final report

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Sheep evisceration

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Abstract

In collaboration between Meat & Livestock Australia (MLA) and the Danish Meat Research Institute (DMRI) *project no. A.TEC.0063,* this scheme design has been conducted from November 2008 and is finalised with this report February 2009.

This report explains the ideas of how to automate the sheep evisceration process.

The analysis confirms that it is feasible to develop an automatic machine for sheep evisceration.

The objectives agreed between MLA and DMRI have been completed.

Contents

1 Background

Evisceration is a hard and repetitive manual process in an environment which is associated with humidity and smell. Automation of sheep evisceration would offer better working conditions and could be implemented in the meat industry provided the return of investment is sufficiently good. It would reduce the requirement for manual process operations and provide for more interesting jobs in the maintenance of equipment.

On request from MLA, DMRI Consult has outlined a step-wise tentative development plan for automation of sheep evisceration (sfdoc 44738, 7 November 2007).

Based on the configuration of the present equipment for automated pig evisceration, presently found at 10 meat plants and developed by DMRI, a feasibility study / scheme design has been conducted to verify if a similar or adapted equipment could be developed for the Australian sheep industry.

The first step of the development was a scheme design phase which will be the basis for MLA's decision whether to continue the project and initiate development of the equipment.

Figure 1

2 Objectives for the scheme design – sheep evisceration

Danish Meat Research Institute has the task to assist the Australian ovine industry by proposing a realistic scheme to develop an automated evisceration system. In this study, several objectives have been set for the analysis.

- Type of species to be treated
- Size of carcass, i.e. min. and max. weight/dimensions
- Processing requirements, i.e. input to and output from the equipment
- Quality requirements
- Capacity requirements
- Separation conditions of offal
- Hygiene requirements
- Manning requirements
- Cost benefit calculation comprising savings on manpower, operational expenditure and price of the equipment
- Estimate of market for the equipment
- Identification of an Australian or possibly New Zealand technology developer/machine manufacturer who, under the guidance of DMRI, will be capable of developing and subsequently marketing the equipment
- Development plan comprising detailed budgets and time schedule
- Detailed requirement specification
- Evaluation of the feasibility of a development project

Figure 2 Objectives

A qualified evaluation for a successful automated evisceration machine for sheep has been carried out based on the collected information and experience from visiting representative sheep abattoirs in Australia, combined with achieved knowledge from DMRI's development of a commercial machine for pork evisceration.

Differences between sheep evisceration and pork evisceration do exist. These differences can be evaluated as minor or major but must all be handled properly.

Issues that have to be addressed together with the objectives are:

- Typical evisceration procedure in the sheep industry
- Biological and species diversity
- Differences in weight and dimensions
- Hygiene
- Differences in species e.g. ruminant vs. non-ruminants
- Line speed
- Traditional work setup, legislation and workflow management

Most of the issues will be addressed in this report, but some still remain to be fully settled in the further development work, e.g. veterinarian approvals, approval of changed workflow by unions and management, bobby calf and goat evisceration etc.

3 General overview

A stepwise approach including description of the pre-described objectives, explaining actual situation in Australia and clarifying demands for an automated evisceration machine expressed in the pre-specification, are the main issues in this section.
In order to give a common overview, a description of the average procedure of the entire process is given.

Typical procedure
It must be underlined that variation exists between the abattoirs, but a general manual evisceration includes the following steps:
All abattoirs perform electro stunning, cutting of the veins, followed by a bleeding time of several minutes.
Pelting is performed by several persons, changing the hanging principle of the carcass. Avoiding hair on the carcass is important as a hygienic requirement. Shearing is normally not performed, but a limit of 2 inches, determines this additional action. Deheading is always performed before the evisceration process is started.

Average manual evisceration includes:

1. The bung end is cut free with a knife.
    a. Prior to this operation, some abattoirs secure the bung end by injecting a tampon or cone cup to the rectum.

2. The belly is opened from the hind legs towards the breastbone by using a knife.
    a. Extremely skilful precautions must be taken not to damage any intestines during the last part of this operation.
    b. Usually the first cut is done from outside-in, changing halfway from inside the belly with the knife facing out towards the operator.
    c. The major part of the intestines drops out of the carcass revealing the fat end to be exposed.

3. Releasing the fat end by tearing in a downwards and outgoing direction. The kidney and major part of the kidney fat are loosened, revealing the kidney string to be clearly identified.
    a. If the rectum has not been secured, a knot can be made or alternatively the ft end can be placed as the lowest point outside the carcass.

4. The intestines are manually removed by a lifting and turning action and placed in automated and disinfected trays.
    a. The placement is usually done by a 180 degree turn and lifting action, which, from an occupational health point of view, must be hard.

5. Breastbones are cut by using a hydraulic scissor tool.
    a. This accessory is hinged on an outbalanced and expandable wire released

uncontrolled after each operation.
   b. Usually no cleaning or sterilisation between each carcass cut is performed.

6. Liver and kidneys are removed from the carcass by tearing them away from the soft tissues.
   The intestines are placed in a tray either in separate rooms or together by a movement and turning of approx. 180 degrees.
   a. Alternatively, the items could be to toss round the back which demands a particularly good artistic skill.

7. The diaphragm is successively cut in each side by using a knife through an outgoing circular movement.
   a. The kidney string is finally cut as close as possible to the vertebra.
   b. The pluck remains in the carcass/neck, hanging downwards only attached softly to the inside by tissues and other fibres.

8. Manual removal of the pluck and placement in synchronised trays with the intestine completes the actual evisceration process.

9. Separating the heart, gall bladder, liver etc. leaving the carcass and plucks ready for veterinarian inspection completes the slaughtering process.

The different tasks are performed by several operators depending on line speed, local agreements etc. To visualise an average manning situation, a table based on the visited abattoirs is given below. Each abattoir has its own individual layout, and therefore many aspects can give variations to the generalised table below.

	Descriptions	**Number of operators**		**Additional task**	**Comments** (e.g. Visit 1)
1	Fat end	1		Turning of the carcass	#2
2	Belly opening				
3	Releasing the fat end	2		Liver/Kidneys removal	#3
4	Intestines removal			Kidney fat	#6
5	Breastbone cut	1			#4
6	Diaphragm cut	2			#5
7	Plucks removal				
8	Separating plucks	2			#8
9	Separating intestines	1			#9
10	Veterinarian Inspection	2		Kidney release	#7 One for the carcass One for the plucks/intestines
	Total	11			+1

Table 1 at line speed max 10 head/min

3.1 Species:

Species which have been observed during the visits to plants include lambs and sheep only, though some abattoirs also handle bobby calves on the same line. According to information received from Australian abattoirs, approx. 5% are bobby calves. These species must be able to pass through the equipment, preferably to be processed in the same equipment. An optimum result would allow evisceration of bobby calves, goats, etc. but will be a target for a future development scheme.

Information on biological diversity of different sheep breeds and categories have, to some extent been gathered during the visits. Further information might be collected through databases queries and report readings later. The analyses and evaluation are related to observations concluded as average, minimum and maximum values being significant for the industry.

The difference between ruminant and non-ruminant species must be highlighted. The different combinations of intestines e.g. the paunch, the honeycomb and abomasum as well as no soft tissues are attached to the inside of the carcass isolating the stomach. Compared to pig evisceration, this reduces the complexity but also changes the behaviour of the intestines. The overall picture is difficult to predict precisely prior to actual testing and verification.

Weight and dimensions: Data recordings during visits have given an overview of values related to weight and dimension. Collecting data through the national registered database e.g. NLRS has not been possible. Individual correspondences with subcontractors (MAR and Miller Mechanical) and visited abattoirs (CFR) have been conducted.

The data below are based on 500 samples

CCW							
Data 2008			A	B	C	D	E
Lamb estimation	kg	20-22					
Sheep estimation	kg	22,0					
Measured Average	kg	22,3	1.072	812	225	425	105
Standard Deviation		8,19	68	35	15	28	11

Abattoir data 1

Further investigation and collecting through published material finalising the set of data are required to verify the average weight and deviation.

