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Cost benefit analysis for automated evisceration of lamb and beef carcases

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Executive summary

This Cost Benefit Analysis for an Automated Evisceration of Lamb and Beef Carcases Report has been prepared by Mercer Technologies at the request of Meat & Livestock Australia (MLA) and Australian Meat Processor Corporation (AMPC). The report follows a number of discussions on automated evisceration and a visit by two Mercer Technologies consultants to a number of Australian meat plants, as arranged by MLA. This Report and analysis is preparatory to MLA and AMPC considering development of an automated system for evisceration for lamb and/or beef carcases. The evisceration procedure is seen as a primary candidate for automation because it is dirty and difficult to the point where we understand it creates a number of OHS issues and it is also likely to be one of the least desirable tasks in terms of staff retention/job satisfaction.

While a number of approaches to automating evisceration have been attempted over the years, none have become commercial due to various shortcomings. In this report, these issues have been addressed sufficient to provide one reasonably robust means of automating the evisceration procedure so that the costs of automating can be established relative to the existing manual methods. The proposed methods are subject to significant development with the attendant risks and other methods may be more appropriate. Any development will follow the normal MLA/AMPC project process.

It is recommended that development of an automated system for lamb evisceration proceed as soon as possible and that development of automated beef evisceration be considered after review of the lamb development.

Acknowledgments

The authors wish to acknowledge the assistance of all the industry personnel who contributed information to discussions during site visits, and subsequently, that form the basis of this report. Thanks also to those at AMPC and MLA would have helped arrange site visits in Australia, source detail and provided salient comment in discussions.

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1 Introduction

Carcase evisceration is seen as a difficult and dirty job that typically results in staff turnover and falls short of OHS recommendations. Lamb evisceration requires a lift and turn action which OHS recommends should be avoided while beef evisceration creates similar issues by requiring reaching to high points and forward into the carcase to make the necessary cuts.

It is most important that the process of evisceration maintains the hygienic status of the carcase by keeping faecal matter contained within the viscera separate from all of the edible carcase components. This means that all membranes of the viscera must remain intact and the weasand and bung sealed off or enclosed appropriately during evisceration.
Meat plant procedures for evisceration of both lamb and beef have changed little over the years. Even the use of inverted dressing for lambs returned to the 'conventional' procedure just before evisceration. An extension of inverted dressing to incorporate evisceration was developed in New Zealand but the need for an extra four metres of foreleg chain, complications with ringing & bunging and the need for further development of the system designed to clear the gut and pluck, meant this system was never commercially accepted.

Beef evisceration was set to change substantially when a new approach was introduced but abandonment of the overall concept left many valuable ideas in limbo for consideration in future developments. The analysis presented here is based on an automated evisceration procedure and system, yet to be developed, simply as a means of ascertaining the costs and benefits due in changing from the existing manual process. The comparison, and the analysis presented below, assumes installation of a commercial system priced according to the method developed above, with development as a separate cost issue. Details of the automated method of evisceration discussed above are a present confidential.

2 Current process

Carcases are prepared for evisceration by removal of the pelt or hide and by ringing and bunging to enable the bung to be dropped through the pelvic girdle, into the gut cavity. The weasand will have been sealed by a clip or plug inserted soon after exsanguination.
At present, both lamb and beef carcases are manually eviscerated while the carcase hangs from its hind legs. The gut is removed first, taking with it the bung and finally the weasand, the two most likely causes of contamination. The pluck is removed after the diaphragm is cleared, generally by pulling it through the brisket cut in order to release the trachea from its attachment to the backbone in the neck region. The procedures are detailed in Tables 1 & 2 per task performed with variations noted where these have been observed.

