final report

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Cost Benefit analysis of customised manual assist equipment installed in two plants for aitch bone removal and knuckle pulling

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Contents

1. Executive Summary

The topic of the study was related to the installation of newly developed manual assist equipment for semi-automated removal of the aitch bone and the knuckle from the hindquarter of beef. The equipment consisted of a Proman aitch bone puller, and a Robotic Technologies LTD (RTL) Beef Boning Unit being used for aitch bone pulling, and a customised knuckle puller. Two processing plants were observed in the study. Plant 1 was using the Proman aitch bone puller and the customised knuckle puller, while plant 2 was using a combination of the RTL Beef Boning Unit for removal of the aitch bones and the customised knuckle puller.

The objective of the study was to quantify the costs and benefits that the processing plants were realising with the installation of the new equipment. Benefits included reduced injury resulting in reduced OH&S costs, increased yield, increases in the available labour pool, and benefits through increased chain speed. Costs were itemised as 1) capital cost, 2) cleaning and 3) maintenance. Risks were also identified that could have a negative impact, these included mechanical injury to operator, damaged product and mechanical failure.

The review establishes that the manual assist equipment provides several important benefits for the beef processing industry. Perhaps the most significant included the perceived benefit on the long term health and viability of operators who often work in the highly repetitive, high strain environment on a long term basis. Other significant benefits to the labour pool included increased flexibility in the management staff, and a reduction in the time required for training operators.

An economic analysis was conducted on the viability of the equipment installed in processing plant 1 and 2. The summary results are presented in table 1, and show that installation of the manual assist equipment resulted in immediate economic returns for the plants reviewed with a payback period of 1.66 months and 1.71 months for plant 1 and 2 respectively. Yield gains were identified as one of the biggest economic drivers. While trial data sets did not allow advanced fatigue modelling, these yield gains were attributed to enhanced operator performance through reduced fatigue, and improved technique.

Operational differences are observed between the different manual assist equipment and are discussed in the results section and summarised in Table 15.

Table 1: Summary of cost benefit analysis for reviewed manual assist equipment.

SUMMARY PERFORMANCE MEASURES	Plant 1 (2 systems)	Plant 2 (1 system)
Capital cost	$152,000	$81,000
Gross return per head	$3.64	$3.64
Total costs per head	$0.32	$0.15
Net benefit per head	$3.31	$3.48
Net benefit / manual assist unit	$548,909	$567,888
Annual net benefit for the plant	$1,097,819	$567,888
Payback (months)	1.66	1.71
NPV	$6,525,010	$3,374,890

PLANT SPECIFIC DRIVERS	Plant 1		Plant 2	
Daily head being processed	1,428		703	
Annual number of days operation	232		232	
Annual number of head processed	331,296		163,096	
Achieved increase in yield benefit (%)	1.19		1.19	
Interest rate for NPV	7%		7%	
Manual assist equipment	Proman	KN	RTL	KN
Number of systems	2	2	1	1
Useful working life	8	10	8	10

COST - BENEFIT ANALYSIS OF MANUAL ASSIST EQUIPMENT	Plant 1		Plant 2	
Benefit summary	$/hd	Total plant benefit	$/hd	Total plant benefit
1. Increase in yield (kg/head)	$2.84	$941,125	$2.84	$463,313
2. Increase in chain speed	$0.00	$0	$0.00	$0
3. OH&S savings	$0.78	$259,774	$0.78	$127,886
4. Labour benefits	$0.01	$3,480	$0.01	$1,713
Total $ Benefit	**$3.64**	**$1,204,380**	**$3.64**	**$592,912**
Capital cost	$0.06	$18,700	$0.06	$9,975
Cleaning	$0.01	$3,834	$0.01	$1,917
Maintenance	$0.02	$8,274	$0.03	$5,484
Risk of mechanical operator injury	$0.03	$10,000	$0.00	$0
Risk of product damage	$0.20	$65,753	$0.05	$7,649
Risk of mechanical failure	$0.00	$0	$0.00	$0
Total $ Cost	$0.32	$106,561	$0.15	$25,025
Total Net $ Benefit	$3.31	$1,097,819	$3.48	$567,888

2. Background information

Aitch bone and knuckle removal are some of the most physically demanding tasks on the boning line in a beef processing room. To overcome some of these challenges semi-automated or manual assist equipment has recently been developed to assist boners in the removal of aitch bones and knuckle primal. Part of the commercialisation phase of this new equipment is to conduct a cost benefit analysis to assess its benefit to a beef processing plant. The benefits of the equipment can be broadly broken into four main opportunities including increasing yield, increasing efficiency, increasing the available labour pool and OH&S savings.

From an economic view early work suggests that one of the most significant benefits of the equipment may be achieved in yield gains. It is hypothesised that these yield gains will be mostly due to a reduction in fatigue. While the equipment is designed to reduce fatigue, given the nature of the work, it's likely that it won't eliminate fatigue.

The current project focused around 3 different types of equipment that had been developed and incorporated into the boning rooms. Two of the systems the 'RTL' and the 'Proman' were being used for removing the aitch bone. The third technology termed 'the knuckle puller' was customised and developed specifically for the removal of knuckles. A review was conducted at two different sites, the first consisted of two boning lines with two Proman systems and a knuckle pulling system installed, the second plant with only one boning line had one RTL unit installed, and one knuckle pulling unit installed.

Customised Proman

The customised aitch bone pulling systems installed at plant 1 were developed in conjunction with a Swedish company called Proman. The systems currently installed in the plant are the result of three major development phases. The same system is now available commercially, and is manufactured and sold through Proman. Essentially the system consists of a sophisticated drive mechanism that operates an arm that provides a power stroke. The end of the arm has a chain with a hook that attaches to the aitch bone. The system is controlled and operated by a PLC which has different settings and can be adjusted to provide up to three phases of different power and speed settings during the pull cycle. The hook is attached to the aitch bone, the pull cycle on the equipment is activated, and as the aitch bone is removed the boner marks with a knife to assist removal.

RTL

The history behind the development of the RTL system involved the New Zealand company Robotic Technologies Limited (a joint venture between Silver Fern Farms Limited formerly PPCS, and Scott Technology Limited), Meat Livestock Australia as well as industry partners from meat processing plants in Australia. The RTL system is now commercially available through RTL. It was designed for the removal of aitch bones and knuckles from the hindquarter. It consists of an overhead mounted pneumatic ram with a connected arm that has 2 horizontal pivot points (Figure 1). Boners place the hook on the aitch bone, and using a finger control to activate the ram and provide a controlled downward force on the aitch bone as it is pulls away from the hind quarter while marking with a knife in the other hand.

Figure 1: RTL system in operation – removal of aitch bone from butt

Knuckle puller

Traditionally the knuckle primal is removed from the hind quarter, pulling down with a hook in one hand from the distal end and seaming between muscle primals either side with a knife in the other hand. The pulling of the knuckle away from the femur bone and other muscle primals does require a fair amount of force and over the period of a shift is generally considered to be physically demanding. The system was developed with the use of a pneumatic ram under the stand, and a chain (with a hook), connected to an overhead counter balance mounted on a roller, allowing the upper part of the puller to move with the chain. The operator inserts the hook into the knuckle as they would manually, then activates the ram by a pneumatic trigger on the hand piece (Figure 2), pulling the hook down with the knuckle attached. This action greatly reduces the physical strain the operator is exposed to.

Figure 2: Hand piece of the customised knuckler puller

Figure 3: Semi pulled knuckle

Figure 4: Knife releases muscle seams on downward pull

3. Objectives

1. To identify the impact of fatigue on yield loss under manual boning conditions in plant 1.

2. Quantify the yield benefit that can be achieved through the use of semi-automated boning devices.

3. Identify and calculate the value of other benefits associated with the manual assist equipment

    a. Work place health and safety costs

    b. Labour pool benefits

    c. Benefits to existing infrastructure

4. Calculate costs and risks associated with the use of equipment

5. Provide a Cost – Benefit summary for the two equipment configurations in review

4. Methods

Yield loss

Previous work (MLA project #: A.PIA.0120 Cobotic Systems) showed that some of the most significant gains achieved through the introduction of manual assist equipment for hindquarter boning was through improved yields. An important part of the existing project was to run a series of trials assessing the impact of the manual assist equipment on yield.

Trial Design

Yield data was collected on two different days. Data on day one was collected under manual operation; data on day two was collected with the use of the Proman system. Time frames, the number of measurement samples (Hindquarters – HQ's), and the average saleable meat yield (rump, knuckle, Topside, Silver side) for each treatment are shown in Table 2.

Table 2: Trial design for yield experiments

Time Period	Manual			Manual assist		
	Time	# HQ's	Avg. SMY (kg)	Time	# of HQ's	Avg. SMY (kg)
TP 1	6:30 - 8:15	5	39.13	6:15 - 7:30	4	42.30
TP 2	8:43 - 10:05	5	40.44	8:30- 11:40	5	34.92
TP 3	10:20 - 11:40	6	39.99	13:45 - 14:40	7	32.23
TP 4	12:45 - 14:00	4	46.23	N/A		
TP 5	14:10 - 14:30	4	42.29	15:00 - 15:10	5	30.38
Total		**24**	**41.33**		**21**	**34.35**

Quantifying cost of yield loss

Two main sources of yield losses were identified where the manual assist equipment could make a difference. These include loss of muscle to the aitch bone, and loss of muscle to trim due to inaccurate seaming between the different muscle primals. Figure 5 shows the aitch bone in relation to the rump and where there is potential opportunity for yield loss of the rump to the aitch bone. This is one of the highest values losses because primal meat was lost to rendering.

