high humidity and condensation.

2.0 Project objectives

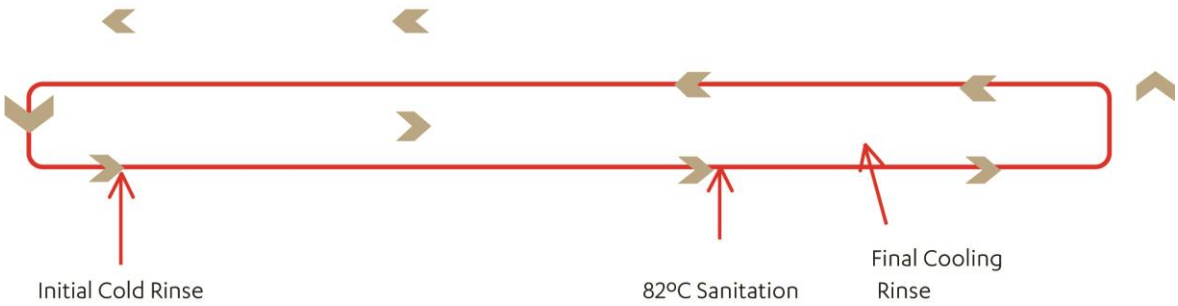
Through design and development of steam sterilisation techniques within the Australian red meat processing industry, this study aims to investigate the use of steam sanitation of viscera tray surfaces as a way of optimising water reduction.

3.0 Methodology

3.1 Current Flow Analysis

Using an ultrasonic flow meter, flow conditions were calculated at all four evisceration tables (2x180 beef and small stock, 2x246 beef and small stock). All tables are relatively consistent in flows (initial cold rinse, 82°C sanitation step and final cooling rinse) (Figure 1).

Figure 1. Current flow diagram



In order to determine accurate conclusions as to current water usage (kL/hr.), flow measurements were taken at all four tables, six times a day, over a period of two days. Once average hourly usage was calculated, daily, monthly and yearly costing's were able to be determined.

3.2 Cleaning - Performance Monitoring of Existing 82°C Water Sanitation Method

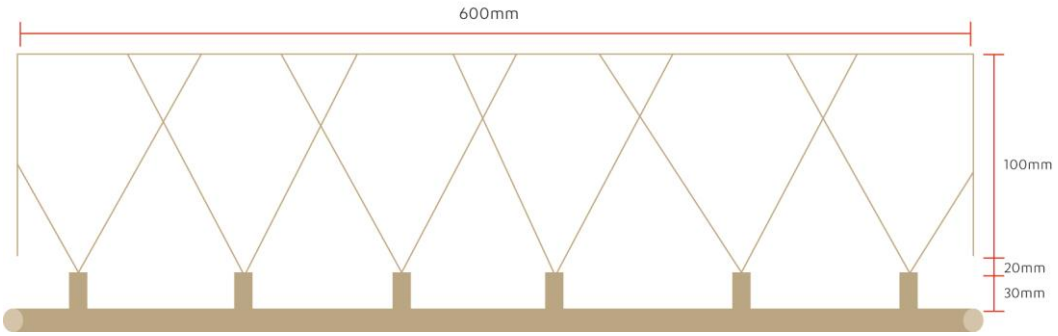
Microbiological and visual cleanliness of evisceration trays were monitored to ensure required sanitation is currently being met. Microbial assessment was achieved by testing two trays three times daily (morning, post smoko and post lunch) over five days using Petrifilm. Samples were tested for total viable count of total plate count, *E. coli* and coliforms. Visual analysis of cleanliness was recorded in terms of high, medium and low soil. Soil types included stain, blood, tissue, and fat.

3.3 Steam Injection Design and Implementation

For this study, food contact grade steam was generated via Simon's electric steam boiler VS300 with a steam capacity of 47.7kg/h and VS610 with a steam capacity of 159.1kg/h, currently employed for steam generation. Both boilers had a maximum design pressure of 750kPa. A spray bar design (Figure 2 and Appendix, Figure 7) employing flat fan nozzles with an overlapping triangular spray pattern was designed to ensure total cover of tray surfaces. A required temperature of 82°C is required for sanitation. During the initial study the tray surface was 120mm away from the nozzle; therefore, the temperature was measured at a distance of 120mm from nozzle. During the secondary study the tray surface was 140mm away from steam bath therefore, again, the temperature was measure at a distance of 140mm.