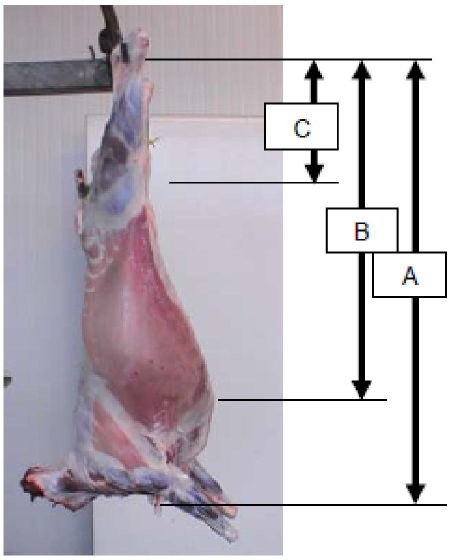


Figure 3 Main measurements A, B & C

	Mar-08	Feb-08	% change	YTD 2007/08	YTD 2006/07	% change
Eastern states* slaughter ('000 head)						
Cattle and calves	342	356	-4%	3,443	3,570	-4%
Lamb	1,317	1,437	-8%	13,717	13,103	5%
Sheep	704	803	-12%	6,254	7,934	-21%
Eastern states* production (tonnes)						
Beef and veal	78,491	85,418	-8%	729,766	758,644	-4%
Lamb	27,788	31,142	-11%	289,211	268,921	8%
Mutton	15,122	17,600	-14%	139,591	163,686	-15%
	Apr-08	**Mar-08**	**% change**	**YTD 2007/08**	**YTD 2006/07**	**% change**
Eastern states* exports (tonnes sw)						
Beef and veal	34,695	30,028	16%	302,234	318,261	-5%
Lamb	11,888	10,326	15%	120,099	106,089	13%
Mutton	10,532	10,546	0%	99,797	106,079	-6%
	Apr-08	**Mar-08**	**% change**	**Apr-07**	**% change**	
Eastern states saleyard prices (¢/kg cwt)						
EYCI	318.0	323.4	-2%	316.6	0.5%	
ESTLI	350.5	349.0	0.4%	333.5	5%	
Grain prices^ ($A/tonne)						
Sorghum	305.0	306.3	-0.4%	277.8	10%	
Feed barley	328.8	321.8	2%	311.3	6%	
Feeder paddock sale (¢/kg lwt)						
Shortfed	172.5	173.2	-0.4%	171.7	0.5%	
Longfed	182.0	182.5	-0.3%	197.8	-8%	

* NSW, Victoria, South Australia and Tasmania ^ delivered Sydney Sourced from ABS, DAFF, Landmark, MLA's NLRS

Table 2 NSW, Victoria South Australia and Tasmania, FY07/08, CCW, Ref. FeedBack 08

From the above data the numbers are summarised and listed in the table below.

Slaughtered Head	[head]	19.971.000	13717000	6254000
Slaughtered production	[Kg]	428.802.000	289211000	139591000
Average weight		21,47		
Calculated Standard Deviation	[Kg]	2,8		

Table 3 Summarised data from NSW, Victoria South Australia and Tasmania, FY07/08, CCW

To verify the above values, associated data from Denmark are collected.

Type	Average weight [kg]	Calculated Standard Deviation (SD)	
Lamb	20.8	2.82	
Sheep	31.6	8.75	Small numbers make this value not representative

Table 4 Denmark 2006

The deviation of 2.8 kg with average weight of 21.5 kg will be included in the pre-specification

Offal: Disposal of offal shall remain unchanged to current processes, but the separation may be changed due to selected method.

During the visits, several veterinarians were interviewed about regulations regarding the handling of offal, e.g. keeping the plucks and intestines together in trays. No final conclusion could be made, which is why this issue has to be settled finally during the next phase. A precise demonstration of the method visualising the impact makes this much easier.

DMRI expects that a change in the handling of offal can be approved, despite minor changes, and will most likely achieve a better result.

Hygiene: The effect on hygiene of Automatic evisceration of pigs has been tested at two Danish slaughterhouses with a varying degree of automation before the evisceration. In both cases, the automatic evisceration reduced the numbers of E. coli on the cut face and adjoining areas by approx. 1 log-unit. (Christensen, H. og T. Jacobsen (2000).Automatic evisceration – Hygiene investigation. Ref.nr. 18.311, Report 14. September, 0330.doc. Jensen, T. og H. Christensen (2002). Hygiene optimised slaughter - Automatic bung loosening, opening and evisceration – microbiological carcass tests. Ref. nr. 18.311. Rapport at 5. July. SFDokumenter: 7734.1.)

To achieve accurate and efficient hygienic solutions in an automatic machine, the supplier must provide precise user directions and maintenance instruction to ensure a stable hygienic level.

A hygienic design must be followed during the development phase, and microbiological tests must be performed during installation. It is feasible and recommended to clean / wash tools to a sufficient level between each carcass. Uncontrolled splashing of water should be avoided in the final machine construction.

<u>Perspectives:</u>

Whenever the belly is opened and the intestines drop out, there is a risk of damaged intestines. Contamination of the carcass can be reduced by several methods some of which have proven significant improvements.

Speed: Line speed is higher compared with traditional pork evisceration, in particular from an automation perspective. Maximum speed for automatic evisceration of pork equals 360 per hour = 6 per minute. Due to the speed difference, the evisceration process may be more difficult but not impossible to perfect in relation to a hygienic sustainable solution.

Maximum line speed	10 head/min	Processing time equals 6 sec incl return and cleaning.

Table 5 Speed

Traditional cuts:
Another difference between pork and sheep evisceration is the muscle inside skirt position. Market demands often require special cuts, e.g. with the inside skirt attached.

Figure 4 Retail sale

Other skirt muscle issues have been observed during abattoir visits and relate mainly to the production setup.

Chilled skirt muscle remaining in the carcass facilitates the logistics due to less handling but increase the weight and thereby the payment to the supplier.

Separating the skirt muscle from the carcass as cold parts can also be easier. Disadvantages of this are hygiene issues, e.g. pockets trapping and isolating contaminated areas or pieces of meat. This leads to extra handling or in extreme cases customer claims.

Generally, it is concluded that the inside skirt must remain on the carcass.

4 Technical pre-specification

As a pre-described specification minimum and maximum numbers have been made. By 3 standard deviations approx. 99% of all processed carcasses will be classified as carcasses suitable for automated processing.

Species		Sheep		
Minimum weight	[kg]	13,8		
Maximum weight	[kg]	30,7		
		A	**B**	**C**
Minimum length	[mm]	868	707	179
Maximum length	[mm]	1.277	918	272
Line speed	[head/min]	10		
Hygene		Best practise		

Table 6 Technical pre- specification

5 Methods overview

Based on the project information background and visits in the industry, several principles for automatic sheep evisceration have been analysed.

In summary, three main methods, with a few variations have been the result.

As a primary condition, a dedicated automated robotic solution has been chosen, as this allows simultaneous operations. As a consequence of the need to perform multiple operations fast, a standard industrial robotic solution will not be able to perform the required processes with sufficient speed and meet all requirements. A combination of robotic and dedicated equipment may well be developed, but a relatively lower speed must be expected.

All three ideas cover the following single tasks:

Cutting through the diaphragm and along the inside skirt.

Cutting the kidney string.

Pushing the intestines out of the carcass.

5.1 Method one

Method one handles the intestines and plucks as two items with the liver attached to either the intestines or the plucks.

First variation covers:

- Eviscerate the intestines into a tray whereby the plucks set and liver remain together.
- The liver is manually torn off the paunch at the abomasums.
- The plucks are positioned partly outside the carcass.
- Manual cutting of the gullet releases the intestines from the carcass.
- Manual removal of the plucks from the carcass into associated tray.
- Manual removal of the liver from plucks into the associated tray.

Second variation covers:

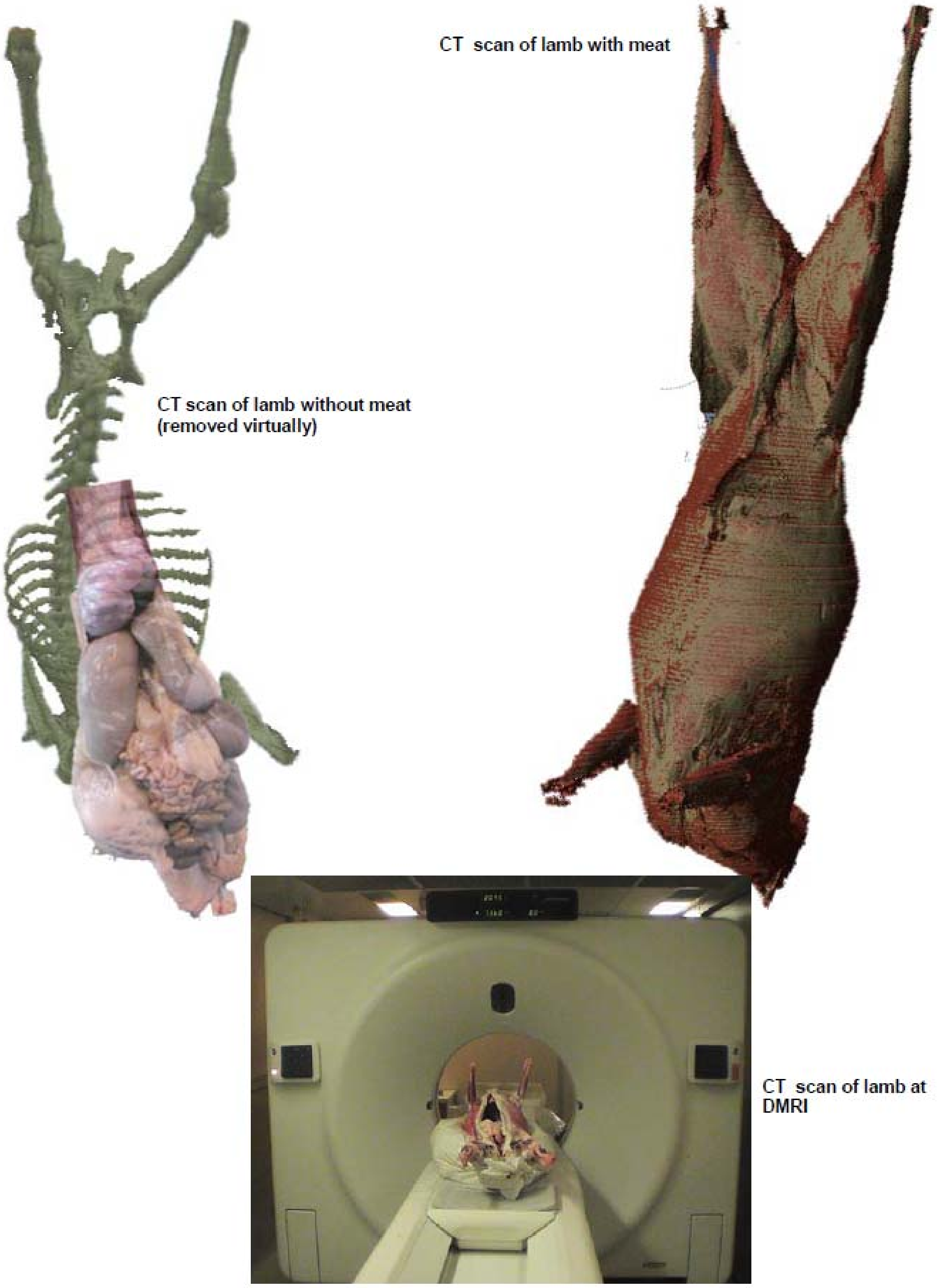
- Eviscerate the intestines into a tray, leaving the plucks set partly outside the carcass.
- The intestines are manually cut off at the gullet start point together with the liver.

Manual removal of the plucks from the carcass into associated tray

5.2 Method Two

Method two handles the intestines and plucks as one item with the liver attached naturally to the paunch.

- Eviscerates of the intestines and plucks into one common tray.
- The liver is manually torn off the paunch at the abomasums.
- The plucks are manually separated from the intestines by a determined pull and placed in associated areas on the tray.
- The intestines are manually separated



5.3 Method three

Method three handles a different approach to the evisceration compared with all known processes, known as “front leg evisceration”.

Eliminating the potential contamination risk by avoiding contact with prime contamination sources must be a better solution than trying to prevent damaging the fragile intestines or paunch by designing well-balanced tools. This strategy is characterised as preventive rather than corrective. By trying to develop an automated process guided by this strategy, the idea below evolved.

By keeping the carcass shackle to the front leg as, for example, with the automated breastbone saw, the fragile intestines will by naturally be positioned towards the hind leg and therefore well away from the diaphragm.

This method ensures a safe entry of tools above or below the diaphragm eliminating potential risk of damaging the intestines.

5.4 Detailed methods descriptions

5.4.1 Methods one and two

For both methods, the main procedure will follow the following steps:

Preparation:

- With the carcass shackled by the hind legs by e.g. a triangle hook or in chains, the left and right legs are kept well apart. Hind legs needs not be divided.
- Gullet secured and loosened from the trachea.
- Fat end loosened and breastbone cut open by sawing.
- By opening the belly, the intestines falls out only secured by the soft attachment to the vertebra and liver.
- By manually pulling in the bung end and ensuring that this intestine is either strapped or placed in a secure way to eliminate contamination on the carcass from bung end secretions, this manual operation prior to the automatic process will initiate the evisceration.
- Detection of the breastbone position either by a manual system or by vision must be performed as part of the preparation.

Automated process:

- By a synchronised movement, the carcass is secured on the leg, on the back, around the belly as well as inside the carcass approx. around the neck.
- Simultaneously, a tray to support the intestines is guided from below and upwards towards the breastbone/diaphragm attachment point.
- Using an opening tool, the breastbones are spread further to allow two curved diaphragm bars to enter on the lower side of the diaphragm. Inside the carcass among the plucks, an axial turning of these bars opens the carcass up to a fixed size and shape. The shape of the bars determines the trajectory of the diaphragm cutting tool. From above, an adaptive diaphragm and kidney string cutting tool follows a path between the two kidneys toward the vertebra producing a minor hole in the diaphragm as close to the vertebra as possible.
- By a successive upwards movement, the kidney strings are cut.
- This tool also contains two knives each capable of making a circular movement.

- By this movement, each knife will follow the shape of the diaphragm bars from the topside of the membrane as well as on the inside of the bars preventing any intestines from being damaged, leaving the skirt muscle on the carcass.
- By releasing the tray downwards and pushing the adaptive diaphragm tool further, the intestines will be eviscerated into the tray. Finally, by pressing the plucks downwards, the soft attachment to the vertebra (if not released by a manual operation earlier) is loosened, allowing the plucks to fall out of the carcass only attached to the neck.
- The evisceration process ends by releasing the carcass, cleaning the tools while returning to the start point.
- Two operators ensure that the carcass is ready for the automated process.
- Intestines are eviscerated into a tray Manual removal of the plucks by a second operator into a separate but associated tray compartment for the automatically eviscerated intestines, ensures that the intestines, liver and plucks are associated with the carcass.

Advantage:

- Almost similar to current pork evisceration processes.
- A reduced number of complex operations.

This process is relatively simple compared to existing pork evisceration equipment, which is why the overall successful expectations of this method are high.

Disadvantages:

- Increased speed makes the implementation of the automation process more difficult.
- Opening of the belly manually, allowing the intestines to fall entirely out of the carcass prior to the automated process.
- New operation by cutting the diaphragm from inside the carcass at a fixed distance from the breastbone

Pre investigation of methods at Danish abattoir

5.4.2 Method three:

Preparation:

With the carcass shackled to the front legs by e.g. a triangle hook or in chains, the left and right legs are kept well apart. Hind legs needs not be divided.

- Fat end loosened
- Gullet (Oesophagus) secured and loosened from the trachea.
- Breastbone cut open by sawing.

Automated process

- By a synchronised movement of the carcass and secured on the back, around the belly as well as inside the carcass approx. around the pelvis bone, starts the evisceration process starts.
- Simultaneously, a tray to collect the intestines is guided from below and upwards below the breastbone/diaphragm attachment point.
- Spreading the breastbone by a mechanism seeking optimal access to the plucks above and below the diaphragm is essential to the process.
- Inserting diaphragm bars with flexible knives securing a fixed carcass shape.
- Cutting the kidney string followed by penetration of the diaphragm through a vertical movement. Cutting along the fixed path followed by an extended vertical movement tearing the plucks away from the soft tissue to the vertebra ends this operation.
- Simultaneous to the insertion of the diaphragm bars, a belly-opening knife placed above the intestines tray opens up the belly with a vertical movement towards the rectum. By use of gravity, the entire intestines drop out of the carcass into the tray.
- The evisceration process ends by releasing the carcass, cleaning the tools while returning to the start point.

Advantages:

- One benefit of this method is opening of the belly from the breastbone a start point where minor risk of damaging the intestines exist, because gravity ensures they are well away from the operating knives.
- Less risk of damaging the intestines prior to or during cutting of the diaphragm. This leads to lower risk of contamination of the carcass.
- This process takes advantage of gravity when cutting the diaphragm by protecting the intestines much more than the other solutions.
- Evisceration of intestines and plucks into trays simultaneously,

Disadvantages:

- Increased speed makes the implementation of the automation process more difficult.
- New method compared with automated pork evisceration.
- Several new operation tasks and lack of experience increase the risk of this method

Selection

Based on an evaluation by DMRI engineering and meat technicians of the aforementioned methods, **Method two** tends to have the greatest potential.

To visualise the impact of automated evisceration of sheep at an average plant, a modified layout is given below. The impact covers both a redesigned process with existing tray equipment as well as the effect on required operators.