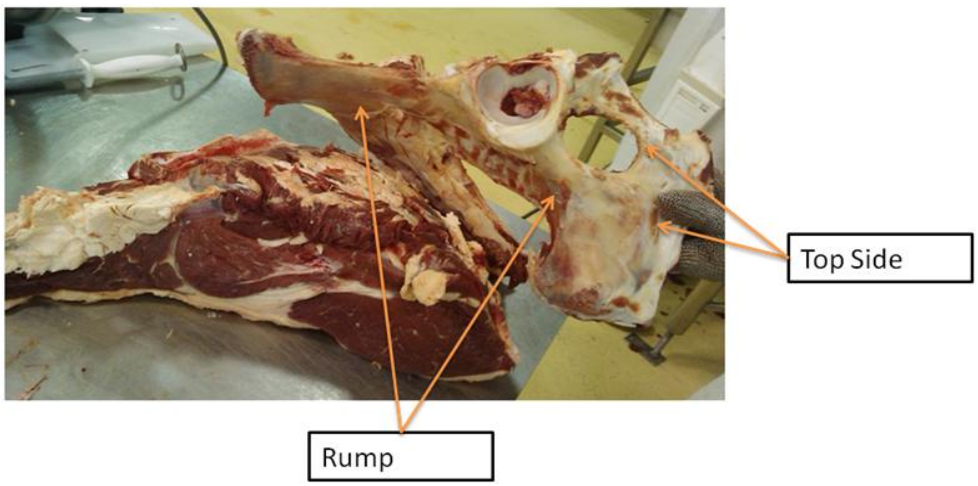


Figure 5: Shows the main opportunities where yield loss can occur in relation to the aitch bone with hindquarter primal

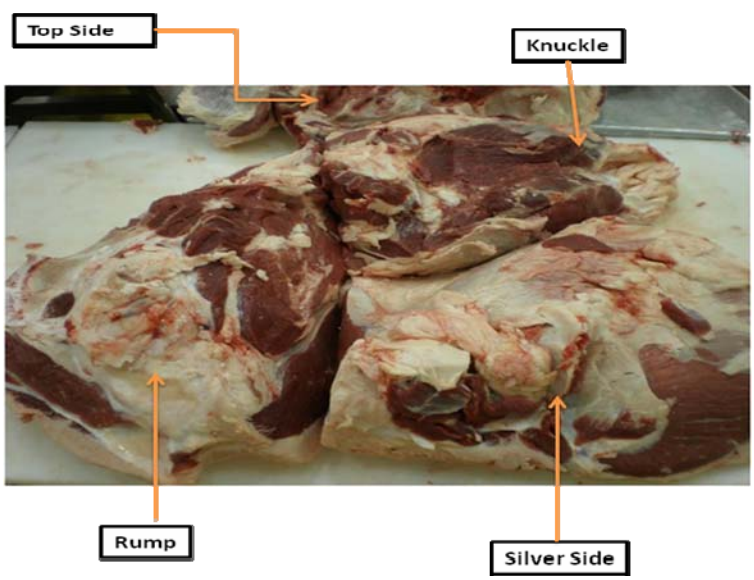


Figure 6: Orientation of hindquarter muscles showing surfaces where opportunity for inaccuracy between seaming lines can occur.

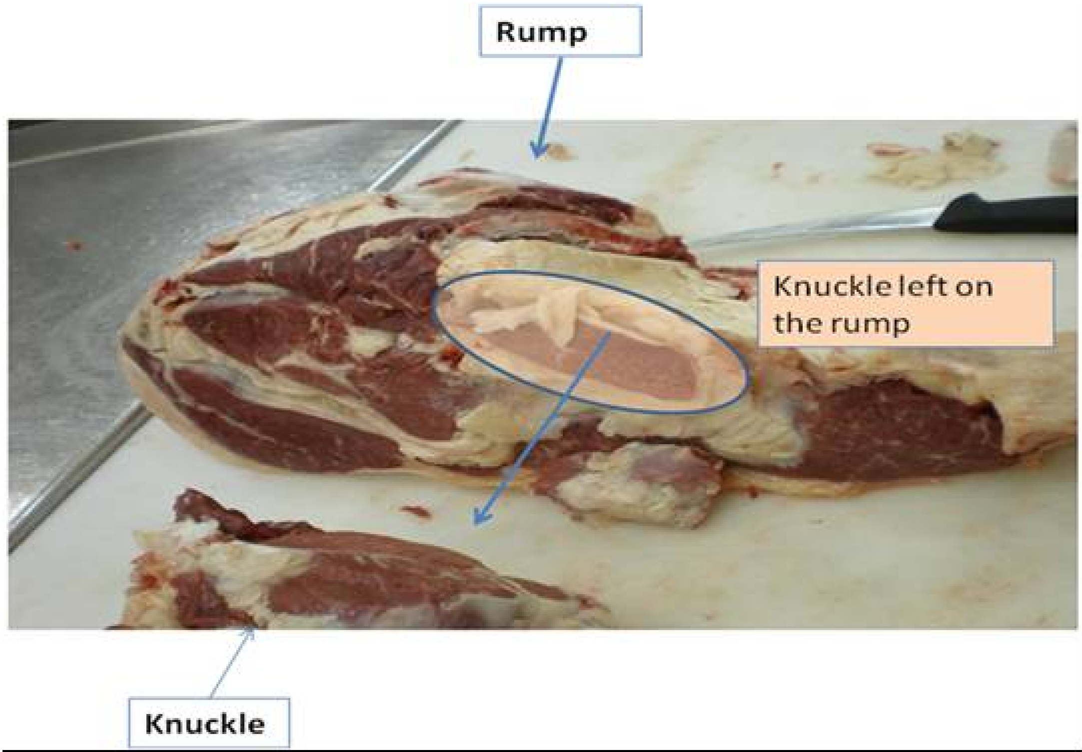


Figure 7: Loss of knuckle to the rump

Based on the muscles seen in Figure 5, Figure 6 and Figure 7, Table 3 shows the location where losses of hindquarter muscle primal were measured from. Hindquarters including their associated aitch bones and femur bones were selected from the line by collecting the respective muscles and bones as they were processed along the chain.

Table 3: Source of yield loss for hind quarter muscle primal

Primal	Location of loss	
Rump	Aitch Bone Top Side Trim	Knuckle Silverside
Knuckle	Rump Top Side	Silver Side Trim
Top Side	Aitch Bone Knuckle	Silverside Trim
Silver Side	Knuckle	Top Side
Tenderloin	Aitch Bone	
Shin	Silverside	

Table 4 provides an example of costing out the value of yield loss. Once the weight of the meat in question was established, its value according to correct boning and seaming procedures was first calculated. Then the actual value after foreign muscles were removed and downgraded to trim was then calculated according to yearly average prices (Table 5). The difference between these two values was used to determine the cost of yield loss.

Table 4: Method used for calculating loss:

	7am				
	Start of day				
Source of loss	**weight (Kg)**	**Achieved value**	**True Value**	**Diff**	**Value to primal**
Loss of rump to aitch bone	0.077	$0.03	$0.48	$0.45	
Loss of rump to centre of aitch bone	0.018	$0.01	$0.11	$0.10	
Loss of rump to knuckle	0.047	$0.16	$0.29	$0.13	**$0.68**

Table 5: Prices used to calculate value of yield loss:

Item	Approx value $/kg to processor	
	Heavy Grain	Yearling
D rump	$6.25	$7.00
Tri Tip	$7.00	$5.10
Knuckle (whole)	$4.50	$4.50
Knuckle (denuded)	$5.60	$5.60
Topside	$4.50	$4.70
Silver side	$4.00	$4.00
Trim (65CL)	$2.60	$2.60
Trim (85CL)	$3.50	$3.50
Trim (95 CL)	$3.75	$3.75
Rendering	$0.34	$0.34
TDR	$18.00	
Shin	$4.50	

Other benefits

Other benefits including i) OH&S benefits, ii) labour pool benefits and iii) increased chain speed benefits were established through a series of onsite interviews with the use of survey material (Appendices). Industry data was also obtained from Queensland health websites and relevant industry journal articles (see bibliography).

Costs

Costs were established through data collected and interviews with representatives from the company.

Statistical Analysis

Statistical analysis of yield trial data was conducted by Dr Olena Kravchuk from the statistical unit of the School of Land, Crop and Food Sciences, University Queensland.
(http://www.uq.edu.au/uqresearchers/researcher/kravchuko.html?uv_category=prj)

5. Results and Discussion

The following results and discussion section is designed to discuss the benefits and challenges associated with the use the three different manual assist technologies presented in the background information. Consistent with objective #5 of the project the final section, 'Cost Benefit Summary', establishes the commercial value of the technologies in relation to the plant where they are installed. The breakdown of the costs and benefits of the technologies have been calculated down to a $ / head value. Depending on the configuration of the manual assist equipment Table 6 shows plant specific variables that are the main drivers for calculations.

Table 6: Plant Specific information

PLANT SPECIFIC DRIVERS				
	Plant 1		Plant 2	
Daily head being processed	1,428		703	
Annual number of days operation	238		238	
Annual number of head processed	339,864		167,314	
Achieved increase in yield benefit - range must be within .86 - 1.6 %	1.19		1.30	
Interest rate for NPV	7%		7%	
Manual assist equipment	Proman	KN	RTL	KN
Number of systems	2	2	1	1
Useful working life	8	10	8	10

Proman

Yield

Potential yield benefits achieved through the use of the Proman system were almost entirely related to gains achieved through improved removal of muscle from the aitch bone. It was proposed that the yield gains would be the result of either improved boning technique with the inclusion of the equipment, or reduced operator fatigue. As stated in the methods section trials were designed to measure loss over time with both manual and manual assisted boning methods.

Table 18 and Table 19 in Appendix 1 show the source and amount of yield loss that occurred from the rump over time for both manual assisted and manual boning treatments. Table 7 and Figure 8 should be read together. Figure 8 clearly shows that yield loss as a percentage of the rump is higher at the start of the day for manual boning compared with manual assisted. Manual boning yield losses continue to increase throughout the shift relative to percent yield loss observed in the manual assisted treatment. Manual yield loss improved for a short time after the lunch break. Smaller cattle were boned in the last time period of the manual assisted shift and are possibly contributing to the reduction in yield loss seen in the final measurement.

More detailed explanation of yield loss is included in section 'Summary of yield analysis' below and in the yield data tables in Appendix 1.