2.1 Lamb

Table 1 Lamb evisceration process

Task	Action	Comment
Gambrelling	Hangs the hind legs as a pair on a skid on the final transport rail. Not considered part of evisceration at present.	Will influence how any automated procedure can operate.
Fore hocks cut	Drops the carcass to hang on the gambrel. Not part of the current evisceration process.	Will need to be taken into account for automation.
Ringing and bunging	This is not strictly part of the evisceration process but it has a significant effect on hygiene.	Current gambrelling before normal ringing & bunging which means the task is performed on a vertical carcass, hind legs up.
Belly rip	Classic action is to create an insert cut in the flank at the crotch and turn the knife so that heel of the blade makes the cut while the knife handle and the operator's fist protects the gut from puncture.	Cannot be performed earlier due to the effects of pelt pulling.
Bung pull	Grab bung a pull down and out to keep its end clear of carcass.	In lamb processing it is common to simply drop the bung onto the carcass gut or leave it hanging to avoid its contaminating the edible carcass. Some plants will milk the bung and remove the dirty end at this point, others will 'milk' at ringing and bunging.
Gut removal	The gut attachments to the spine are broken and the gut is lifted clear and placed on the viscera tray in a turning action. The lift action is required to pull the weasand through the diaphragm. Most plants have a viscera tray system running alongside the dressing chain, necessitating the turn action.	The lower viscera tray may cause degradation of edible viscera or the carcass if paunch is spilled. More discrete placement of pluck in the lower tray can require a bending action.

	Some plants have the tray below the carcass in order to avoid the turning action.	
Brisket cut	A brisket cutter is placed into the gut cavity, pushed down through the diaphragm and the pluck and activated to cut the brisket.	Some plants in New Zealand do not cut the brisket, preferring to keep it as one piece for removal at primal cutting. It is probable that the brisket is cut to allow easier removal of the trachea.
Pluck removal	The diaphragm is cut to provide access to the chest cavity. The attachments to the spine are broken and the pluck is either lifted out of the chest cavity or it is pulled through the brisket cut with some knife action required to release the trachea from the spine.	Breaking the trachea attachment to the spine in the neck region appears to be the main reason for cutting the brisket.
Liver removal	The liver is most often removed with the gut and sometimes separated before the gut is placed on the viscera tray.	
Trim	Remnants of the diaphragm may be trimmed at this stage. Trimming may also involve removal of kidney fat and other debris from the chest cavity.	

2.2 Beef

Table 2 Beef evisceration process

Task	Action	Comment
Ringing and bunging	As with the lamb process, this is not strictly part of the evisceration process but it has a significant effect on hygiene.	Beef bungs on all the sites visited were bagged in order to maintain the best hygiene.
Brisket cut	Beef briskets are generally cut with a reciprocating saw just prior to evisceration.	The brisket is cut to allow easier removal of the pluck and especially the trachea. There is no evidence to suggest that the brisket saw is causing damage to the pluck.
Belly rip	Classic action is to create an insert cut in the flank at the crotch and turn the knife so that heel of the blade makes the cut while the knife handle and the operator's fist protects the gut from puncture.	For some operators (in spite of carcass lowering systems) the insert cut required a significant reach action such that this cut was made lower than usual, creating a risk of puncturing the gut. There is a significant OHS issue with the knife blade action leaving the knife tip facing the operator.
Bung pull	Grab bung a pull down and out to keep its end clear of carcass. On beef carcasses some knife action is generally required to break the bung attachments to the spine in a tidy manner, as it is drawn downwards.	It was noted that some plants are pushing the bung further into the carcass cavity than others.