3.3.1 Study One

Figure 2. Steam spray bar design and small stock tray measurements



Three 1/8-CD3 (one-piece nozzle to use with steam) nozzles ranging in size (0.5, 1.0 and 2.0) were sourced. All nozzles were wide deflected flat spray. The generated pressure from the boiler produced steam at 550kPa that was then delivered to the spray nozzles. A direct correlation between steam pressure and temperature can be derived using steam tables. A 0-1000kPa pressure gauge was installed prior to spray nozzles, which was used as an external reference to ensure desired pressure/temperature was being reached. Table 1 shows the base angle produced by each nozzle and steam production (kg/hr.) when at a pressure of 550kPa.

Table 1. Nozzle type trialled and corresponding steam production

Nozzle type-size	Steam produced (kg/hr) at 550kPa (148°C)	Base angle
CD3-0.5	0.40	39°
CD3-1.0	0.91	48°
CD3-2.0	1.80	55°

This study was run on the small stock evisceration table where the maximum tray width was 600mm and the tray height was 100mm being the highest of all four tables. The amount of nozzles required, to allow for adequate cover, were as follows:

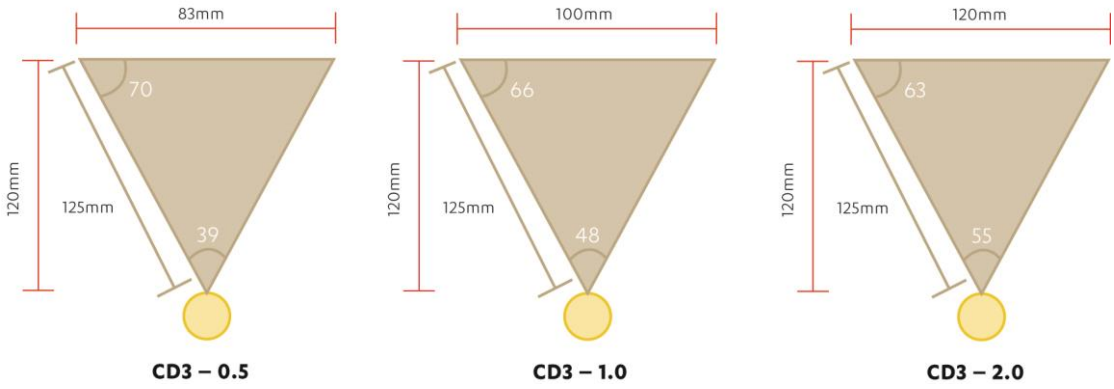
CD3-0.5 – 8 nozzles

CD3-1.0 – 7 nozzles

CD3-2.0 – 6 nozzles

Using triangular spray pattern calculations (Figure 3), the required amount of nozzles needed to adequately cover each tray was calculated for both small stock and beef.

Figure 3. Triangular spray pattern and corresponding angles produced when steam is exerted at a pressure of 350kPa



Each bar containing the different sized nozzle and required nozzle numbers were tested in order to determine which nozzle produced the desired pressure/temperature.

3.3.2 Study Two

Study Two, food contact grade steam was also generated via a Simon's electric steam boiler used for steam generation and redirected into a coil placed within a tray of 600mm x 400mm (steam bath) that would then heat water to boiling point and produce steam. The steam would then sanitise the trays passing over it. The boiler has a maximum design pressure of 750kPa.