Table 7: Summary of trial design for data collection of rumps

	MANUAL				
Measure Time	7:28 am	9:22 am	11:05 am	1:13 pm	2:18 pm
Rump Weight (kg)	8.40	8.24	6.93	8.72	7.50
Number of rumps	5	5	6	4	4
% Variation (SD)[1]	1.4	4.6	2.8	2.8	3.9
	MANUAL ASSISTED				
Measure Time	6:45 am	10:25 am	14:04 pm	14:57 pm	
Rump Weight (kg)	8.47	7.72	6.91	6.53	
Number of rumps	4	5	7	5	
% Variation (SD)	0.4	1.4	1.9	0.2	

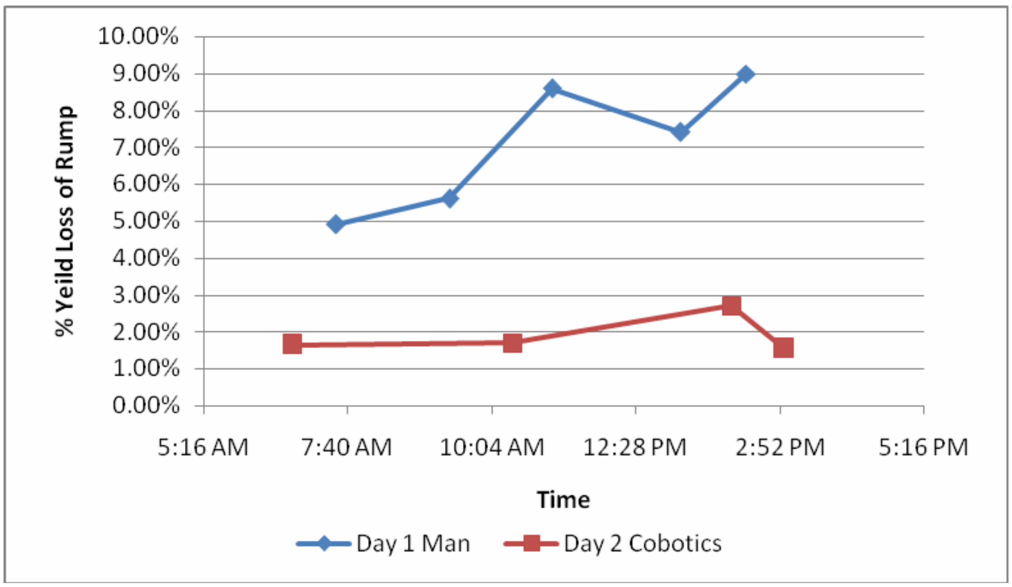


Figure 8: Comparison of % yield loss of rump under manual boning conditions vs. manual assisted

Table 8 presents the data for the whole of each treatment. A third column is then provided showing the difference in yield loss for the different sources of loss. The important summary point from this table is whilst yield loss is still measured from the rump with the use of manual assisted equipment there is an overall reduction in yield loss from the rump of 5%. The difference in yield loss between the two treatments results in an overall increase in value of $2.45 per head from the rump only.

[1] SD = Standard Deviation

Table 8: Summary comparison between data sets for two different boning methods

	MANUAL Total for Day	MANUAL ASSISTED Total Day	Difference between two boning methods	
Rump Weight	**7.90 (kg)**	**7.31 (kg)**	**0.59 (kg)**	
Numbers of rumps	**24**	**21**		
Source of loss	**weight (Kg)**	**weight (Kg)**	**weight (Kg)**	**Diff in value ($)**
Loss of rump to aitch	0.071	0.046	0.024	$0.14
Loss of rump 2	0.024	0.015	0.009	$0.05
Loss of rump to knuckle	0.189	0.000	0.189	$0.52
Loss of rump to topside	0.039	0.006	0.033	$0.09
Loss of rump to Silver side	0.201	0.003	0.199	$0.55
Loss of rump to trim	0.000	0.034	-0.034	-$0.09
Loss of Tri Tip to Knuckle	0.027	0.040	-0.013	-$0.04
Loss rump per side	**0.551**	**0.144**	**0.407**	**$1.22**
Loss of rump per side ($)	**$1.82**	**$0.59**	**$1.22**	
Loss of rump per hd ($)	**$3.64**	**$1.18**		
% loss of rump	**6.98%**	**1.97%**		
$ DIFFERENCE BETWEEN MANUAL ASSISTED AND MANUAL FOR RUMP (Per head)	**$2.46**			
YIELD DIFFERENCE BETWEEN MANUAL ASSISTED AND MANUAL FOR RUMP	**5.01%**			

Labour Pool Benefits

Previous work in a different plant showed that installation of the equipment had a beneficial impact on the logistics of staffing the boning room. Where this job has previously been restricted to staff with specific strength ability, introduction of the manual assist equipment allows selection of staff members from a broader pool. Introduction of the manual assist equipment reduced the number of events where the throughput of boning room plant was actually limited due to absenteeism from boners on the aitch bone and knuckle pulling. Operation managers did not considered this to be an advantage that provided a direct dollar benefit for the current plant due to the existing skill base that has been recruited and employed by the plant. However, should labour become a scarce resource at some time in the future the manual assist equipment will provide a direct benefit as the semi-automation will increase the pool from which staff can be drawn to fill these positions.

Training

Significant benefits were identified in the training of new operators. The main advantage being that a boner could become productive, and be able to operate successfully at chain speed in a shorter amount of time as compared to the manual boning system. The shorter training time also results in a reduced amount of damaged product during the training period. Transition from manual boning to using the new equipment was not considered a challenge, and once experienced operators had tested the equipment it was adopted as standard practice with limited resistance.

Table 9 shows the benefit calculated at a saving of 1c per head. The aitch bone job had previously been the most difficult job, and was now one of the more preferred jobs with manual assist equipment.

Table 9: Reduced cost of training with installation of manual assisted equipment

Training benefit	
Number of staff being trained each year	3
Reduction in hrs required to train beginners	40
Hourly training cost	$29.00
Saving per trainee	$1,160.00
Total Saving	$3,480.00
Saving per head	**$0.01**

OH&S

Possibly one of the most significant benefits achieved with the use of the Proman system is the reduced strain on the operator.

Table 10 presents data from a number of industry sources, used to calculate the approximate upper arm injury cost associated with the manual break down of the hindquarter for each beef animal processed. Data shows the breakdown of injury types that relate to this specific task of manually breaking down the hindquarter. This data has been compiled by the Queensland Government and includes claims from all self insured organisations, and all organisations participating in work cover. Important assumptions made in estimating a final figure include:

- A conservative estimate of 65% of these claims being from the boning room, as opposed to the slaughter floor;
- An estimate of 60% of boning room injuries for these types of disorders (upper limb and shoulder) are a direct result of manual boning on the chain;
- The assumption that these Queensland state wide figures are representative of the entire industry and therefore applicable to this plant.

Table 10: Musculoskeletal Disorders recorded from workers compensation claims made in Queensland in meat processing plants in 2006-07

Musculoskeletal Disorders	
Type of injury	**Number of Claims**
Trauma to muscles & tendons	1,218
Trauma to joints & ligaments	534
Disease of muscle, tendon & related tissue	449
Residual soft tissue disorders due to trauma or unknown mechanisms	374
Total Number of claims	2,575
Average payment for all compensation claims	$2,889
Averaged cost of workplace injury to Qld. livestock industry	$7,439,044
Assumption 1: 65% of all claims are from the boning room as slaughter floor has less strain	65.0%
Assumption 2: 60% of all boning room musculoskeletal claims will be a direct result of injury from Boners on the chain	60.0%
Total QLD cost of musculoskeletal injury as a direct result of boning on the chain	$2,901,227
Number of head processed in QLD	3,700,000
Number of beef processed in Australia	8,800,000
Musculoskeletal injury cost of boners on chain / head processed	**$0.78**

Source data for Table:

(ABS 2005; Fletcher 2008; QLD-Government 2008)

Using plant specific data the cost and number of workplace insurance claims relating to the removal of the aitch bone and the knuckle were also reviewed for the plant for 19 months prior to installation of the equipment, and 19 months after the equipment was installed. The reduction in the cost of claims relating to this task after equipment was installed for the time period was $41.730. However discussion with OH&S and Training managers highlighted this number would likely be conservative because of the nature of the injuries that are incurred during this type of job. Injury incurred due to repetitive strain and the severity of the injury are usually time dependent. It is therefore expected that damage incurred prior to installation of the manual assist equipment may continue to manifest even after installation of the equipment, further reducing post installation claims overtime.

Increase in Chain Speed

No increase in chain speed is observed for plant 1 with the installation of the manual assist equipment.

Costs and risks

Capital Cost

Cost of the Proman system is listed at $60,000. For plant 1, two units are required, one for each boning line. Installation costs and other necessary hardware are allowed for in the capital expenditure. Using the plant details provided in Table 6, the workings for capital cost are provided in Table 11.

Table 11: Capital cost of Proman

Capital	Capital outlay	Qty	
Customised Proman system	$60,000.00	2.00	$120,000.00
Proman Installation	$10,000.00	2.00	$20,000.00
Total Proman Capital Cost			**$140,000.00**
Annual cost of Proman			$17,500.00
Annual Cost per head			**$0.05**

Note1: Installation costs are based on standard installation costs now that the system has been refined and developed. Several aspects of the current system required customisation costs to make the system suitable to Australian plants. Those additional costs were not included in the installation costs presented in Table 11.

Note2: Opportunity cost of capital: If the application of this technology is being assessed in relation to other capital expenditure options within a plant, it may also be helpful to consider the opportunity cost of the capital. The approximate outlay for the equipment is listed at $152,000.00. At an earning capacity of 5%, investing the capital elsewhere would result in a missed opportunity cost of $7,600.

Cost of Cleaning

Cleaning allows for 12 minutes cleaning time for each unit (both knuckle puller and Proman) for each day of operation, at a labour rate of $20.66/hr. During a normal cleaning operation units are hosed down, which takes a couple of minutes. Then it is foamed and scrubbed down. Finally it is sanitised, and the sanitiser rinsed off.

Cost of maintenance

Maintenance allowance was 4 hours per unit per month at a cost $29.68/hr. Replacement parts allowance was $4000 per annum / per unit. This cost may be considered slightly low and depending on the nature of some repairs this figure would also be inadequate.

Risk of mechanical failure

Although there is a risk of equipment failure, no cost has been associated with this occurrence due to the fact that the boning line can still continue to operate at the same speed, and still requiring the same number of staff members. Repair costs are included with the maintenance costs.

Risk of Mechanical injury

1. Operation of the Proman systems requires a boner working on either side of the equipment (1 left-handed, and 1 right-handed). Management from plant 2 who had previous experience with the Proman system considered the left and right handed boners working together a source of risk for a knife injury. However administrative controls have been implemented to eliminate the risk of injury with a left and right handed boner working together, and to-date, this has resulted in no report of injury.

2. A hook connected with a chain to the pulling arm of the Proman is used to pull the aitch bone from the hindquarter. At times the hook can release from the aitch bone during the pulling cycle either due to the bone breaking, or the hooking mechanism slipping. This results in the hook springing back in the direction of the operator. If the hook on the Proman system connected with the operator in this situation there may be risk of injury. Again there were no known incidences of injury being recorded for this situation. There were no known incidents of injury at the plant due to the further extensive administrative controls that have been implemented.