Gut removal	The gut attachments to the spine are cut progressively and the gut is encouraged to fall from its cavity, over the brisket cut and onto the viscera conveyor.	Most carcasses were lowered during the initial stages of gutting to the extent that the neck of the larger ones would contact the gutting table. On all sites visited, the gut was allowed to contact the apron and boots of the operator as it progressed onto the viscera conveyor.
Liver & kidney removal	As the gut is lowered or removed, the kidneys and liver are exposed enough to be removed. Most plants removed the left kidney and then the right kidney with the liver attached. Other plants removed the kidneys first followed by the liver.	It is critical that the liver is not damaged in the removal process because of its value. Kidney & liver removal before completion of gutting was probably necessary while the carcasses were in their lowered position.
Pluck removal	The diaphragm is cut into at least two sections and removed to provide access to the chest cavity. The pluck attachments to the spine are progressively cut and the pluck is pulled out through the brisket cut with some knife action necessary to release the trachea from the spine.	Detachment of the trachea from the spine in the neck region will be one of the significant challenges to automating evisceration.
Trim	On the plants visited, all trimming was conducted after the carcass was split.	

3 Developments to Date

3.1 Lamb

In the late 1980's the Meat Industry Research Institute of New Zealand (MIRINZ), to our knowledge, produced a system for automated lamb carcase evisceration that was trialed at Katanning in Western Australia.

Description of process.

After final pelting, the carcase hind legs were gambrelled-up as in the present process.
- The fore legs remained suspended in a spreader on the fore-leg chain.
- A specially designed brisket cutter was placed in through the neck opening so that its belly rip extension pierced the diaphragm and progressed to the crotch region of the belly.
- The brisket cutter was activated.
- The belly rip knife pierced the belly flap and cut it along its length as the tool is withdrawn from the carcase.
- The fore-leg hocks were cut and the carcase dropped to be suspended on the traditional skid and gambrel.
- The belly flaps were spread open with a pair of hooks.
- The carcase remained aligned with the rail as a spade like tool entered the gut cavity at the crotch end and progressed down the backbone to sever all of the gut and pluck attachments. The spade tool spread the brisket to allow both gut and pluck to flow out of the neck opening and the brisket cut.
- The gut and pluck dropped together into a gut tray.

The system was never taken up by industry for a number of reasons:
1. An extra four metres of fore-leg chain was required to support the carcase during the process.
2. Issues of where and how ringing & bunging would be performed were not resolved.
3. The gut and pluck where removed in the single action of a spade like tool that was used to break the gut and pluck attachments in succession as it passed from the crotch and through the brisket. The action often punctured portions of the gut either as a result of a spade pinch against the spine or from snagging on the brisket cut.
4. The spade tool was used to spread the brisket enough to leave space for both the gut and pluck to pass through the neck/brisket opening. The process occasionally broke ribs.
5. Gut and pluck were not able to be separated due to the nature of the process.

3.2 Beef

The Meat Research Corporation of Australia (MRC), now reformed as Meat & Livestock Australia (MLA) produced an extensive development in FutuTech, which was designed as a demonstration of a concept for automation of as much of the beef slaughter dressing process as was then possible. Incorporated into this concept was a means of automated evisceration.

The belly rip cut was performed on the carcase support cradle during preparation for hide removal. After hide removal, the carcase, hanging on all four legs, was tilted hind legs down to allow gut to flow out between the hind legs as a probe was driven down the length of the backbone inside the carcase cavity to break all the appropriate attachments. Both gut and pluck dropped into an elevated tray for capture. It seems likely that the probe would interfere with some gut runners and occasionally at least puncture these to cause contamination problems.

Use of the system was highly dependant on the radical changes made in carcase preparation that was part of the FutuTech process such that it was difficult to insert many of the automated tasks into existing chain processing practice. However, some aspects of the demonstration may be appropriate to future developments.

4 Assumptions & Justifications

The following assumptions have been made in formulating a cost/benefit for automation of the evisceration process on a lamb and a beef chain respectively.