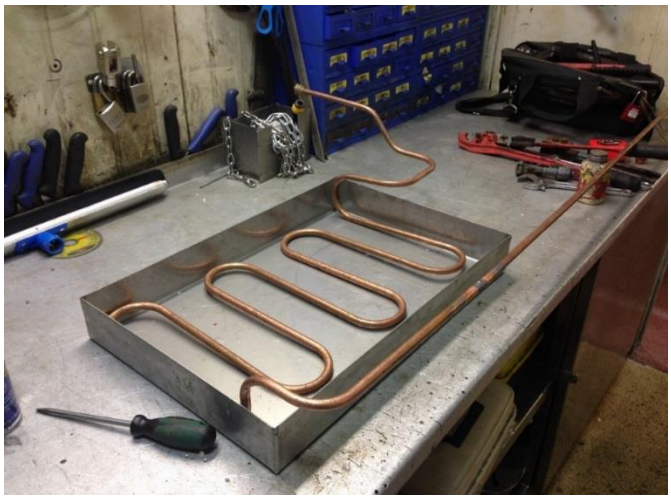
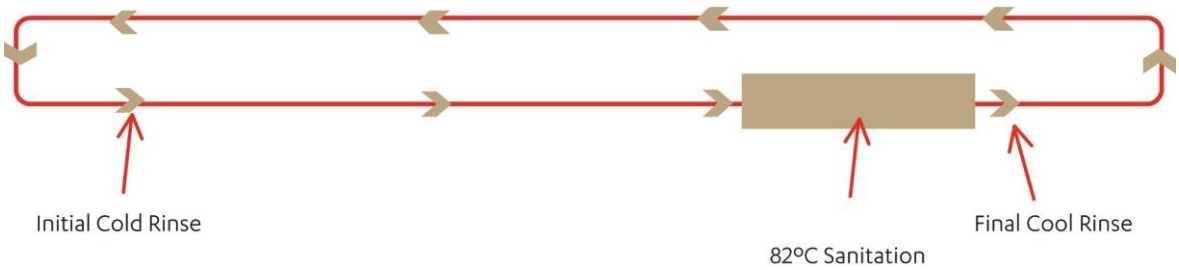


Figure 4. Coil placed in tray to generate steam

This study was also run on the small stock evisceration table where the maximum tray width was 600mm and the tray height was 100mm, the highest of the four evisceration tables within the plant.

Figure 5. Flow diagram with proposed stream sterilisation application



The evisceration table flow was now initial cold rinse followed by the steam sanitation and then a final cold rinse (Figure 5).

3.4 Steam Injection Trial and Performance Monitoring

Both studies were fitted to the small stock evisceration table in Est 180 at Midfield Meat International. Flows and steam pressure where to be monitored to determine water use and ensure temperature control for optimum sanitation (Appendix, Figures 6-9). With regard to Study One, a direct correlation between steam pressure and temperature can be made with steam tables. Flow conditions were to be recorded and analysed using the same method that was used for the 82°C water sanitation. Average consumption was to be determined in order to calculate daily, monthly and yearly costing.

Fog, condensation and humidity was also to be monitored to ensure employee comfort and equipment maintenance.

3.5 Cleaning - Performance Monitoring of Steam Sterilisation

Microbiological and visual cleanliness of evisceration trays were to be monitored to ensure required sanitation was met. Using Petrifilm, swabs were to be taken pre steam rinse/bath and post to ensure microbes were present and therefore eliminated. Microbial assessment was to be achieved by testing two trays three times daily (morning, post smoko and post lunch) over five days at both the pre and post steam sanitation stages. Samples were to then be tested for total viable count of E. coli, coliforms and total plate count. Visual analysis of cleanliness was to be recorded in terms of high, medium and low soil. Soil types included stain, blood, tissue, and fat.

4.0 Results

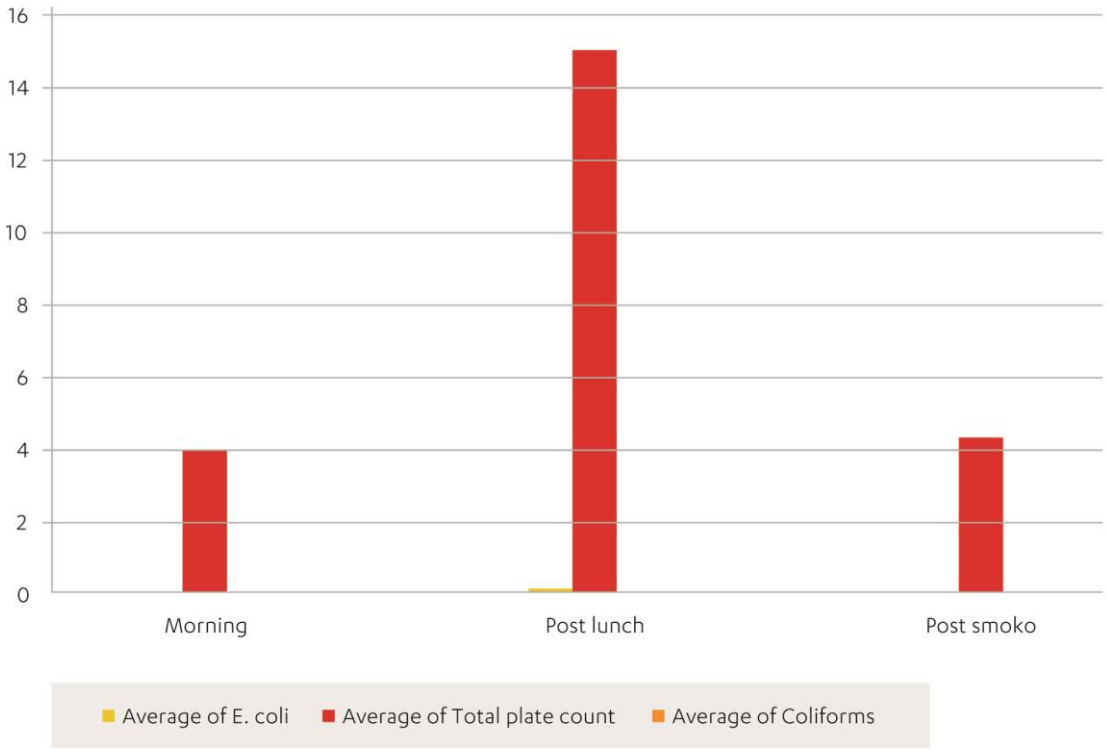
Current flow condition on the small stock evisceration tables were recorded using an ultrasonic flow meter. Six random recordings were taken each day over a period of two days, totalling 12 samples. Averages were calculated in order to determine daily consumption (Table 2). Average daily consumption was found to be 10.378kL. Through further calculation daily cost per head, on the assumption of an average of approximately 4000 sheep processed on this table, was determined to be $0.004.