Cost of damaged product

In some instances use of the Proman also caused damage to the surface of the rump resulting in excessive trimming to the surface. This resulted in down grade in the marketing specification of a higher value “EU” product to being sold on the local domestic market at a lower value.

RTL for semi-automated aitch bone removal

Yield

Preliminary observations were made to compare the difference in yield loss achieved with removing the aitch bone under manual operating conditions as compared to yield loss with the inclusion of the RTL aitch bone removal method. Higher losses of rump to the aitch bone were observed under manual operating conditions as compared to rump losses seen with the use of the RTL equipment. Data obtained in the scoping studies did not contain significant integrity for statistical analysis. Further trials were designed and planned, however no data was obtained due to failure of the mounting brackets for the RTL unit on specified trial dates.

Labour pool Benefits

Operators claimed the job could be done as effectively manually. But during manual yield trials it took about 40 minutes for boners to ask when they could go back onto the RTL, indicating their preference for the machine.

OH&S

Essentially the RTL unit is providing benefit to the same task outlined and described under the Proman systems. However there are some significant user / ergonomic differences between the two systems and these are summarised in Table 15.

Increasing chain speed

It was also observed that plant 2 where the RTL equipment was installed had a faster chain speed than plant 1. Discussions with operators and management established that faster operating speeds were possible with the RTL equipment as compared to the Proman aitch bone pulling system. However concerns were also raised over the risk of an increase in damaged product at faster operating speeds due to excessive force available to the operator to pull off aitch bones. This situation did not appear to be a problem for boned product processed at plant 2 with RTL. Operating speeds were approximately 28 seconds per head, with approximately 24-25 operators.

Costs and risks

Damaged Product

Tearing of the rump can occur if operators apply too great a strain on the muscle without keeping up the knife work to release the rump from the aitch bone.

The manager indicated just as much damage can occur using the previous manual method where the boning hook is placed directly in the rump muscle and can sometimes tear out of the muscle leaving a large gash, although we did not obsevre this ourselves.

Use of the RTL system allows the full aitch bone to be removed prior to removal of the rump. Although the sequence of boning does not create an improvement in yield, the use of the RTL system removes the downward force the boner previously had to apply and enables them to more effectively mark the aitch bone to release the rump and topside.

Knuckle puller

As discussed in the background information one of the main drivers for the development of the specialised knuckle pulling equipment was to reduce operator strain. In theory the introduced technique shouldn't make a big difference on the yield as a skilled boner will achieve high yielding results without the equipment. However it is also hypothesised that the inclusion of manual assist equipment over the period of the day will have a positive influence on reducing operator strain, and therefore fatigue. There is also a chance that a reduction in fatigue will result in better seaming accuracy between the topside and the silverside during removal of the knuckle. The following results and data present the benefits and costs associated with the use of the equipment.

Yield

- Results showed the largest yeild loss in pulling knuckles occurs on the seaming line between the knuckle and the topside. Marking the seam between the topside and the knuckle occurs well before the puller. This cut goes right in to the bone and is difficult to find the seams. As a result topside and silverside can be left on the knuckle (or knuckle on both these cuts) as foreign muscle that must be removed as trim.

- Averaged 30 grams of Topside on Knuckle. Averaged 70 grams of knuckle on Topside. Depending on which side of the seam the boner cuts there will be an average of 45 grams of foreign material on the other primal at a value of approximatley $1.00 loss in value. ($1.00/kg * 2 sides * .045kg *250,000 = $22,500 per annum)

- Knuckle tearing can occur with use of the knuckle puller.

    - Due to the nature of the machine, boners tend to let the machine pull the full force of the knuckle to remove it with limited or no knife work to seam and release the meat.

    - The chain above the knuckle puller obstructs right handed boners from properly cutting away the topside from the femur bone on the right side of carcases (the same is true for left handed boners on left sides). This is where damage to the knuckle can occur, resulting in yield loss.

    - Weight of primal lost to trim is around 180 gms when the mucle tears enough to require trimming. Damage to knuckle occurs about 6-10 times per day but occurs at leat 20 times per day on Mondays due to drier, colder meat.

    - This occurs more with bigger cattle, probably because the machine is used more.

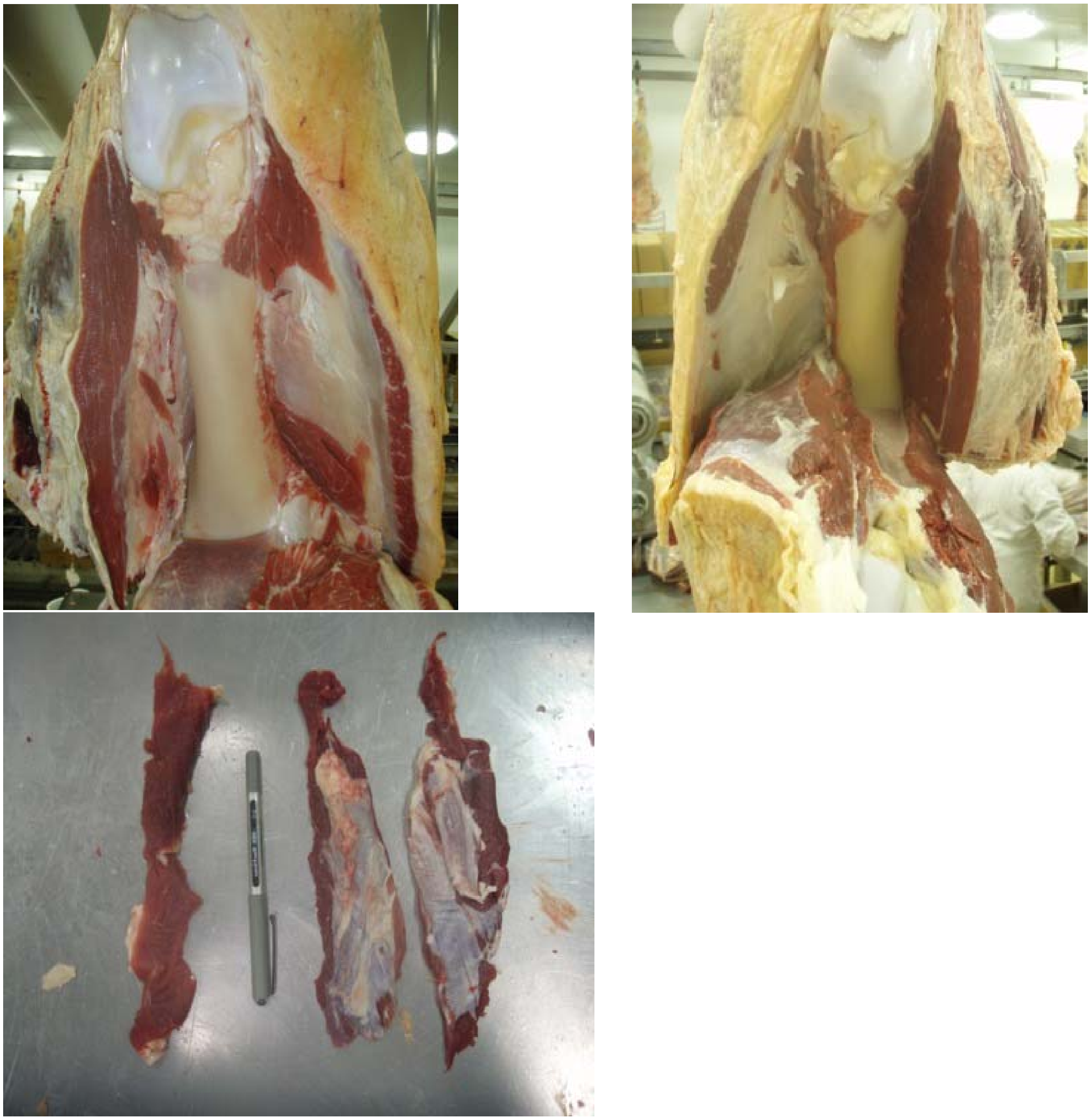


Figure 9: Potential opportunity for yield loss to occur on knuckle puller.

Labour pool Benefits

Significant benefits are believed to be relevant to the labour pool with the introduction of the knuckle pulling equipment into the boning room. These include a reduced amount of time required in training to have learning boners productive. An example of this was observed at one of the plants where a trainee on night shift was a middle aged man, and had been boning for three days so was still learning the system. He relied heavily on both the RTL and Knuckle pullers to do his job. Even when going back to manual removal of rump first, he would still rely on the RTL system to remove the top of the aitch bone from the topside. For boners that have years of experience boning manually and are still very strong, the difference between the manual and assisted technology may not be large. However for older or smaller framed people the abaility to learn the boning jobs appears to be much easier with manual assist.

It is also important to note that the equipment allows operators to be drawn from a larger pool of potential staff members due to the reduction in strength required for boners to perform the boning task.

OH&S

It is expected that the type of safety benefits seen with the use of the knuckler puller will be similar to those covered under the Proman technology. This is because the strain is largely relevant to the upper body, shoulders, arms and wrists. Both of the plants surveyed for the company in review were using a combination of either Proman and Knuckle pulling equipment or RTL and knuckle pulling equipment. For calculation of the dollar benefit of the knuckler puller to OH&S costs in the Cost-Benefit model, the aitch bone puller and the knuckler puller are considered together. As previously stated, this was estimated at $0.78 per head.

Increasing chain speed

The knuckle pulling equipment is not expected to provide any increase in chain speed, and in fact if an operator was pressed for time they would often chose not to use the manual assist equipment in preference to manually removing the knuckle. Some operators expressed frustration with the system not being able to move sideways with the chain.

Costs and risks

Capital cost

Capital cost of the Knuckle pulling system is based on a per unit price of $4000. This assumes a manufacturer is responsible for the design and fabrication costs of the system. The costs for the company in question will be different as they will have incurred the development costs; however the unit cost to the company is more likely to be less than $2000.00 per unit. Two plants were studied where the knuckle pulling systems were installed, one plant had two boning chains, and the other plant had one. Using the plant details provided in Table 6, the workings for capital cost are provided in Table 12.

Table 12: Calculations for customised knuckle puller.