4.1 General

- The costs of research and development are not included in the analysis in order to show the cost/benefit at installation.
- Analysis is based on the costs and benefits associated with a single chain. The breakdown is shown annually for an elapsed period of six years.
- Overhead allowances are based on a single chain plant.
- A discount rate of return of 10% is used.
- Labour is costed at $35,000 plus 40% on-costs ($56,000p.a.) that includes provision of administrative, dining rooms, annual leave, sick leave, showers, laundry and parking. The cost is assumed to be the equivalent cost of one full time employee (FTE) for the determination of other costs. Worker compensation, staff turnover and absenteeism are not included in labour costs.
- Worker compensation is conservatively estimated at $6,000 per worker per annum.
- Staff turnover is conservatively estimated at 8%. The cost/value of staff turnover per labour unit is then calculated as 0.08 of one FTE, or $4,480 p.a. per labour unit displaced.
- Absenteeism is conservatively estimated at 6%. The cost is calculated as 0.06 of one FTE, or $3,360 p.a. per labour unit displaced.

4.2 Lamb

4.2.1 Capital cost

The anticipated system capital cost for an automated evisceration system for lamb anticipates the need for a greater speed of operation compared with that required for beef. A robot or equivalent dedicated machine and a number of tools are expected to be the main costs.

4.2.2 Labour cost

A net reduction of two labour units is sustained per chain. This is based on removing one unit from the gutting operation and one from the pluck. In some plants a third unit may be removed from the brisket cutting depending on whether this task can be removed or automated as part of the system.

4.2.3 Hygiene improvement

Carcase hygiene will be improved through a reduction in punctured gut and in nonsterile surface contact with the carcase. Punctured gut results in detain and downgrading of carcases through removal of the contaminated portion or possibly by rejection of the whole carcase. Detain/retain work and use of hand held knives will contaminate carcasees more than machine activity because hands cannot be sterilized as well as machine sections. Hygiene improvement is estimated to be the equivalent of $3,733 p.a. time saving, while the improvement in product loss anticipated due to reduced trim at detain/retain is calculated at $27,000 for a total benefit or saving of $30,733 p.a. (see Appendix 1).

4.2.4 Other aspects

- The capability to easily revert to manual processing is assumed.
- The evisceration process can be conducted within the six second cycle time of a plant processing at a rate of ten carcases per minute.
- Maintenance is estimated from the need to sharpen blades and provide a preventative maintenance program for the anticipated equipment. Maintenance is expected to be higher in the first year of operation while staff familiarize themselves with plant needs.
- Maintenance will be required only during normal processing and cleaning breaks, i.e. tea, lunch and wash-down.
- It may not be possible to keep gut and pluck physically separated.
- All carcase sizes from twelve kilograms up to twenty-five kilograms can be accommodated on the same system.
- Tooling changes are not included in the cycle time given above.
- Ringing and bunging is not included in the evisceration procedure cycle time. Using the automated method developed for this analysis would require that ringing and bunging be conducted on the fore-leg chain extension. This has been proven possible in attempts to ring and bung before pelting.

4.3 Beef

4.3.1 Capital cost

The system capital costs for a beef system are consistent with the longer processing cycle time relative to that required for a lamb system

4.3.2 Labour cost

A net reduction of one labour unit is sustained per chain.

4.3.3 Hygiene improvement

Carcase hygiene will be improved through a reduction in punctured gut and in nonsterile surface contact with the carcase. Punctured gut results in detain and downgrading of carcases through removal of the contaminated portion (It is very seldom that evisceration will cause a whole carcase to be rejected). Detain/retain work and use of hand held knives will contaminate carcases more than machine activity because hands cannot be sterilized as well as machine sections. Hygiene improvement is estimated to be the equivalent of $2,100 p.a. time saving, while the improvement in product loss due to reduced trim at detain/retain is calculated at $23,288 p.a. for a total benefit or saving of $25,388 p.a. (see Appendix 2).

4.3.4 Other aspects

- The capability to easily revert to manual processing is assumed.
- The evisceration process can be conducted within a forty-eight second plant cycle time.
- Maintenance is estimated from the need to sharpen blades and provide a preventative maintenance program for the anticipated equipment. Maintenance is expected to be higher in the first year of operation while staff become familiar with equipment needs.
- Maintenance will be required only during normal processing and cleaning breaks, i.e. tea, lunch and wash-down.
- It may not be possible to keep gut and pluck physically separated.
- The system can be flexible enough to process all carcase sizes from yearlings through to prime bull.
- Tooling changes are not included in the evisceration procedure cycle time given above.
- Ringing and bunging is not included in the cycle time. In the automated method formulated for ringing and bunging would occur as in the current process and in the same position on the chain.