Table 2. Current water consumption at the 82.5°C sanitation stage with daily, monthly and yearly per head costing

180 Small Stock									
Date	Sample	Usage L/s	Usage kL/hr	Average kL/hr per hr	Average daily consumption (kL)	Costings per day	Costings per week	Costings per year	Total $ per head per day
21-5-14 afternoon	1	0.2765	0.9954	0.9714	10.6854	$15.71	$78.54	$3,926.88	$0.004
	2	0.2821	1.01556						
	3	0.2509	0.90324						
21-5-14 morning	1	0.2985	1.0746	0.98148	10.79628	$15.87	$79.35	$3,967.63	$0.004
	2	0.2845	1.0242						
	3	0.2349	0.84564						
22-5-14 afternoon	1	0.2321	0.83556	0.8934	9.8274	$14.45	$72.23	$3,611.57	$0.004
	2	0.2511	0.90396						
	3	0.2613	0.94068						
22-05-14 morning	1	0.2129	0.76644	0.92748	10.20228	$15.00	$74.99	$3,749.34	$0.004
	2	0.2871	1.03356						
	3	0.2729	0.98244						
Average water consumption				**0.94344**	**10.37784**				
					Average costing	**$15.26**	**$76.28**	**$3,813.86**	**$0.004**

The existing sanitising method were tested to categorically ensure the current technique was working to the standard required. Using Petrifilm 30 swabs were taken over a period of five days. Swabs were tested for *E. coli*, coliforms and total plate count. Microbial assessment was determined to be within the parameters required for organoleptic standards, as was visual cleanliness (Figure 6).

Figure 6. Microbial analysis of current 82.5°C sanitation method. Total viable count recorded for *E. coli*, coliforms and total plate count



4.1 Study One

4.1.1 Trial One

The pre designed steam bar with CD3-1.0 sized nozzles was connected to the VS300 boiler, with a set pressure of 500kPa, and trialled on the small stock evisceration table (Appendix, Figure 6 and 8). Results found the steam temperature at the nozzle release point ranged from 75°C to 90°C. However, temperature dropped exponentially with distance from nozzle. At a distance of 120mm from release, temperature was recorded at approximately 30°C.

4.1.2 Trial Two

Using the VS300 boiler, with an increased pressure of 650kPa, on the small stock evisceration table, separate bar sets with nozzles CD3-0.5 and CD3-2.0 were trialled. Similar results as trial one were recorded. Temperature at nozzle was slightly higher using CD3-2.0 and lower using CD3-0.5, however, not significantly.