	Description	**Number of operators**		**Additional tasks**	**Comments** (e.g. Visit 1)
0	Fat end secured				Prior to evisceration process
1	Throat secured				
2	Breastbone cut	1			#2
3	Belly opening Loosened the fat end until kidney string and secure fat end by e.g. knot	2		Turning of the car-case Secure carcass ready for evisceration.	#3
	Automatic evisceration				
4	Separating intestines from plucks and separating liver from plucks set and dehinding the kidneys, cutting the heart and placing in separate tray areas	3		By rotating of e.g. 3 operators, optimum hygiene is ensured.	#4 If the intestines and plucks set are not eviscerated completely from the carcass, the operators shall pull the intestines/pluck s set down
7	Separating of intestines at tray	1		Back up of heart removal etc.	#7
8	Inspections	2			#8 One for the carcass One for the plucks/intestines
	Total	9			

Table 7 at line speed max 10 head/min

Using this layout with a changed workflow, a reduction of two operators will be possible compared with a manual operation.

E.g.: Potential layout at installation at abattoir with narrow space

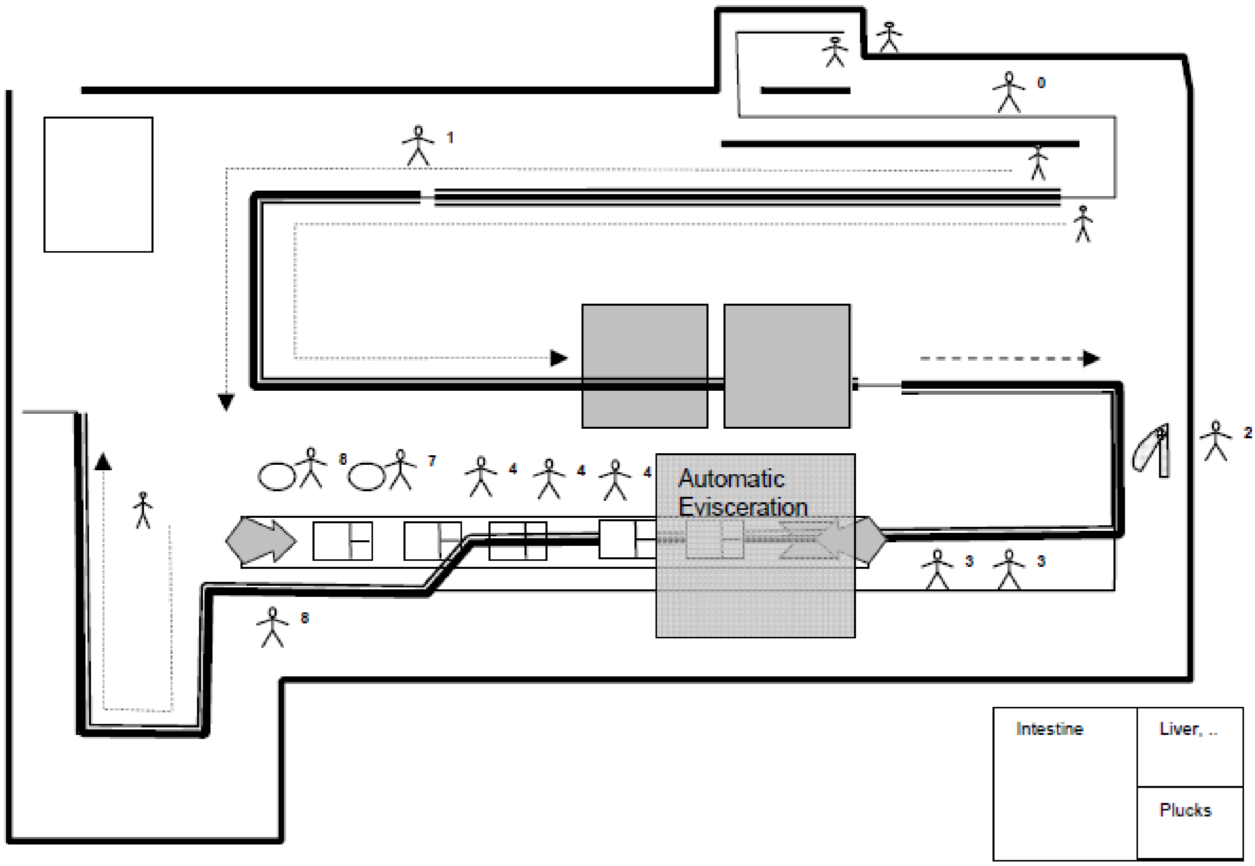


Figure 5

The small changes in the layout of the chain process including a minor change in height are estimated as acceptable.

It seems possible to extend the existing tray line to be used together with an automated process. A backup area with manual platforms is recommended, but due to limited space conditions in many plants this may not be an option.

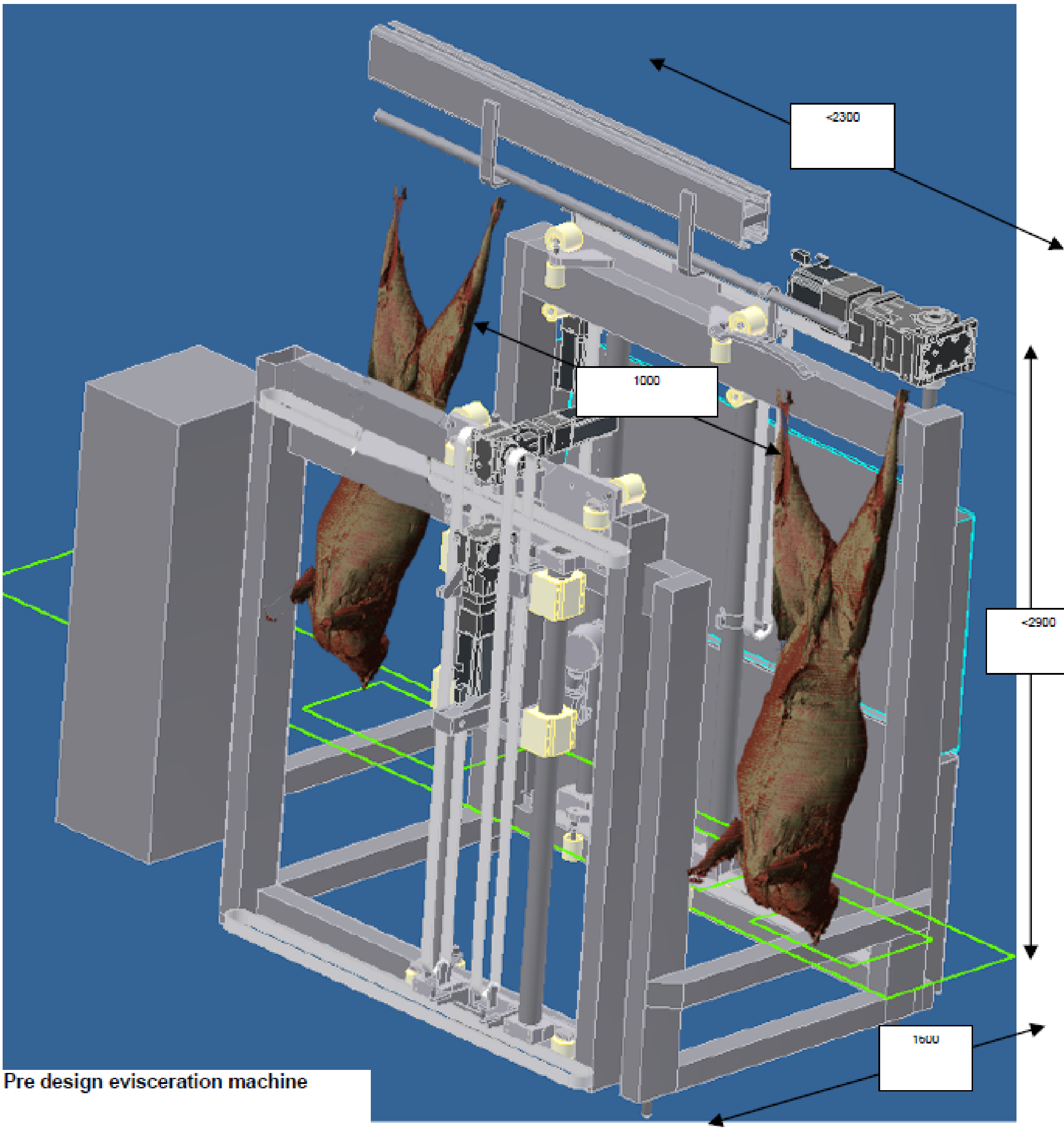
6 Tentative design

A tentative design of the evisceration machine will be based on equipment which differs from the existing pork evisceration machine in relation to mechanical design.