5 Analysis and Results

5.1 Lamb

Calculation of NPV & IRR for Lamb

Year		0	1	2	3	4	5	6
Benefits								
Tangible								
	Reduced manning (two staff - sustainable)	$112,000	$112,000	$112,000	$112,000	$112,000	$112,000	$112,000
	Reduced Worker Compensation (2)	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000
	Reduced absenteeism (2)	6720	6720	6720	6720	6720	6720	6720
	Reduced staff turnover (2)	8960	8960	8960	8960	8960	8960	8960
Intangible								
	Improved carcass hygiene	$30,733	$30,733	$30,733	$30,733	$30,733	$30,733	$30,733
Total Benefits		$170,413	$170,413	$170,413	$170,413	$170,413	$170,413	$170,413
Costs								
	System capital cost	$410,000						
	Operations & Maintenance	$20,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
	Training	$5,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000
Total Costs		$435,000	$12,000	$12,000	$12,000	$12,000	$12,000	$12,000
Net Cash Flow		-$264,587	$158,413	$158,413	$158,413	$158,413	$158,413	$158,413

Net present value	**NPV**	**$1,056,955**
Internal rate of return	**IRR**	**56%**

Calculation of Payback Period for Lamb

Year	0	1	2	3	4	5	6
Discount factor	1.00	0.91	0.83	0.75	0.68	0.62	0.56
Discounted Total Benefits	$170,413	$154,921	$140,837	$128,034	$116,395	$105,813	$96,194
Discounted Total Costs	$435,000	$10,909	$9,917	$9,016	$8,196	$7,451	$6,774
Cumulative benefits minus costs	-$264,587	-$120,575	$10,346	$129,364	$237,562	$335,925	$425,345

Payback Twenty-three months

5.2 Beef

Calculation of NPV & IRR for Beef

Year	0	1	2	3	4	5	6
Benefits							
Tangible							
Reduced manning	$56,000	$56,000	$56,000	$56,000	$56,000	$56,000	$56,000
Reduced worker compensation (1)	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000
Reduced absenteeism (1)	3360	3360	3360	3360	3360	3360	3360
Reduced staff turnover (1)	4480	4480	4480	4480	4480	4480	4480
Intangible							
Improved carcass hygiene	$25,388	$25,388	$25,388	$25,388	$25,388	$25,388	$25,388
Total Benefits	$95,228	$95,228	$95,228	$95,228	$95,228	$95,228	$95,228
Costs							
System capital cost	$390,000						
Operations & Maintenance	$20,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
Training	$10,000	$7,000	$5,000	$5,000	$5,000	$5,000	$5,000
Total Costs	$420,000	$17,000	$15,000	$15,000	$15,000	$15,000	$15,000
Net Cash Flow	-$324,773	$78,228	$80,228	$80,228	$80,228	$80,228	$80,228

Net present value	**NPV**	**$690,865**
Internal rate of return	**IRR**	**12%**

Calculation of Payback Period for Beef

Year	0	1	2	3	4	5	6
Discount factor	1.00	0.91	0.83	0.75	0.68	0.62	0.56
Discounted Total Benefits	$95,228	$86,570	$78,700	$71,546	$65,042	$59,129	$53,753
Discounted Total Costs	$420,000	$15,455	$12,397	$11,270	$10,245	$9,314	$8,467
Cumulative benefits minus costs	-$324,773	-$253,657	-$187,353	-$127,077	-$72,280	-$22,465	$22,821

Payback Sixty-six months

6 Summary

The analysis provides NPV, IRR and Payback Period calculations based on data available to Mercer technologies, the authors and from assumptions highlighted in the report. The following results are presented accordingly.