4.1.3 Trial Three

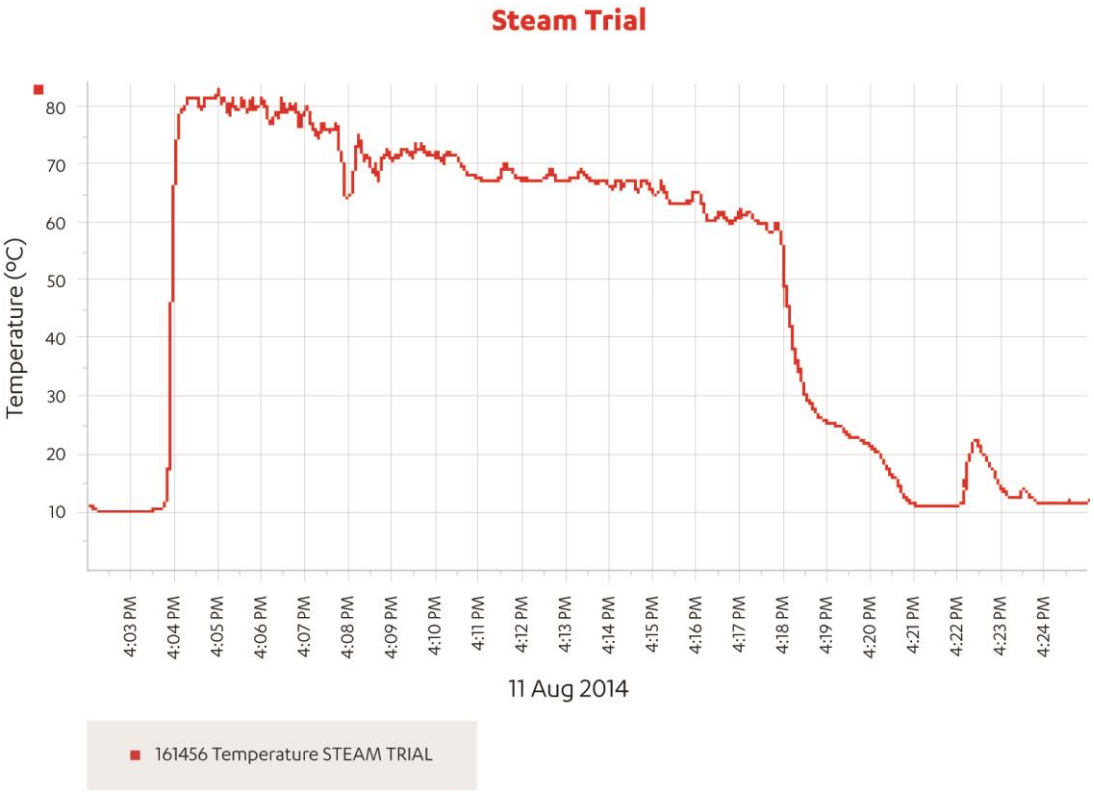
All three bar sets were connected to boiler VS610, currently housed outdoors underneath the production floor (Appendix, Figure 10). Steam bars were turned on and temperature recordings were taken using a hand held thermometer. Temperatures at all nozzles were found to range between 70°C to 80°C and approximately 30°C at a distance of 120mm.

During all three Nozzle trials, steam was let run for 20 minutes in order to expel any residual water and air in pipes before temperature was recorded and all pipework was isolated to the steam trial line. Steam was found to be quite wet and condensation was high.

4.2 Study Two

The steam bath design was found to produce steam at a temperature of approximately 82.8°C at the distance of 140mm. The required temperature is 82°C and therefore results are satisfactory for organoleptic sanitising (Figure 7).

Figure 7. Steam trial temperature data showing peak temperature of 82.8°C produced by steam bath - note temperature drop at 4:08PM due to boiler being switched off during trial.



Visual assessments showed the larger trays being cleaner than the smaller trays due to a longer application/travel time (Figure 8). Of spoil numbers recorded almost all were classed as minor. Microbiological post sampling and the visual assessments were conducted with the results showing almost 100% elimination of bacteria (Figure 9).