Major estimated dimension are shown at the figure below and will be adjusted to the actual layout e.g. distance between drop fingers (approx. 1000 mm), opening direction of panels etc.
The machine will be designed as a unit, with a speed synchronised to the actual line speed. The contemplated design will contain a fixation unit, operating from the back and several tool operating simultaneously from the belly side.

Standard supply of hot (>55C) and cold water, compressed air (>6 bar) and electricity (>16A at 240 VAC, 50/60HZ) will be required.

Data in mm



Pre design evisceration machine

7 Economic evaluation

Estimations of development cost, machine cost, benefit and time schedule calculation are given in this section.

Balancing the line according to equal work strain after installation is a critical factor in terms of making a cost benefit calculation. Some variations in economic benefit occur when installing the same equipment at equivalent plants, and exact calculations must be done with respect to the actual plant.

Process overview pinpoints the main process, and determinates the individual operation time in order to calculate the total processing time and thereby max capacity.

Equipment price estimation makes a best price estimate based on the main component and a retail profit. The result equals the price each plant must pay for one unit.

PayBack estimation tries to visualise a window with different setups, like processing capacity, shift numbers and labour savings. The calculation results in a payback time [year].

Input for this calculation is:

- Production:
    - Number of machines
    - Production capacity (head/hr)
    - Production time (hr/week and week/year)
- Direct pay:
    - Cost savings as average cost/year, all inclusive.
    - Number of operators saved.
- Capacity cost:
    - Maintenance / unit
    - Cleaning, etc
- Yield:
    - Yield: Better if positive and a decreased level if negative.
- Secondary gain
    - Improved working environment (e.g. less turning, twisting of body)
- Veterinarian benefits
- Investment
    - Unit price
    - Installation cost
    - Rebuilding cost covering associated cost when installed

In order to visualise different setups at abattoirs, a calculation window covering variations in essential parameters, has been established.

Net Present Value calculation adds up the investment and visualises the total benefit for one machine.

Calculations <u>must be</u> performed with respect to specific installation costs e.g. wages, installation cost, rebalancing the line, utilisation rate etc. and therefore the table <u>must only</u> be used as a <u>rough</u> guideline.

The estimated number of reduction of operators is correlated with additional work processes, which means that one operator may manage other processes, and therefore this influences the calculation in an unpredictable way.

Basis for these calculations are 2 shifts, an average labour cost of $Aus 70,000.00, 10% of interest rate and a currency rate of 3.8 $Aus vs. DKK.
Fluctuations in currency are seen and must be taken into account when finalising development plans and contracting development work.

Business case calculation concludes the calculation section and gives a full picture of the total investment and the consequences for the industry as a whole.
In this calculation a number of installed machines in the industry as well as a time line for the implementation are anticipated by DMRI only and these assumptions and all other data must data be verified later.

Process overview
Based on the technical specification, an estimation of the individual process steps has been made

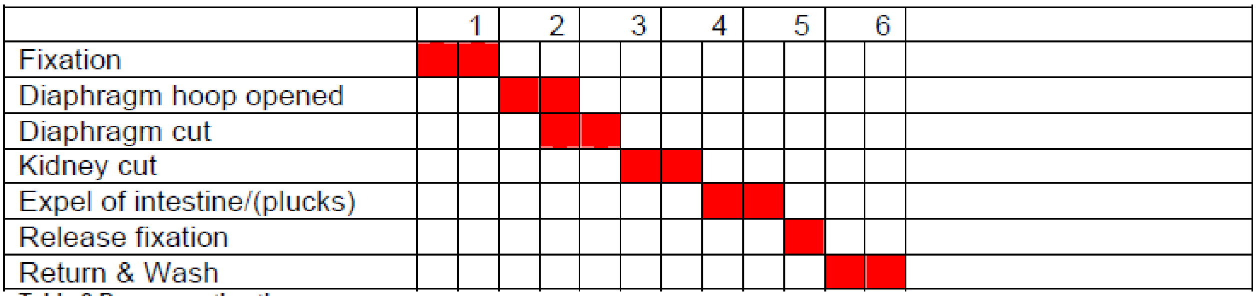


Table 8 Process estimation

By this process, 6 seconds will be the total process time, which is estimated to be the maximum speed.

Equipment price estimation has been done through calculations based upon previous experience with similar complexity of technology.
The complexity seems a little lower than for pork evisceration, but the increased speed and a couple of new processes influence the estimation.

The price level related to a regional developer and manufacturer of equipment also plays a large role. Experiences from pork evisceration have been the basis for this estimation but a tolerance of +-25% may very well be expected.

Estimated price of equipment delivered to a plant by a manufacturer, including installation

	$Aus	
Main Unit, excluding modification of plant tray		
		Incl. Manufacturer overhead.
Total	**455,000** +-25%	70%

Table 9 Machine price
This value may well be reduced, if produced in Australia or New Zealand, by up to 40% due to lower levels of labour cost.
Also the overhead cost may well be different depending on warranty, payment of licenses, patent etc. Included in this calculation as 70%, the overhead is high.

To visualise the impact of such variations, calculations are also given with lower investment costs included in the following calculations

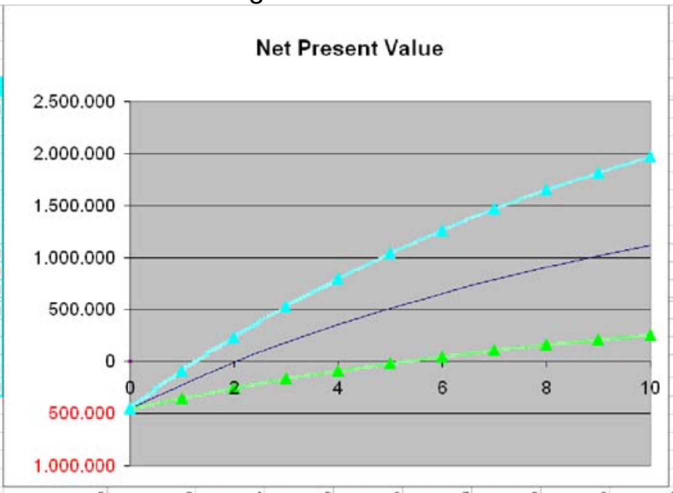
PayBack estimation gives an overview of when significant parameters changes at individual abattoirs e.g. unit cost of the machine or labour reduction per shifts.
The first main parameter is the labour saving costs, stated as **Labour reduction per shift**.
The second main parameter is the influence of cost level of producing equipment related to the Oceania region vs. the Danish cost level. This will of cause influence the prices of the commercialised, stated as **Total Unit Investment**.
These two vital parameters significantly change the financial benefit. The table below shows the impact of a limited number of variations of the aforementioned parameters.

Cost benefit											Max Capacity		
Evisceration lamb	[head/year]	2.520.000	2.520.000	2.520.000	2.520.000	2.520.000	2.520.000	2.520.000	2.520.000	2.520.000	3.024.000		
Shift		2	2	2	2	2	2	2	2	2	2		
Capacity	[head/hr]	600	600	600	600	600	600	600	600	600	720		
Labour reduction per shift		1	2	3	1	2	3	1	2	3	2		
Total Unit Investment		455.000	455.000	455.000	375.000	375.000	375.000	295.000	295.000	295.000	455.000		
Period of investment	10												
Calculation rate	10%												
Annual savings		115.500	255.500	395.500	111.000	251.000	391.000	106.500	246.500	386.500	242.000		
Direct pay		140.000	280.000	420.000	140.000	280.000	420.000	140.000	280.000	420.000	280.000		
Capacity cost		24.500	24.500	24.500	29.000	29.000	29.000	33.500	33.500	33.500	38.000		
Yield		0	0	0	0	0	0	0	0	0	0		
Book depreciation		74.049	74.049	74.049	61.030	61.030	61.030	48.010	48.010	48.010	74.049		
Annual net gain	[$Aus]	41.451	181.451	321.451	49.970	189.970	329.970	58.490	198.490	338.490	167.951		
Payment per carcase	[$Aus]	0,02	0,07	0,13	0,02	0,08	0,13	0,02	0,08	0,13	0,06		
Payback time (Year)	[year]	5,3	2,1	1,3	4,3	1,7	1,1	3,4	1,3	0,8	2,2		
Production												Dayshift	Nigthshift
Number of machines		1	1	1	1	1	1	1	1	1	1	1	1
Capacity	[head/hr]	600	600	600	600	600	600	600	600	600	720	625	625
Hour / week		44	44	44	44	44	44	44	44	44	44	44	40
Weeks/year		50	50	50	50	50	50	50	50	50	50	50	50
Evisceration lamb	[head/year]	2.520.000	2.520.000	2.520.000	2.520.000	2.520.000	2.520.000	2.520.000	2.520.000	2.520.000	3.024.000	1.375.000	1.250.000
Direct pay													
Cost saving per pers		70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000
Total number of operators, saved		2	4	6	2	4	6	2	4	6	4	2	2
Savings per year		140.000	280.000	420.000	140.000	280.000	420.000	140.000	280.000	420.000	280.000		
Capacity cost													
Maintenance		13.000	13.000	13.000	16.250	16.250	16.250	19.500	19.500	19.500	22.750		
Cleaning		6.500	6.500	6.500	6.500	6.500	6.500	6.500	6.500	6.500	6.500		
Other (power, water etc)		5.000	5.000	5.000	6.250	6.250	6.250	7.500	7.500	7.500	8.750		
Total per year		24.500	24.500	24.500	29.000	29.000	29.000	33.500	33.500	33.500	38.000		
Yield													
Yield per carcase		0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		
Annual production	[head]	2.520.000	2.520.000	2.520.000	2.520.000	2.520.000	2.520.000	2.520.000	2.520.000	2.520.000	3.024.000		
Total pa		0	0	0	0	0	0	0	0	0	0		
Secondary gain													
Working environment		0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		
Veterinarian gain		0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		
Gain per carcase		0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		
Annual production		0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		
Total per year		0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		
Investment		100%	100%	100%	80%	80%	80%	60%	60%	60%	100%		
Units		400.000	400.000	400.000	320.000	320.000	320.000	240.000	240.000	240.000	400.000		
Installation		35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000	35.000		
Rebuilding cost		20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000		
Total Unit Investment		455.000	455.000	455.000	375.000	375.000	375.000	295.000	295.000	295.000	455.000		
Period of investment		10	10	10	10	10	10	10	10	10	10		
Calculation rate		0	0	0	0	0	0	0	0	0	0		
Book depreciation		74.049	74.049	74.049	61.030	61.030	61.030	48.010	48.010	48.010	74.049		