- The analysis for automated lamb evisceration produces an NPV of $1,056,955, an IRR of 56% and a payback period of 23 months.
- The analysis for automated beef evisceration produces an NPV $690,865, an IRR of 12% and a payback of 66 months.

The analyses should be regarded as conservative since the costs have been generally overstated and the benefits understated. Some meat companies may recognize benefits beyond those stated and adjust the outcome accordingly. A rework of the related spreadsheets is possible on request.

Experience with development of an automated lamb evisceration system will provide further information will enable a review of the costs and benefits of a system for beef. Changes in the circumstances in the industry may alter the need for automation.

7 Recommendations

- It is recommended that an automated lamb evisceration system be considered for immediate development with view to obtaining the benefits as early as possible.
- It is also recommended, since the benefits of an automated beef evisceration system are not as clear, that this be considered after successful demonstration of a lamb system.

8 The Authors

Doug Phillips – Until recently worked at MIRINZ on mechanical development, including the early work on the inverted dressing system and subsequently many of the automated boning systems. Doug is qualified in engineering (electrical) and business studies and has a total of 36 years experience overall in the meat industry.

Gary Broome – Is a consultant food technologist retained by Mercer Technologies. Gary is qualified as a microbiologist and biochemist and has extensive experience both locally and internationally as an advisor to industry and governments in meat, fish and horticulture processing, storage and transportation.

9 Appendix 1 Calculation of Hygiene Improvement – Lamb

Information/Assumption	Number	Units
a process cycle time of	9	seconds per carcass
and a work hours of	7.5	hours per shift
produces	3,000	carcasses per chain per shift
assuming	240	operational days per year
produces	720,000	carcasses per shift per chain per year
Time cost of evisceration detain/retain		
if	10%	production goes to detain/retain
and	10%	are due to evisceration problems
then	7,200	carcasses per year are affected by evisceration issues
requiring	2	minutes average attention each
represents	240	hours of effort per year
or	0.13	Full Time Equivalent (FTE)
or	$7,467	where one FTE = $56,000
assume	50%	reduction through better evisceration
makes a saving of	**$3,733**	per shift per chain per year
Product loss due to trimming		
from above	7,200	carcasses per year are affected by evisceration issues
and assuming	50%	reduction of trim through better evisceration
gives	3,600	carcasses per year
with average carcass weight of	15	kg per carcass
and assuming	10%	by weight average trim
loss is	5,400	kg per year
at	$5	$ per kg
representing a saving of	**$27,000**	per shift per chain per year
Total savings then are:	**$30,733**	per shift per chain per year

10 Appendix 2 Calculation of Hygiene Improvement – Beef

Information/Assumption	Number	Units
a process cycle time of	48	seconds per carcass
and a work hours of	7.5	hours per shift
produces	562.5	carcasses per chain per shift
assuming	240	operational days per year
equals	135000	carcasses per shift per chain per year
Time cost of evisceration detain/retain		
if	2.00%	production goes to detain/retain
and	30%	are due to evisceration problems
then	810	carcasses per year are affected by evisceration issues
for avge of	3	minutes average attention each
requiring	135	hours of effort per year
or	0.08	Full Time Equivalent (FTE)
or	$4,200	where one FTE = $56,000
assume	50%	reduction through better evisceration
makes a saving of	**$2,100**	per shift per chain per year
Product loss due to trimming		
from above	810	carcasses per year are affected by evisceration issues
and assuming	50%	detain/retain due to evisceration
gives	405	carcasses per year
with average carcass weight of	230	kg per carcass
and assuming	5%	by weight average trim
loss is	4,658	kg per year
at	$5	$ per kg
representing a saving of	**$23,288**	per shift per chain per year
Total losses are then:	**$25,388**	per shift per chain per year