Figure 8. Total tray spoil number of the 300 trays analysed

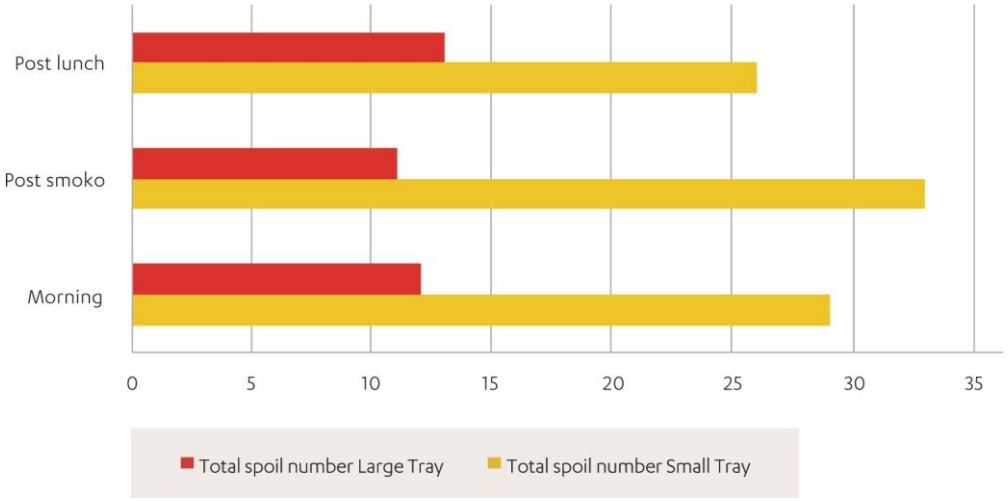
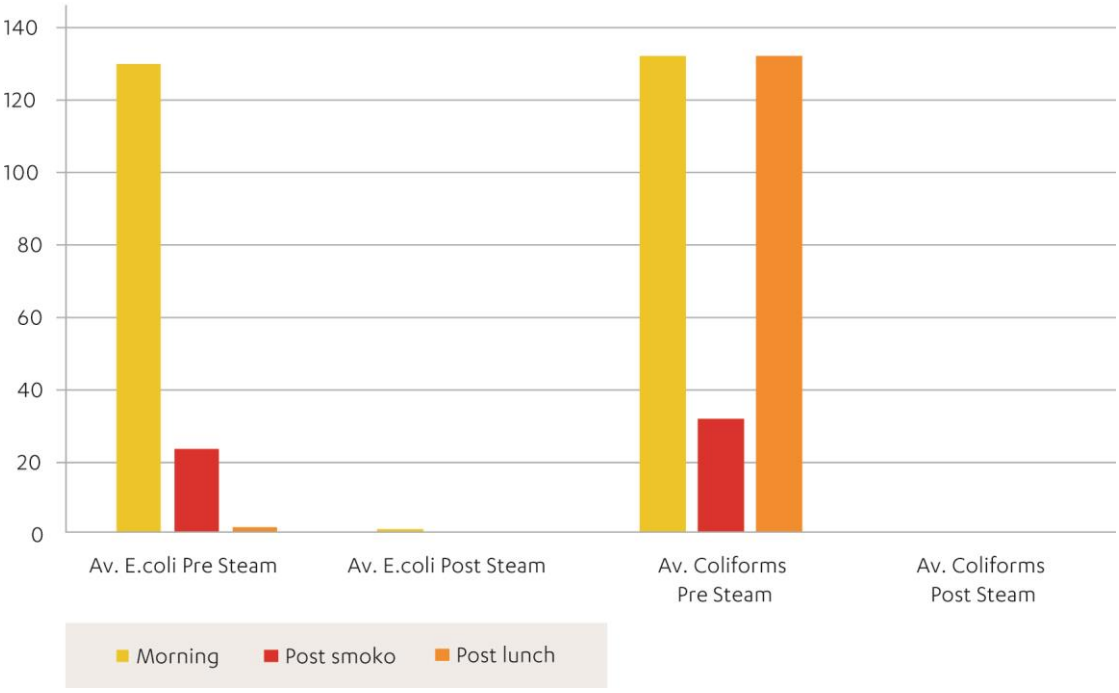


Figure 9. Average plate counts for *E.coli* and Coliforms pre and post steam



Fog was visually assessed to be minimal at the trial site which did not impact the OH&S conditions of the employees, this may have been helped by an existing exhaust fan.

5.0 Discussion

Through trial results and information gathered, current conditions were found to perform sanitising methods to satisfactory organoleptic standards. Visual and microbial analysis determined that the current three stage cleaning, sanitation and cooling method was producing acceptable results.

All three designs, of the steam injection bars, were found to produce steam at a temperature of approximately 30°C at the distance of 120mm. The required temperature is 82°C and therefore results are unsatisfactory for sanitising. Further research into steam physics and trial performance indicated that the aforementioned steam injection design lacks the ability to produce steam at the required pressure, ensuring that at a distance of 120mm the mandatory temperature of 82°C was met. As the steam reaches the nozzle release point the pressure immediately drops to one atmosphere (100˚C).