Capital	Capital outlay	Qty	
Knuckle puller	$4,000.00	2	$8,000.00
Knuckle puller Installation	$2,000.00	2	$4,000.00
Total Knuckle puller Costs			**$12,000.00**
Annual cost of Knuckle Puller			$1,200.00
Annual Knuckle puller Cost per head			**$0.004**

Cost of damaged product

Some design issues were noted with the knuckle puller and limited the benefit provided. The system was not ergonomically friendly and does not move with the chain. This resulted in staff preferring not to use the knuckle puller unless forced by management. In some cases the knuckle puller also resulted in damaged product as seen in Figure 10. The severity of the damage ranged from small amounts of the knuckle requiring trimming, to the whole knuckle having to be sliced and sent to trim.

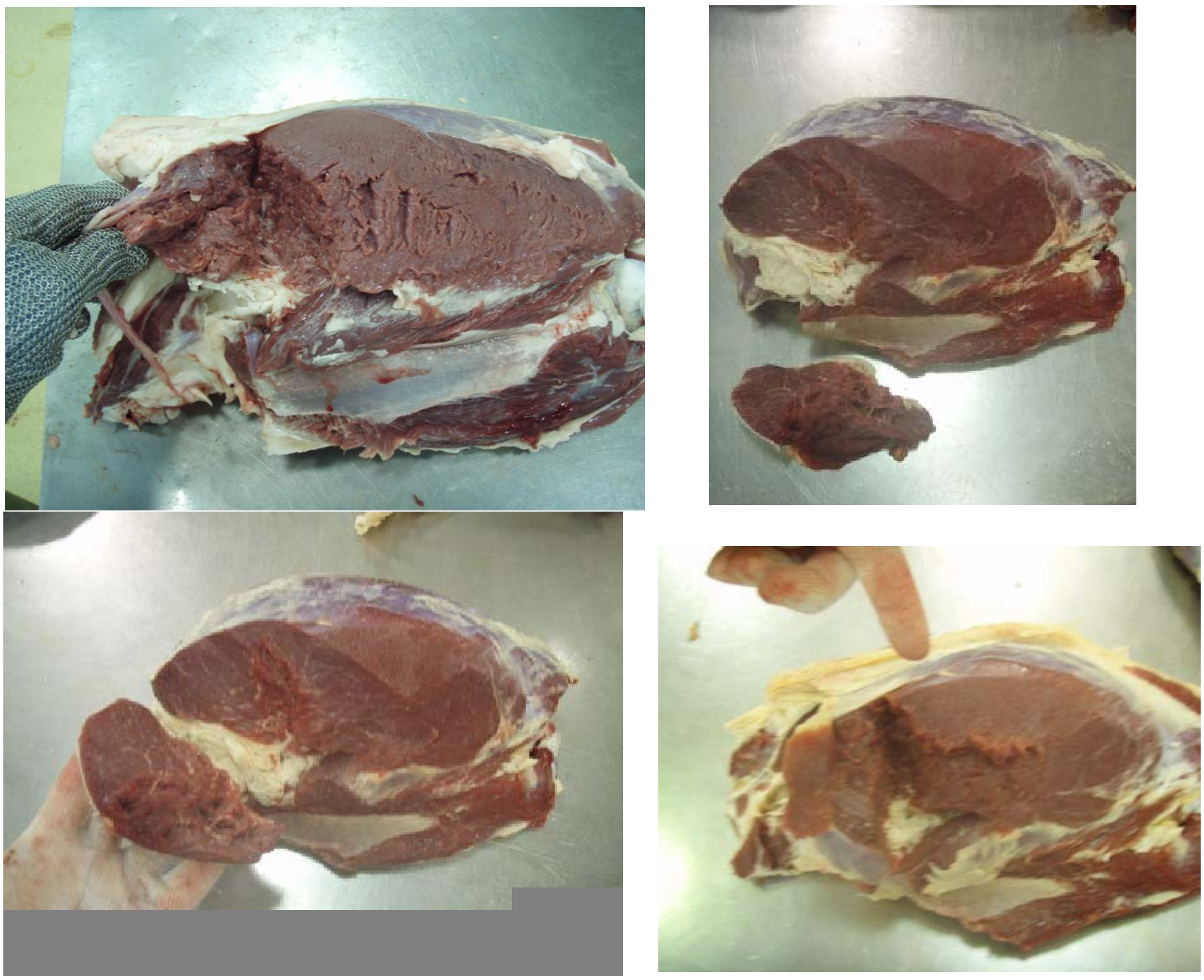


Figure 10: Damage to knuckles caused by knuckle puller

Ergonomics

As the chain speed increases the system becomes more difficult to use due to its stationary position in relation to carcases moving along the chain.

Bigger cattle are harder to bone manually. They are also more conducive to use of the knuckle puller because the chain moves at a slower speed.

The system does not have the ergonomic appeal of the equivalent RTL knuckle puller system for the following reasons:

- Angle of the handle in relation to the cut could be improved
- Size of the handpiece is quite large and may be difficult for smaller hands to grasp
- System needs to move faster up and down to immitate human movements
- Knuckle pulling would ideally have a 2 meter range of sideways movement to match the chain speed and provide similar flexibility to move with the chain as manual boning.
- Hard to bone right handed across the chain to remove the knuckle on the the topside side of the femur bone for right side of carcase. The same difficulty with the other seaming line is experienced by left handed boners.

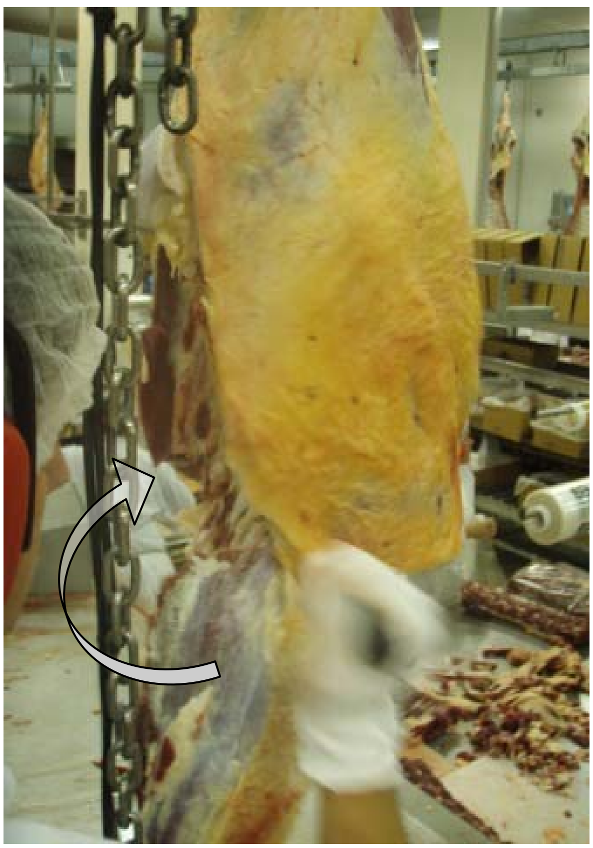


Figure 11: Image showing difficulty associated with right handed boning and removal of knuckle on right topside- side of femur bone

Summary of yield analysis

Due to the large amount of information collected on the impact of manual assisted equipment on operator fatigue and yield loss, a brief summary is provided here prior to cost benefit analysis, explaining the robustness of the data.

Figure 12 shows the change in saleable meat yield (SMY) loss during the day (current plant in P1). The transparent line shows results from same trial conducted under manual boning conditions however in a different plant. Similar trends are observed between the two plants over time. A similar trend in yield loss is observed for both plants over time during the day. A consistent increase is seen in yield losses up to approximately midday, with some variation in yield seen after midday.

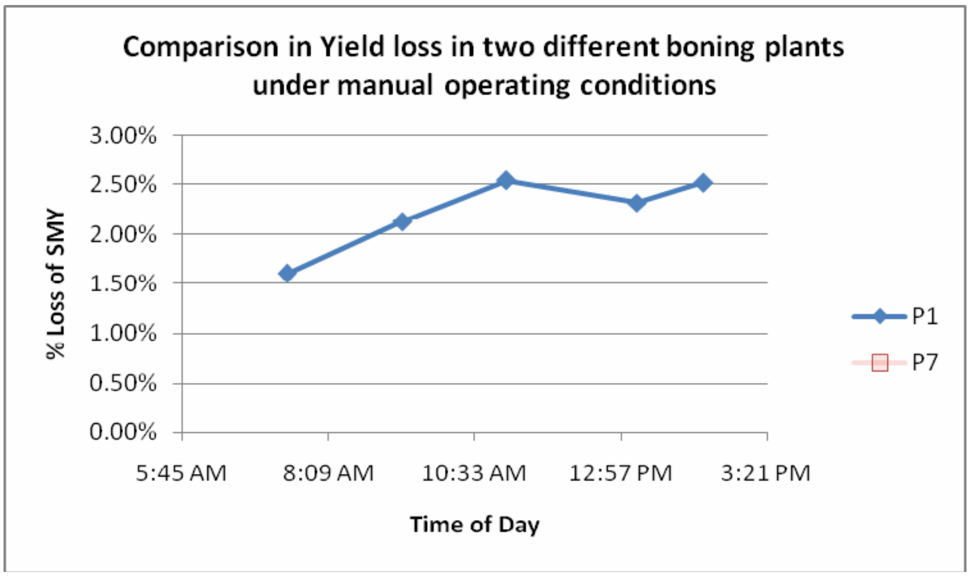


Figure 12: Comparison of yield loss between different boning plants

Figure 13 shows the measured yield loss for both manual assisted and manual boning systems. The yield loss is noticeably lower in the manual assisted treatment. Time did not have a significant impact on the amount of yield loss for manual assisted data.