Table 10 Main parameter 1 & 2 variations

Net Present Value calculation adds up the investment and visualises the total benefit for one machine.
The figures list the numbers of carcasses processed, and the output shows:
Internal Rate shows this investment is reasonable if alternatives have a lower rate.
Net Present Value indicating the final net present value.
Payback Time is calculated again.
Net Present Value Acc meaning the present value of the accumulated investment.
With a fixed speed (600 heads/hour) and unit investments, several NPV values are calculated and visualised in relation to variation of +/- one labour savings.

Capacity /hour	600			
Shifts	2			
Processed head per year	[head/year]	**2.340.000**		
Currency				
Total Investment Cost ex R&D	[$Aus]	455.000	455.000	455.000
Machine(s) / unit		1	1	1
Depreciation time	10			
Interest per year	10%			
Interest per month	0,8%			
Labour Savings		1	2	3
Direct payment	[$Aus]	140.000	280.000	420.000
Capacity cost	[$Aus]	24.500	24.500	24.500
Yield	[$Aus]	0	0	0
Annual cost-saving	[$Aus]	115.500	255.500	395.500
Internal Rate	%	22%	55%	>50%
Net Present Value	[$Aus]	254.698	1.114.937	1.975.176
PayBack Time	[Year]	5,3	2,1	1,3



Net Present Value Acc.	[Year]	0	1	2	3	4	5	6	7	8	9	10
	[$Aus]	455.000	360.000	254.545	167.769	88.881	17.164	48.033	107.302	161.184	210.167	254.698
	[$Aus]	455.000	222.727	11.570	180.391	354.901	513.546	657.769	788.881	908.074	1.016.431	1.114.937
	[$Aus]	455.000	95.455	231.405	528.560	798.682	1.044.256	1.267.506	1.470.460	1.654.963	1.822.694	1.975.176

Table 11 NPV values with different labour savings
These calculations use a perspective from the individual plant that installs such automatic equipment.
The calculation indicates a clear financial advantage when installing this equipment

8 Development cost and plan

Based on estimations debated within the DMRI team, a time/cost schedule can be visualised.
This plan covers 4 different phases including several sub-phases.

The four main phases are named as:

1. Proof of Concept

The first period, "Proof of Concept" covers the initial period where assumed methods will be tested during manual operation simulating the automatic movement. Auxiliary tools and /or operation will be part of this phase. The "Proof of Concept" period covers several individual tasks e.g. diaphragm cut, kidney string cut, fixation etc.
Those test periods must be compressed in time to minimise the travel expenses, and the development of the different methods must be performed simultaneously. The outcome of this phase must prove the principle and the technical specification with tolerances must be written.

2. Mock-Up

The second phase covers a Mock-Up stage which will combine the selected methods from phase one into a single operating unit.

The outcome of this phase must prove the speed and automatic solutions of the selected methods.

3. Prototype

The third phase will be testing the first real machine, produced by the contractor with focus on a reliable solution for wear, hygiene issues etc.
The outcome of this phase must prove the concepts reliability for processing sufficient and acceptable results as well as other approvals.

4. 0-Series machine

The last phase will be a commercialised model installed under guidance of the involved participant and introduced to the industry with a commercialised approach.
During each phase, the intention is to transfer as much knowledge as possible gained from the development of pork evisceration to sheep evisceration project participants.
Each phase covers the costs calculated for each participant as well as additional costs. A total calculation of all expenses covering all 4 periods is also made.
Differences in the participants' fees significantly affect the calculated price and are based on an initial query and indicative prices among potential participants

			[$Aus]	
1	Evisceration	884 dage?	$Aus 4.668.558	15.888,65 tim.
2	Proof of Concept	420 dage?	$Aus 2.347.977	11.270,65 tim.
3	P1 Concept design	160 dage?	$Aus 1.072.513	4.218,65 tim.
4	Diaphragm cut	106 dage	$Aus 234.070	960 tim.
5	P1-1Cutting	40 dage	$Aus 142.336	480 tim.
6	P1-1 Test	20 dage	$Aus 91.734	480 tim.
7				
8	Kidney cut	108 dage?	$Aus 264.154	1.273,48 tim.
10	P1-2 Cutting	35 dage?	$Aus 40.397	280 tim.
9	P1-2 Detecting	40 dage	$Aus 176.259	693,48 tim.
11	P1-2 Test	15 dage?	$Aus 47.498	300 tim.
12				
13	Expel of entistines	130 dage?	$Aus 293.613	1.320 tim.
18	P1-3 Movement	65 dage?	$Aus 13.150	0 tim.
15	P1-3 Tray position	20 dage	$Aus 28.720	160 tim.
17	P1-3 Design	35 dage	$Aus 53.547	280 tim.
14	P1-3 Placement	30 dage	$Aus 134.866	480 tim.
16	P1-3 Test	20 dage	$Aus 63.330	400 tim.
19				
20	Design	67 dage?	$Aus 129.976	585,17 tim.
21	P1-4 Clamping	35 dage	$Aus 53.547	280 tim.
22	P1-4 Releasing	5 dage?	$Aus 17.042	40 tim.
23	P1-4 Cleaning	2 dage	$Aus 1.557	16 tim.
24	P1-4 Test	20 dage	$Aus 57.830	249,17 tim.
26	P1 Materials, proprety etc	0 dage	$Aus 52.600	0 tim.
27	P1 Meat cost	0 dage	$Aus 6.575	0 tim.
28	P1 Traveling cost	0 dage	$Aus 52.600	0 tim.
29	P1 Milestone cost	0 dage	$Aus 10.520	0 tim.
25	P1 Specification	10 dage	$Aus 28.404	80 tim.
30				
31	P2 Experimental equipment	325 dage	$Aus 1.275.465	7.052 tim.
32	Experimental preparation	72,73 dage	$Aus 268.164	1.600 tim.
33	SW	20 dage	$Aus 15.570	160 tim.
34	Installation	10 dage	$Aus 62.489	160 tim.
35	Test	100 dage	$Aus 458.672	2.400 tim.
36	Materials, proprety etc	0 dage	$Aus 26.300	0 tim.
37	Meat cost	0 dage	$Aus 13.150	0 tim.
38	Traveling costs	0 dage	$Aus 39.450	0 tim.
39	Project management	325 dage	$Aus 5.060	52 tim.
40	Quality report	10 dage	$Aus 28.404	80 tim.
41				
42				
43	P3 Prototype	359,5 dage	$Aus 1.580.130	3.838 tim.
49				
58				
59				
60	0-Serie	167 dage?	$Aus 740.450	780 tim.
65				