Microbiological post sampling and the visual assessments were unable to be conducted for the initial study.

The steam bath design was found to produce steam at a temperature of approximately 82.8°C at the distance of 140mm. This is above the required temperature of 82°C and therefore results are satisfactory for sanitising.

At this time, due to the operational facilities available, the Steam Bar and nozzle design (Study One) was unable to produce steam at the desired pressure, and therefore temperature, which would ensure the trays would be sanitised to organoleptic standards. The idea has potential, however, further study into boiler capacity and steam injection technology is required.

Study Two however, indicates that the replacement of the hot wash on the evisceration tables with a steam bath will generate temperatures necessary for acceptable organoleptic sanitation while optimising water reduction.

Further study into steam bath design should incorporate a professionally designed system to improve the following parameters:

- Application time – maximum temperature gained through travel time of trays over steam bath.
- Steam bath size – a longer steam bath would produce higher temperatures consistently and improve results on all size trays.
- Heating coil configuration – numerous coils placed within the tray at appropriate heights for maximum temperature gain.
- Steam tunnel efficiency – enclose steam tunnel by draft proofing from outside cool air as well as ensure that no water is located within the tunnel outside of the bath which can cool the bath when operating.
- Recycle steam trap condensate back into bath depending on temperature
- These improvements would potentially generate higher temperatures more consistently on evisceration tables across the plant.

6.0 Implications for industry

Significant water consumption, energy and waste water disposal savings can be achieved through the introduction of steam sanitation technology within the industry as a replacement for the current hot water sanitation systems. This trial has indicated the efficacy of the application of steam technology to achieve sanitation equivalent to that of the 82°C water sanitation method currently employed throughout the industry.

Due to observations conducted during this study Midfield Meat will now initiate a change to the first cold rinse from potable town water to a chlorinated bore water source assisting in reducing water and heating costs. It was also observed, after the visual and microbial assessment on current sanitising methods was conducted, that half of the nozzles at the initial rinse stage were facing the ground this has led to an investigation in to the potential of using less nozzles, and therefore less water, and whether or not the rinse would continue to adequately wash off fat and tissue.

7.0 Acknowledgments

We would like to thank MLA whose contribution made this study possible. We are also extremely appreciative to whomever encouraged or contributed to this study in particular Matt Boyce formally of Midfield Meat International, whose valuable input meant the study was able to be conducted as it was, also Joel Barclay, Shane Byron, Andrew Westlake, Noel Kelson, Sarah Farrell and O'Brian's Boilers for their help in building on the steam injection sanitation concept/design and their roles in bringing about the trial.

8.0 References

MLA Terms of reference – Water Use Reduction 2008

MLA Full research proposal submission form 2011

AQIS Meat Notice number: 2008/01. Protocol for Alternative Procedures and New Technology Approvals. NSFS Ref 17

Appendix 1

Potential costings and savings

Table 3. Standard costing per 11 hour shift of a) Standard current beef evisceration table and B) Standard sheep evisceration table using 82°C water for sanitation. C) Estimated costing using steam sterilisation technology

a) Shift totals						
	Water	**Heating**	**Trade Waste**		**Total**	**$/kL**
1st Rinse	$ 83.06	$ -	$ 18.82		$ 101.88	$ 2.62
Sanitation	$ 47.63	$ 5.69	$ 15.68		$ 69.00	$ 2.13
Final Rinse	$ 38.28	$ -	$ 8.67		$ 46.95	$ 2.62
Total	**$ 168.96**	**$ 5.69**	**$ 43.18**		**$ 217.83**	**$ 2.44**
b) Shift totals						
	Water	**Heating**	**Trade Waste**		**Total**	**$/kL**
1st Rinse	$ 29.04	$ -	$ 6.58		$ 35.62	$ 2.62
Sanitation	$ 17.46	$ 2.09	$ 5.75		$ 25.30	$ 2.13
Final Rinse	$ 12.34	$ -	$ 2.80		$ 15.14	$ 2.62
Total	**$ 58.85**	**$ 2.09**	**$ 15.13**		**$ 76.06**	**$ 2.43**
C) Shift totals						
	Water	**Heating**	**Trade Waste**		**Total**	**$/kL**
1st Rinse	$ -	$ -	$ 6.58		$ 6.58	$ 0.48
Sanitation	$ 0.05	$ -	$ 5.75		$ 5.80	$ 2.05
Final Rinse	$ 12.34	$ -	$ 2.80		$ 15.14	$ 2.62
Total	**$ 12.39**	**$ -**	**$ 15.13**		**$ 27.52**	**$ 0.88**