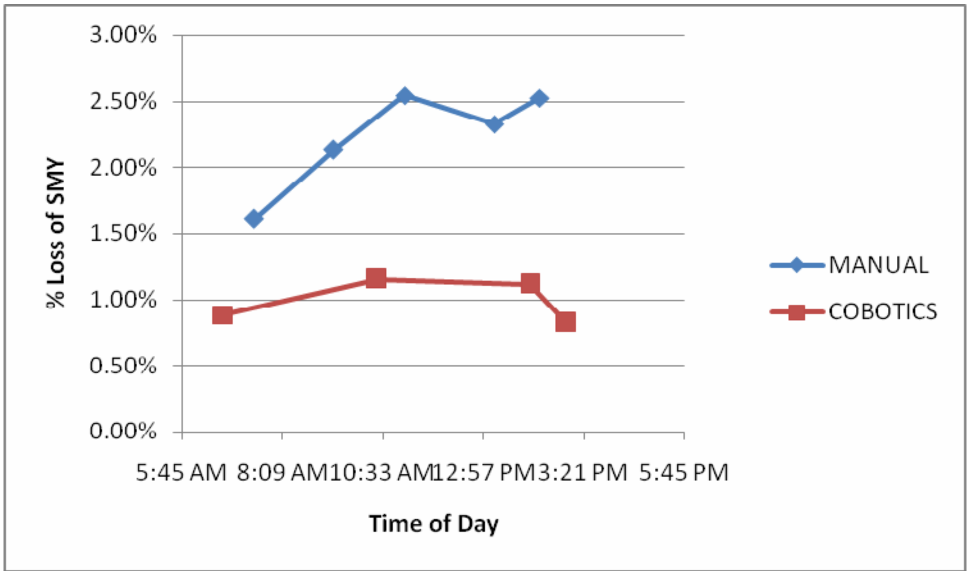


Figure 13: A comparison in yield loss over time during the boning shift using manual and manual assisted hindquarter boning systems.

There was a difference in the average weight of the saleable meat collected for the hindquarter when comparing between the manual assisted and manual treatments. Overall the combined weight of the rump, knuckle, topside and silversides was 7kg lighter per hindquarter for the manual assisted treatment due to lighter carcass weights. There was also a linear increase in the % yield loss with increasing saleable meat. The rate of increase is about 0.02kg loss / kg of saleable meat yield. However the difference in yield loss between manual assisted and manual is confirmed to be significant (p=0.004) even when the weights are standardised (using ANOVA, with total weight as a covariate). For this reason the difference in yield loss is expressed as % yield loss in Figure 13 as opposed to total yield loss.

Table 13: Expected yield range benefit with the introduction of manual assists to manual boning system.

	Minimum	Achieved Yield benefit	Maximum
	.86 % ←	→	1.6%
Achieved yield benefit		**1.19%**	
	0%	44%	100%
$/head Increase in value	$2.05	**$ 2.83**	$3.82

Table 14: Difference in yield loss with use of manual assist equipment vs. manual

	MANUAL BONING	MANUAL ASSISTED	Difference
	Avg. for Day	**Total Day**	
	SM (kg)	**SM (kg)**	
	41.33	**34.35**	
Source of loss	**Value Loss ($)**	**Value Loss ($)**	
Total Loss of Rump	$1.90	$0.59	$1.31
Total Loss of Knuckle	$0.14	$0.12	$0.01
Total Loss of Topside	$0.23	$0.15	$0.08
Total loss of Silver side	$0.03	$0.02	$0.01
Total Loss of Tenderloin (TDR)	$0.57	$0.17	$0.40
Total	$2.87	$1.05	$1.81
Total per animals	$5.74	$2.11	$3.63
Total difference per animal between manual and manual assist without TDR	**$4.60**	**$1.76**	**$2.84**
% SMY Loss (calc from avg.)	**2.23%**	**1.04%**	1.19%

Technology Summary

The following table is presented in a summarised format to highlight some of the differences that were observed and identified between the different manual assist technologies.

Table 15: Comparative analysis between manual assist technologies

Attribute	Proman	RTL	Knuckle Puller
Ergonomics	• Boners have to adapt to a different way of boning. • Attachment of the hook can take some focus. • For trainee boners focus is on knife skills without having to control speed and power of the pull – this is an advantage.	• This system most closely delivers the flexibility and range of human movements possible in manual boning without any strain. • Trainees also have to learn to control the speed and power of the machine as well as the knife. However, trainees almost always used the machine if they were behind while experienced operators may revert to manual boning.	• Size of hand grip commented at being too large with some button triggers to bulky. • Static location of the machine against a moving chain makes this the systems biggest weakness and hardest for the operator to manage. • Pulling chain limits the range of knife movement where right handed boners on

Attribute	Proman	RTL	Knuckle Puller
			right sides of carcases (opposite for left-handed) need to cut across the chain to mark the topside.
Safety	• Accidental release of hook from aitch bone is a concern. Administrative controls are in place and no injury has been recorded. • Supplier procedure of two boners working on either side of a carcase working towards the middle could inflict knife injury. Plant adjusted process to overcome risk.	• Hook could catch on boners belt but controlled by the boner so unlikely. • People walking past the hydraulic arm could be hit if not observing the safety zone.	• Hook may catch on boners belt but controlled by the boner so unlikely.
Training considerations	• All systems reduce the time required for trainees to be able to operate at chain speed. • Comments in other areas of the table indicate specific areas where training will be impacted for each machine.		
Product Damage	• Adjustable settings can minimise accidental tearing of primals if boner is untrained or careless. With careful trained operators this is not likely to be a benefit. • Variation in cattle may prevent optimum use of adjustable settings.	• Operator has complete control of pulling power. This opens more potential to tear primals if untrained but allows greater flexibility for skilled operators on fast chains. • Skilled operators would have more control over the pulling power and speed on a carcase by carcase basis than the Proman systems fixed pulling cycle.	• Tearing of knuckles does occur if operators are not careful and is worse with older cow carcases.
Maintenance	• No significant differences in ongoing maintenance requirement identified		• Limited issues as simple design and parts.
	• Breakdowns involve	• No chain stoppage due to	• Operator can alternate

Attribute	Proman	RTL	Knuckle Puller
	chain stoppage. Rubbing bar must be removed to bone manually.	breakdown. Operator can swing the RTL arm away to bone manually.	with or without the puller.
Operator Acceptance	• Operators who had used both RTL and Proman on a faster chain preferred the RTL system.	• Operators claimed the job could be done as effectively manually. But during manual yield trials it took about 40 minutes for boners to ask when they could go back onto the RTL, indicating their preference for the machine.	• Helpful to operators when boning large carcases. • Smaller carcases at faster chain speeds make the system a hindrance due to time taken attaching hook to knuckle and static location on moving chain.
Key Considerations	• Not suitable for fast moving chains.	• This system gives the most flexibility to integrate on fast moving chains. • Operators can move along the chain with the machine, and choose to bone ahead manually where 2-3 boners do the same job.	• Doesn't move with chain.

Cost Benefit Summary

Based on information and data collected through yield trial work, operational observations, plant operator and management survey's and other industry relevant information discussed in this report, the following cost benefit summary is provided.

It is important to note that some of the drivers and other factors influencing the values presented in the cost benefit analysis will be plant specific (different volumes and configurations) and not necessarily translate into the same dollar values if applied in a different situation or context. Benefits identified in relation to yield gains need to be considered against the assumptions used for statistical analysis (Appendix 2).

Based on the drivers provided earlier (Table 6: Plant Specific information) the following cost benefit provides a summary of the expected costs and benefits that may be expected with the installation of manual assist equipment for the semi-automated removal of the aitchbone and the knuckle. When comparing between the two plants it is best to use the values per head as the number of head processed at each plant differ as per Table 6: Plant Specific information. The configuration of the RTL equipment in plant two provides a higher return per animal, and also has lower costs associated with the equipment. Further discussion is provided below on comparisons between the plants.

Table 16: Summary results of cost benefit

COST - BENEFIT ANALYSIS OF MANUAL ASSIST EQUIPMENT				
	Plant 1 (2 systems)		Plant 2 (1 system)	
Benefit summary	$/hd	Total plant benefit	$/hd	Total plant benefit
1. Increase in yield (kg/head)	$2.84	$941,125	$2.84	$463,313
2. Increase in chain speed	$0.00	$0	$0.00	$0
3. OH&S savings	$0.78	$259,774	$0.78	$127,886
4. Labour benefits	$0.01	$3,480	$0.01	$1,713
Total $ Benefit	**$3.64**	**$1,204,380**	**$3.64**	**$592,912**
Capital cost	$0.06	$18,700	$0.06	$9,975
Cleaning	$0.01	$3,834	$0.01	$1,917
Maintenance	$0.02	$8,274	$0.03	$5,484
Risk of mechanical operator injury	$0.03	$10,000	$0.00	$0
Risk of product damage	$0.20	$65,753	$0.05	$7,649
Risk of mechanical failure	$0.00	$0	$0.00	$0
Total $ Cost	$0.32	$106,561	$0.15	$25,025
Total Net $ Benefit	$3.31	$1,097,819	$3.48	$567,888

Table 17 helps to further refine the comparative process between the two configurations of manual assist equipment. The first point to note about the different manual assist technologies is that configurations are providing extremely positive returns. The rate of return (gross return / total costs) per annum shows that the configuration of the manual assist equipment in plant 1 is providing a $7.22 return for every dollar spent, and a $7.01 return in plant 2 for every dollar spent. The differences in plant volumes are the key driver of this difference. Plant 2 has a slightly quicker payback period, however both pay back periods would be considered quite rapid in a processing plant given the nature of the investment. The main driver for this is an increase in the chain speed achieved with the RTL unit, and a reduced amount of damaged rumps with the use of the RTL.

Table 17: Comparative analysis of finance performance indicators used to benchmark impact between two different technology configurations.

SUMMARY PERFORMANCE MEASURES		
	Plant 1 (2 systems)	Plant 2 (1 system)
Capital cost	**$152,000**	**$81,000**
Gross return Per head	**$3.64**	**$3.64**
Total costs Per head	**$0.32**	**$0.15**
Net Benefit Per head	**$3.31**	**$3.48**
Net Benefit / manual assist unit	$548,909	$567,888
Annual Net Benefit for the plant	$1,097,819	$567,888
Pay back (months)	**1.66**	**1.71**
NPV	$6,525,010	$3,374,890

6. Success in achieving objectives

Given the large gains in profitability that can be achieved through the management of yield loss, accurate measurement remains an important topic for the beef processing industry. However, enquiries at the plant level highlighted the limited amount of detailed yield work that has been conducted across the industry in relation to the variables that drive yield; specifically areas such as fatigue, knife sharpness, and level of operator skill. Methodologies established as a separate part of the current project showed that it was possible to obtain robust data sets relating to specific yield drivers. These methodologies could provide firm commercial information with statistical analysis to assist plants to further refine yield management. The yield trials conducted in plant 1 successfully mapped yield loss over the day using the different treatment methods. No significant time trend was identified in the manual assist data, however significant increases in yield loss were observed between TP1 - TP2, and TP2 – TP3. There was however no significant difference in yield loss measured in the last three time periods under manual boning conditions. Further research into the issues relating to fatigue data in the wider manufacturing industries highlighted the complexity of measuring and analysing the impact of fatigue on the performance of workers. The factors driving the increase in yield loss and the impact of fatigue are not well quantified and further statistical work is required to develop or obtain analysis models which accurately account for the impact of fatigue.