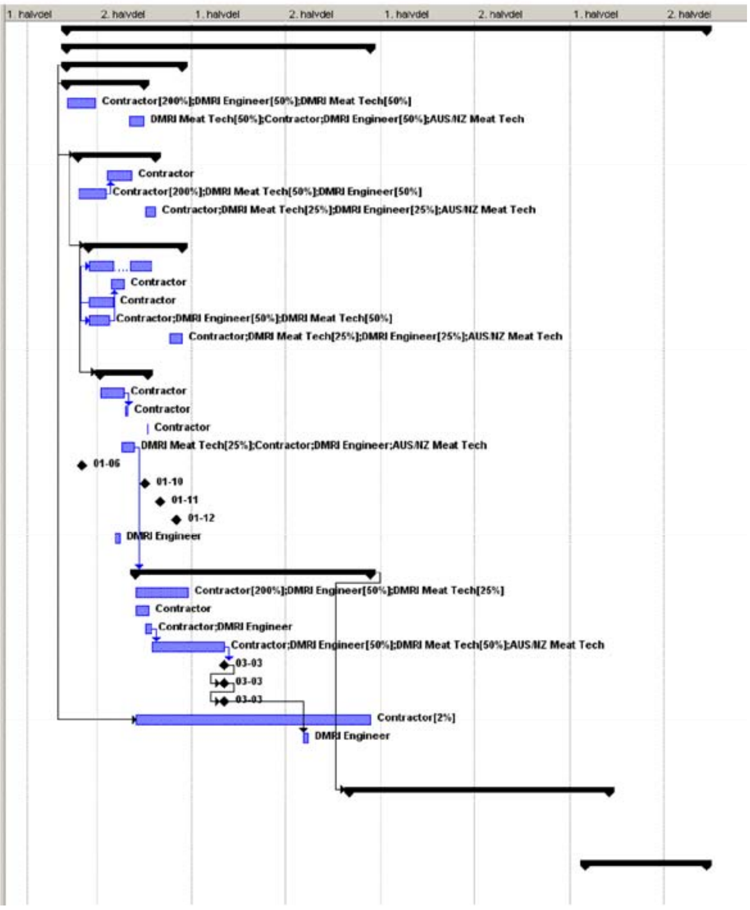


Table 12 Development time and cost scheme

Business case calculation is made to give an Industry perspective and overview for the investment in developing an automated sheep evisceration. With this calculation, it will be clearer to the industry to what extent their investment will be returned to the industry over time, in terms of money. An estimation of a given number of machines installed, covering more than 50% of the potential market is given below.

Net Present Value	År 1	År 2	År 3	År 4	År 5	År 6	År 7	År 8	År 9	År 10
Accumulated number of machines installed	0	0	1	6	11	16	21	26	26	26
Development costs	1.080.000	2.855.000	740.000							
Investment in machines per year	0	0	0	-2.275.000	-2.275.000	-2.275.000	-2.275.000	-2.275.000	0	0
Reduced labour costs per year	0	0	0	980.000	2.380.000	3.780.000	5.180.000	6.580.000	7.280.000	7.280.000
Yield Increase/decrease pr year	0	0	0	0	0	0	0	0	0	0
Maintenance costs per year	0	0	-24.500	-147.000	-269.500	-392.000	-514.500	-637.000	-637.000	-637.000
Net payment per year	-1.080.000	-2.855.000	-715.500	-1.442.000	-164.500	1.113.000	2.390.500	3.668.000	6.643.000	6.643.000
Net payment accumulated	-1.080.000	-3.935.000	-4.650.500	-6.092.500	-6.257.000	-5.144.000	-2.753.500	914.500	7.557.500	14.200.500
Discount factor	1	1,1	1,2	1,3	1,5	1,6	1,8	1,9	2,1	2,4
Net payment per year discounted	-1.080.000	-2.595.455	-591.322	-1.083.396	-112.356	691.085	1.349.375	1.882.264	3.099.009	2.817.280
Net Present Value	-1.080.000	-3.675.455	-4.266.777	-5.350.173	-5.462.529	-4.771.443	-3.422.068	-1.539.804	1.559.204	**4.376.485**
Basics of the cost benefit										
Saving 1. year	50%									
Calculation rate of interest	10%									
Automation										
Number of operators saved per shift	2,0									
Shifts	2									
Line speed , head per hour	600									
Number of head per year	2.340.000									
	[$Aus]									
Investment per machine (purchase and installation)	455.000									
Reduced labour costs per year	280.000									
Yield Increase/decrease per year	0									
Maintenance costs per year	-24.500									
Depreciation and interest (13%)	-59.150									
Net annual gain per machine	196.350									

Table 13 Industry perspective installation

As shown in the table, a "Return break-even point" will be after approx. 6 years from the start point, and the total benefit will be substantial in present money over 10 years.
The successful number of installed of equipments are essential for the calculation, and other factors e.g. R&D cost are less important. These calculations use a macro-perspective and assume that the paybacks are transferred back to the donors.

This calculation also indicates a clear financial advantage when initiating such a programme. **Identification** of an Australian or New Zealand contractor with sufficient capacity to develop dedicated automation equipment has been carried out.

Contractors must fully meet the following requirements:

- To display sufficient technologic knowledge.
- To display an operating automated system developed for the sheep industry
- Capacity of project management
- Access to meat technology technician and test sites.
- To prove readiness in daily support at sites all over Australia/New Zealand.
- To have financial credibility.

Local test sites seem to be the greatest challenge compared with the traditional development setup for the Danish pork industry.

9 Conclusion

This section concludes the evaluation of the sheep evisceration scheme design. Several ideas and all objectives have been worked through.

Danish Meat Research Institute has rejected the idea of using a standard industrial robotic solution for the sheep evisceration process as several operations must be performed simultaneously and the speed required by the industry cannot be accomplished.

Danish Meat Research Institute recommends that evisceration can be done automatically, by developing a dedicated automated system as described in method two.

This idea involves evisceration of the both the intestine and plucks set automatically into a synchronised tray and manually separation of the offal from here.

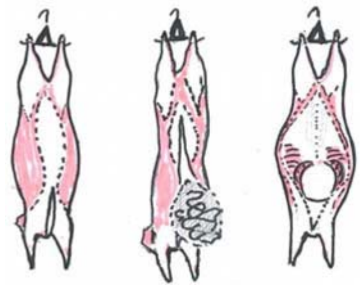
Using the automated evisceration allows a reduction of two operators compared with a manual operation.

With this layout, only minor changes in the operation sequence are expected, compared with the traditional workflow.

All calculations show a significant financial benefit both from an abattoir perspective as well as from the Australian industry perspective.

A risk analysis is also carried out with respect to varying the labour savings numbers and investment costs.

Danish Meat Research Institute is willing to be the supporting consultancy part that provides and transfers knowledge from automated pork evisceration to a regional contractor who will carry out the major part of the development work of a new automated sheep evisceration machine for the Australian Meat Industry. This will allow a faster development process with a higher chance of success.



10 Definitions and Glossary of terms

To support the projects objectives and fulfil the achievement criteria, a technical draft is created.

This draft is based on knowledge achieved from automation in the pork industry as well as existing knowledge on sheep slaughter and biological variation impact on automation.

To unify phrases and establish a clear interpretation the following glossary and category are made:

Sheep category of sex

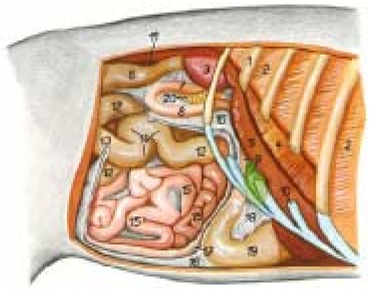
	Age (month)	Sex	Incisors	Splited
Young Lamb	0-5	Female or castrated/entire male	0 permanent	
Lamb	5-10	Female or castrated/entire male	0 permanent	
Mutton	10-18	Female or castrated/entire male	1-8 permanent	
Ewe	>10	Female	1-8 permanent	>18
Wether	>10	Castrated male	1-8 permanent	>18
Ram	>10	Male	1-8 permanent	>18
Other				

Table 14

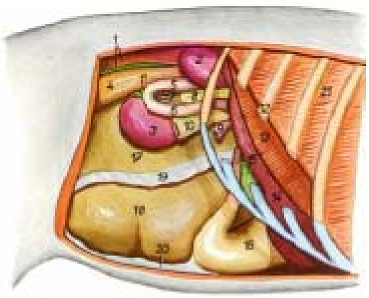
Glossary:

Australian term	Danish term	Comment	Ref
Small intestine	Smaltarm		A15
Bung	Bund ende		
Large intestine	Krustarm		A12,13,14
Bung end Fat end	Fedtende (yderside) Fedtende (inderside)	Rectum	
Diaphragm / Inside Skirt (Backstrap)	Mellemgulv Mellemgulvs muskel		B13
Honeycomb	Netmave	Reticulm	Below A13/14 C35
Paunch	Vommen	Rumen	B17/18
Omasum	Bladmave		Below A13/14
Abomasum	Løbe		16
Trachea	Luftrør		
	Kallun	Smooth muscle on the paunch surface	
Gall blader	Galdeblære		
Kidneys	Nyre		
Gullet	Spiserør	Oesophagus	
Sternum	Brystben		