Trial Photos

Figure 11. Evisceration table where steam injection system was trialled | Figure 12. Steam bars used in trial

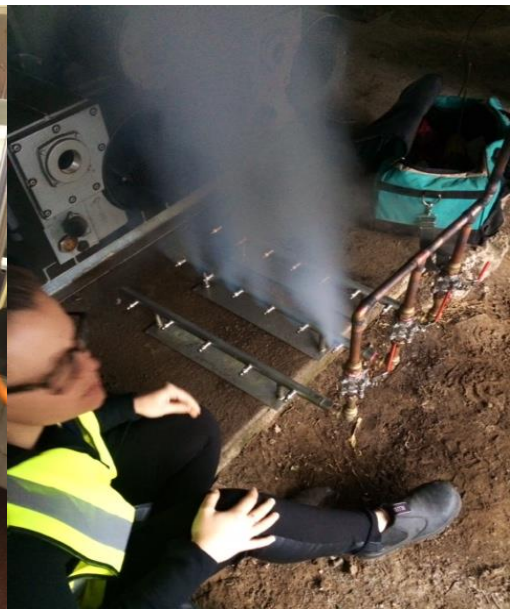


Figure 13. Steam bar attached to sanitation point on table | Figure 14. Steam bars connected to boiler under plant floor.

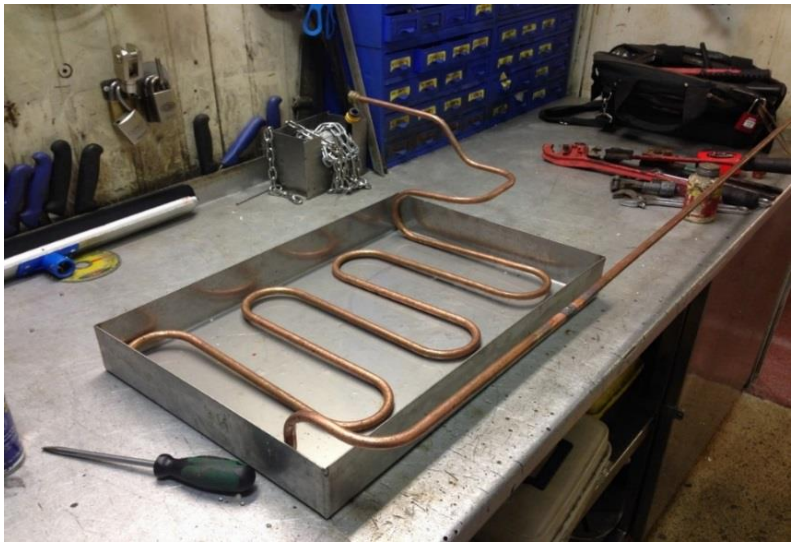


Figure 15. Coil placed in tray to generate steam

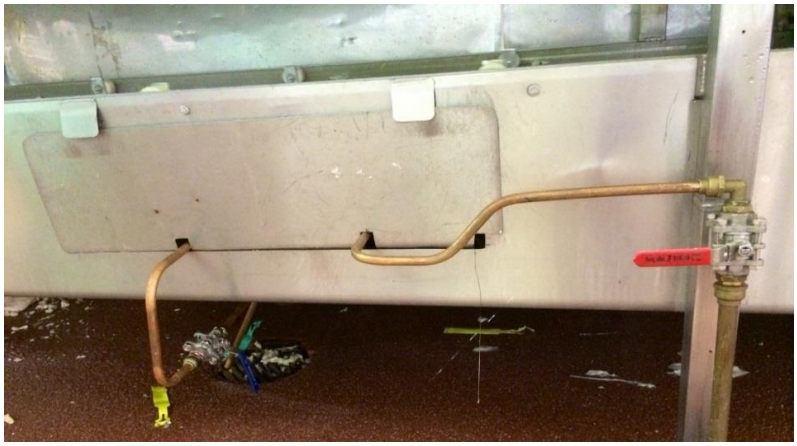


Figure 16. Steam bath tunnel in study two (closed).

Figure 17. Steam bath tunnel in study two (open).