Results from yield trials showed a clear advantage with the use of manual assist equipment for reducing yield loss. A yield saving in the hindquarter between 0.8% and 1.6% was identified with the use of manual assist equipment at 95% confidence ($p<=0.05$).

Other benefits relating to the use of the manual assist equipment were identified and valued through the use of several onsite site surveys, interviews, observation of the equipment under operation, and discussions with other relevant staff members who have been involved with the equipment (OH&S, HR, Management, Accountants, Research and Development and many others). Costs and risks associated with the use of the manual assist equipment were also established in a similar manner.

Any other non-financial pros and cons were also tabulated and presented in the results and discussion of the report.

Finally, with the use of various assumptions the value of yield savings, and other benefits and costs associated with the use of the Proman, RTL and knuckle pulling system were calculated and presented in a cost-benefit model comparing between manual assist systems in plant 1 and plant 2. Net benefits of the manual assist equipment were established as $3.31/ hd for plant 1 and $3.48/hd for plant 2.

7. Appendices

Appendix 1: Summarised yield data

Table 18: Measured yield loss under manual operating conditions

	MANUAL					
	7:28 AM	9:22 AM	11:05 AM	1:13 PM	2:18 PM	Avg. for Day
	SM (kg)	SM (kg)	SM (kg)	SM (kg)	SM (kg)	SM (kg)
Saleable meat Yield	**39.13**	**40.44**	**39.99**	**46.23**	**42.29**	**41.33**
Loss of rump to aitch	0.075	0.053	0.075	0.065	0.087	0.071
Loss of R to centre of aitch	0.016	0.028	0.021	0.028	0.028	0.024
Loss of rump to knuckle	0.139	0.220	0.301	0.263	0.161	0.221
Loss of rump to topside	0.026	0.042	0.009	0.023	0.113	0.039
Loss of rump to Silver side	0.066	0.079	0.316	0.267	0.285	0.201
Loss of rump to trim	0.000	0.000	0.000	0.000	0.000	0.000
Loss of Tri Tip to Knuckle	0.090	0.039	0.000	0.000	0.000	0.027
TOTAL LOSS OF RUMP	**0.413**	**0.462**	**0.721**	**0.646**	**0.674**	**0.583**
Loss of knuckle to rump	0.042	0.078	0.042	0.082	0.056	0.058
Loss of knuckle to TS	0.036	0.008	0.041	0.048	0.040	0.034
Loss of knuckle to SS	0.024	0.043	0.024	0.056	0.072	0.041
Loss of knuckle to trim	0.008	0.000	0.002	0.000	0.000	0.002
TOTAL LOSS OF KNUCKLE	**0.111**	**0.129**	**0.107**	**0.186**	**0.168**	**0.136**

Loss of TS to Aitch	0.017	0.028	0.028	0.032	0.033	0.027
Loss of TS to Rump	0.000	0.096	0.000	0.012	0.000	0.022
Loss of TS to knuckle	0.012	0.030	0.009	0.009	0.024	0.016
Loss of TS to SS	0.028	0.034	0.049	0.033	0.043	0.038
Loss to TS to trim	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL LOSS OF TOPSIDE	**0.056**	**0.188**	**0.085**	**0.087**	**0.101**	**0.103**
Loss of SS to knuckle	0.000	0.000	0.000	0.009	0.014	0.004
Loss of SS to TS	0.039	0.036	0.073	0.094	0.060	0.060
TOTAL LOSS OF SILVER SIDE	**0.039**	**0.036**	**0.073**	**0.103**	**0.074**	**0.063**
Loss of TDR to Aitch	0.004	0.003	0.012	0.024	0.022	0.012
Loss of TDR to Rump	0.007	0.042	0.019	0.029	0.029	0.025
TOTAL LOSS OF TDR	**0.011**	**0.045**	**0.031**	**0.053**	**0.051**	**0.037**
Total	**0.629**	**0.861**	**1.017**	**1.074**	**1.067**	**0.922**
Total per head	**1.26**	**1.72**	**2.03**	**2.15**	**2.13**	**1.84**
% SMY Loss (calc from avg.)	**1.61%**	**2.13%**	**2.54%**	**2.32%**	**2.52%**	**2.23%**

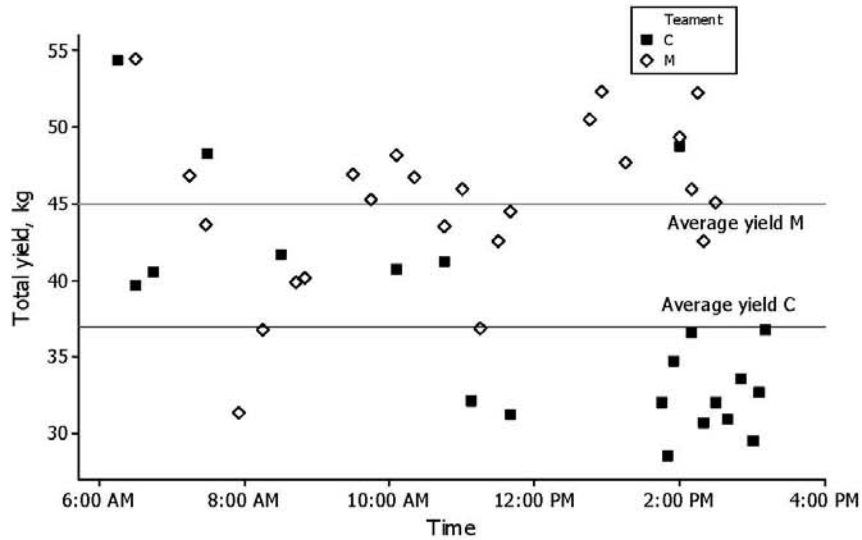
Table 19: Measured yield loss under Manual assisted operating conditions

	MANUAL ASSISTED				
	6:45	**10:25**	**14:04**	**14:57**	**Total Day**
	SM (kg)	**SM (kg)**	**SM (kg)**	**SM (kg)**	**SM (kg)**
Saleable meat Yield	42.30	34.92	32.23	30.38	34.35
Loss of rump to aitch	0.066	0.026	0.046	0.051	0.046
Loss of rump to centre of aitch	0.012	0.015	0.025	0.004	0.015
Loss of rump to knuckle	0.000	0.000	0.000	0.000	0.000
Loss of rump to topside	0.000	0.000	0.014	0.005	0.006
Loss of rump to Silver side	0.000	0.000	0.006	0.003	0.003
Loss of rump to trim	0.000	0.061	0.057	0.000	0.034
Loss of Tri Tip to Knuckle	0.061	0.029	0.039	0.037	0.040
TOTAL LOSS OF RUMP	**0.139**	**0.131**	**0.187**	**0.100**	**0.144**
Loss of knuckle to rump	0.012	0.000	0.000	0.000	0.002
Loss of knuckle to TS	0.010	0.144	0.017	0.003	0.043
Loss of knuckle to SS	0.015	0.008	0.008	0.008	0.009
Loss of knuckle to trim	0.007	0.060	0.048	0.008	0.034
TOTAL LOSS OF KNUCKLE	**0.044**	**0.212**	**0.073**	**0.020**	**0.088**
Loss of TS to Aitch	0.012	0.004	0.014	0.029	0.015
Loss of TS to Rump	0.000	0.000	0.000	0.000	0.012
Loss of TS to knuckle	0.008	0.005	0.006	0.031	0.012
Loss of TS to SS	0.041	0.039	0.032	0.016	0.032

Loss to TS to trim	0.019	0.000	0.011	0.000	0.007
TOTAL LOSS OF TOPSIDE	**0.080**	**0.048**	**0.062**	**0.076**	**0.078**
Loss of SS to knuckle	0.014	0.000	0.000	0.000	0.003
Loss of SS to TS	0.059	0.007	0.032	0.050	0.036
TOTAL LOSS OF SILVER SIDE	**0.074**	**0.007**	**0.032**	**0.050**	**0.038**
Loss of TDR to Aitch	0.038	0.004	0.003	0.003	0.010
Loss of TDR to Rump	0.000	0.000	0.000	0.000	0.000
TOTAL LOSS OF TDR	**0.038**	**0.004**	**0.003**	**0.003**	**0.010**
Total	**0.374**	**0.402**	**0.358**	**0.249**	**0.358**
Total per head	**0.75**	**0.80**	**0.72**	**0.50**	**0.72**
% SMY Loss (calc from avg.)	**0.88%**	**1.15%**	**1.11%**	**0.82%**	**1.04%**

Appendix 2: University of QLD Statistical Analysis

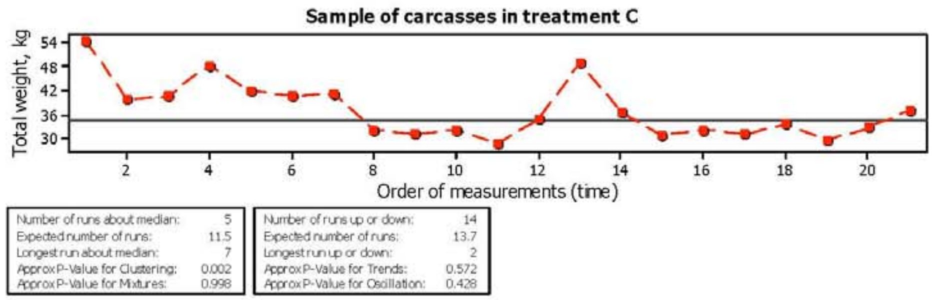
Total yield and saleable yield weight distributions in treatments M and C

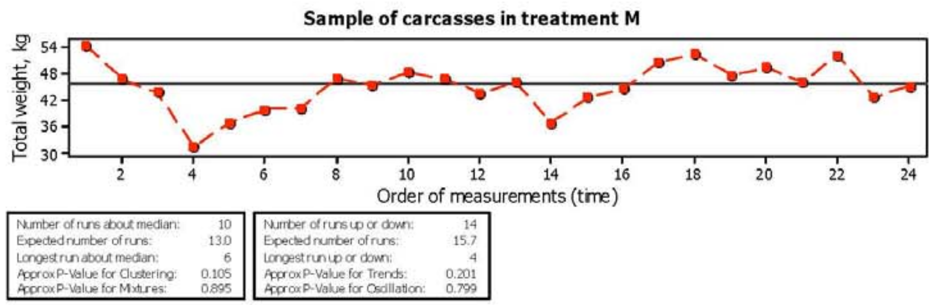


Results for Primal = Weights

Variable	Teament	Total Count	Mean	StDev	Sum
Total	C	21	36.97	7.03	776.40
	M	24	44.97	5.36	1079.30

There were 21 carcasses sampled in treatment C and 24 carcasses in treatment M. The average total yield weight in treatment M was about 8kg heavier than in treatment C (the difference is significant, $p<0.001$, 2-sample t-test).
There was also the lack of randomness detected in sample for treatment C ($p=0.002$, test for clustering), where all carcasses measured in the afternoon happened to produce total yield smaller than 37kg. The selection of carcasses in treatment M satisfied the requirements for random sample.