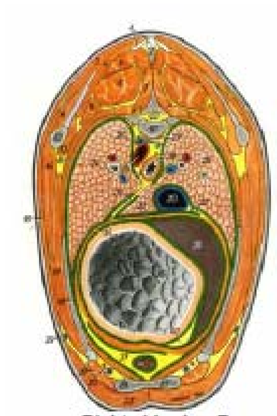
Table 15



Right side view A



Right side view C



Right side view B

Visits:

visit 1

Lines	▯	1
Production capacity		9,6/min -> 9200/day (Beef 700)
Shifts	▯	2 (18 hour)
Kill floor persons	▯	~30
Health and Safety Cost	[%]	Minor

Comments

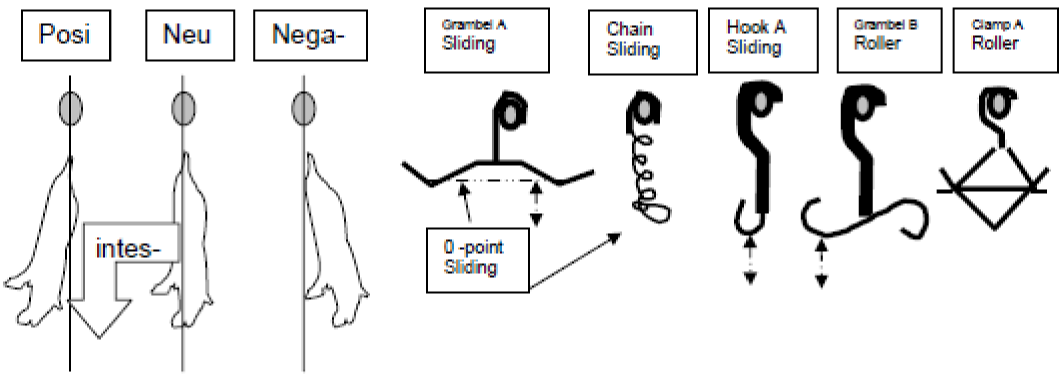
Item	
	June/July slow down

Production average:

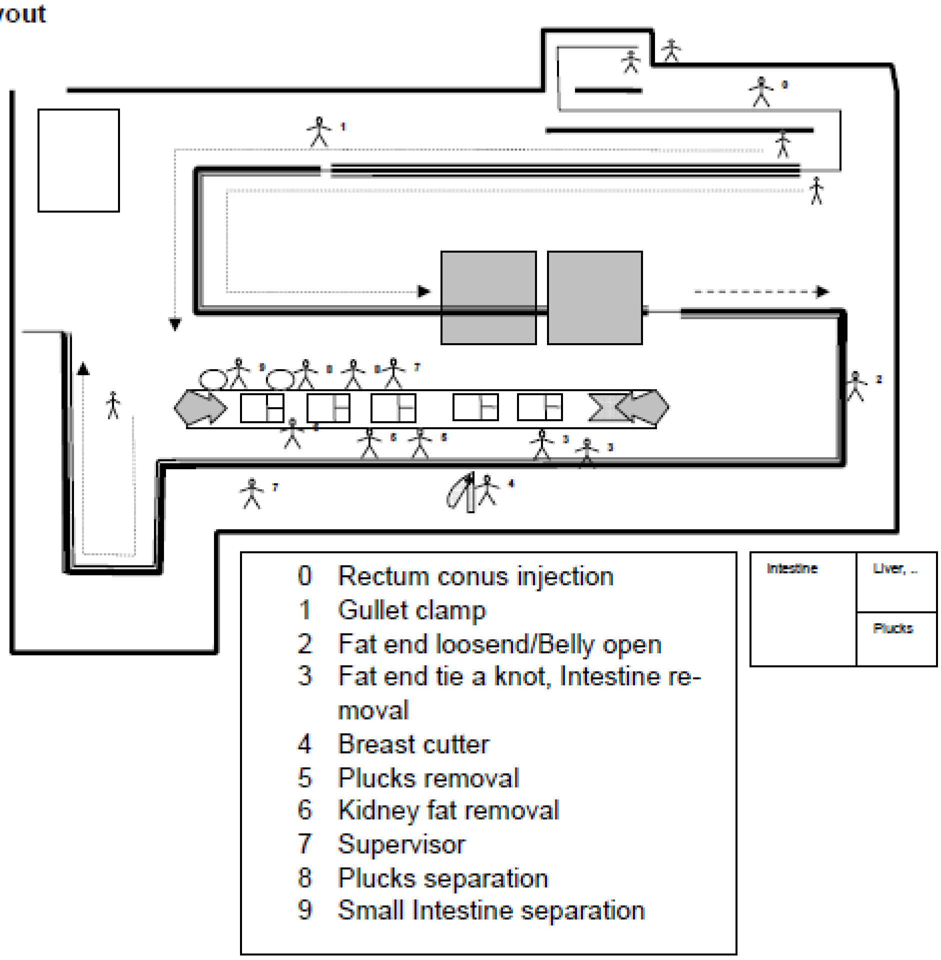
	Age (month)	**Sex**	**Incisors**	**Splited**	**Plant average**
Young Lamb	0-5	Female or castrated/entire male	0 permanent		50%
Lamb	5-10	Female or castrated/entire male	0 permanent		
Mutton	10-18	Female or castrated/entire male	1-8 permanent		50%
Ewe	>10	Female	1-8 permanent	>18	
Wether	>10	Castrated male	1-8 permanent	>18	
Ram	>10	Male	1-8 permanent	>18	150/day
Other					

Hanging principles at Evisceration

Item	**Comments (Yes/NO/Number)**
Right back (RB) Foreleg (FL) / Hind leg (HL)	RB / RBFL / FL / HL
Gambrel, Hook / Orientation at evisceration	Gambrel / HL
1 Hook / 2 Hooks / 4 Hooks	1-3
Sliding pole (A) / Roller Hooks (B)	A
Vertical / Angel (Positive / Negative)	Neutral


Posi
Neu
Nega-
intes-
Grambel A
Sliding
Chain
Sliding
Hook A
Sliding
Grambel B
Roller
Clamp A
Roller
0 -point
Sliding

Layout


0 Rectum conus injection
1 Gullet clamp
2 Fat end loosend/Belly open
3 Fat end tie a knot, Intestine re-
moval
4 Breast cutter
5 Plucks removal
6 Kidney fat removal
7 Supervisor
8 Plucks separation
9 Small Intestine separation
Intestine
Liver, ..
Plucks

Data

Item	**Comments (Yes/NO/Number)**
X-ray / Vision	N
Mechanical	N
Number of measuring	1
Type of measurement	Weight no DB

Length measure must be taken from a defined fix point towards a predominant anatomic point on the carcase. Measured in 1 direction. Fix point can be one of several methods as visualize in the figure.

Item		**Comments (Yes/No/Number/%)**
Length 0- point->Anatomic point (2 SD)		
Weight distribution (2 SD)	14-40	Judgement
Most supplied type (3 races)		
Wool species		
Meat species		X
Grain feed.		
Grass feed.		
Season variation (Fat/Sizes)	N	
Belly measurement		

Normal production layout:

Item	**Comments (Yes/No/Number/%)**
Intestine delivery at: (Tray, Container, etc)	Tray
Plucks delivered at: (Hooks/Tray)	Tray
Intestine delivered at: (Front/Behind/Left/Right)	B
Splited carcase	N
Tenderloin notched	N
Fat end loosened	
Fat end secured (Robber/Back/Bended)	Knot
Operators working with Intestine removal	4
Line manufacture	Old system
Space: (Around/Up/Down)	Very little, Height OK

Hygiene request:

Item	**Comments (Yes/NO/Number)**
On tools (Legislation)	Many times
In carcase	Y
On intestine	Y
Production action if detected	Cut away
Water/Aerosol (spray)	Damp on Breats/Forelegs after, skinned, before open.
Inspection by veterinarians / supervisor	Y
Intestine correlated to carcase / plucks	Y

Identity and Registration:

Item	Comments (Yes/NO/Number)
RFID Tag / Manual marking.	No
Ear marks	Cut away
ID storage time (production data / requirements)	%
Manual / Automatic registration	Manually, devided into batches acc supplyer.

Animal:

Item	Comments (Yes/NO/Number)
Stunned / Shut / Electrical stabbed	Electrical stunned
De- headed	Y
Time gab between feeding / drinking and slaughtering:	Max 24 h, normally 12h