A similar difference in the distributions was present for the saleable meat yield weights. There was about 7kg of saleable meat less in treatment C than in M ($p<0.000$, 2-sample t-test).

Descriptive Statistics: Saleable meat (SM)

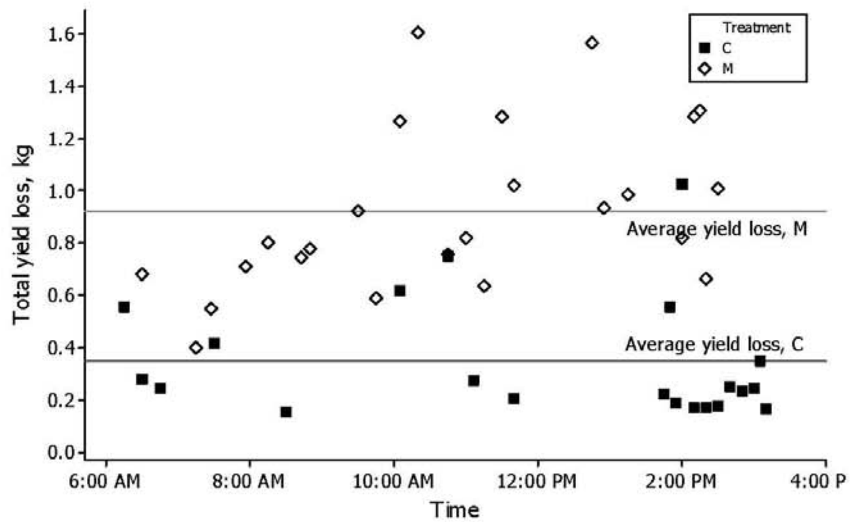
Variable	Treatment	Total Count	Mean	StDev
Saleable meat (SM)	C	21	34.35	6.45
	M	24	41.33	5.04

Total loss distributions in treatments M and C

The total absolute loss was smaller in treatment C than in M.

Descriptive Statistics: Total Yield Loss

Variable	Treatment	Total Count	Mean	StDev
Total Yield Loss	C	21	0.3457	0.2303
	M	24	0.9220	0.3168

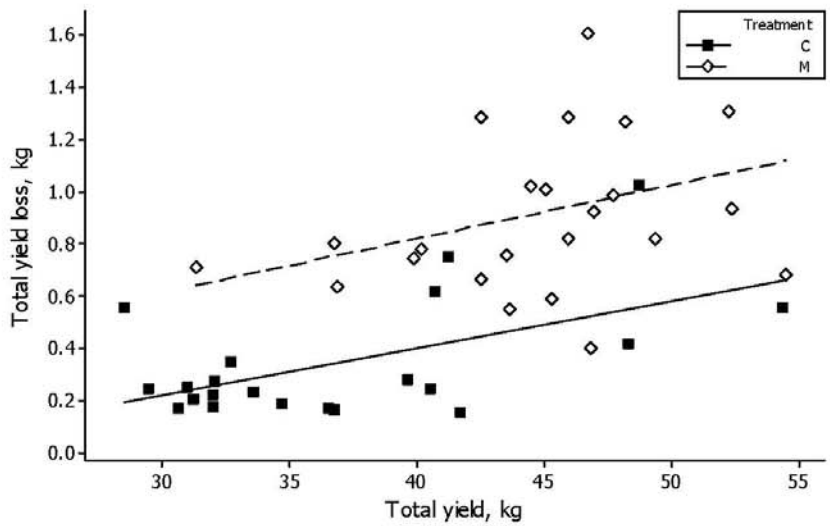


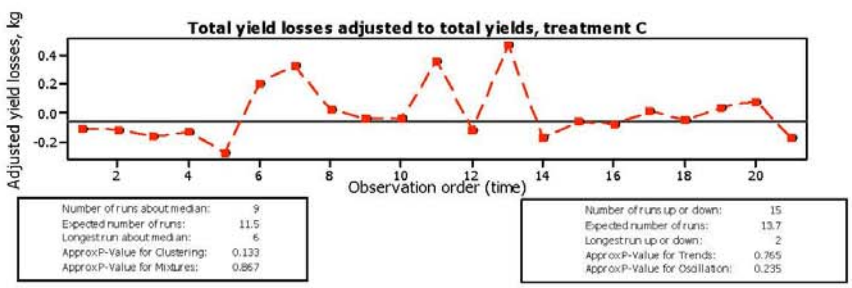
This difference between C and M was confirmed to be significant (p=0.004) even when the difference in total weights was taken into account (ANCOVA, with the total weight as a covariate), i.e. when the weights were standardized.

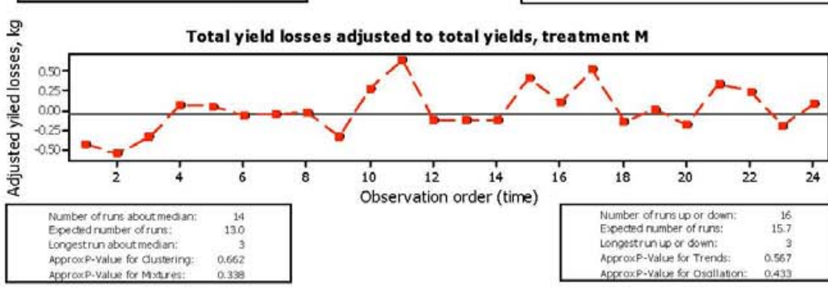
Term	Coef	SE Coef	T	P
Constant	-0.1612	0.2765	-0.58	0.563
Total(Treatment)				
C	0.018030	0.008266	2.18	0.035
M	0.02053	0.01010	2.03	0.049

The losses increase linearly with an increase in total weight (p = 0.035 and p=0.049 for treatments C and M correspondingly). The rate of increase is about 0.02kg total loss/kg total yield in both treatments, and these regression coefficients are not significantly different between the treatments.

The interpretation of this analysis, however, is only valid if the time effect is negligible. This assumption seems feasible as the analysis of residuals does not provide any indication of non-randomness that could be associated with a fatigue or other continuous time-related effects. It is worthwhile noticing that early in the day, 6:15 – 7:30 am, the yield losses were noticeably smaller than what would be expected basing on the corresponding total weights – the significance of this, however, was not high (p=0.09).

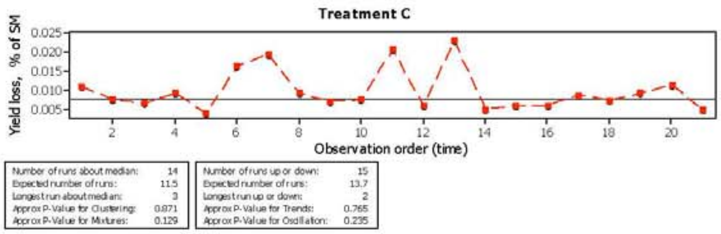


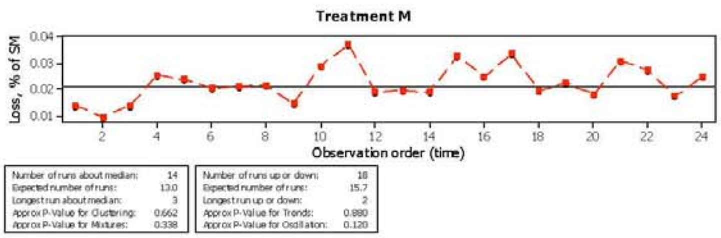




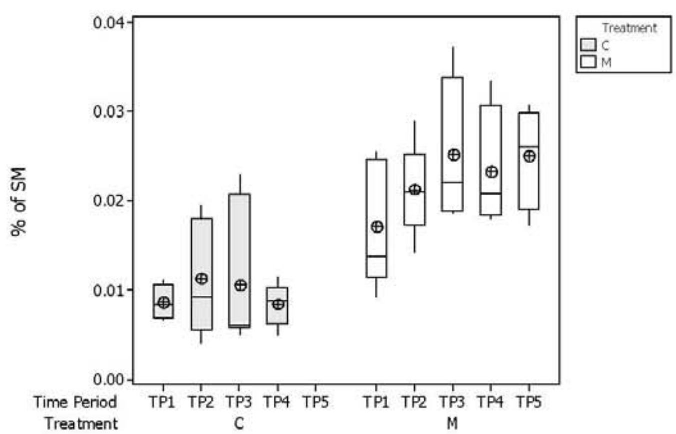
%SM yield loss distributions in treatments M and C

The %SM loss data satisfy the requirement for random sampling for both treatments. There was no significant time trend in either of the treatments.





The %SM loss differs significantly between the treatments ($p<0.001$, ANOVA with time periods (TP) additionally included and not found to be significant).



Note: there are three outliers detected in treatment C: TP2, rep 3, animal 7, TP3, rep 2, animal 11 and TP3, rep 4 animal 13.

With 95% confidence. it is estimated that treatment M results in 0.8—1.6% of SM more losses than treatment C.

```
Least Squares Means for % of SM

Treatment      Mean    SE Mean
C           0.01012  0.001531
M           0.02235  0.001280

95.0% Simultaneous Confidence Intervals
Treatment      Lower    Center     Upper  -------+---------+---------+---------
M-C         0.008275  0.01222  0.01617  (---------------*---------------)
                                          -------+---------+---------+---------
                                              0.0100    0.0125    0.0150
```

The individual 95% confidence interval estimates for the average % of SM are 0.7—1.2 %of SM for treatment C and 1.9–2.5 %of SM for treatment M.

Appendix 3: List of Table and Figures

Tables

Figures