final report

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Improved efficiency in beef deboning

Feasibility studies

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Abstract

In collaboration between Meat & Livestock Australia (MLA) and the Danish Meat Research Institute (DMRI) *project no. p.psh.0358,* this feasibility study has been conducted throughout 2008 and is finalized with this report.
The work has been carried out by the international Feasibility Deboning Beef project group and emerged through visits in Australia, New Zealand, Norway, Denmark and Germany.
Summarized meetings with the project group, milestone reports as well as consultancies with donors and suppliers have been the main sequences of the projects.
All reports have been summed up by DMRI.
This report explains the ideas for automation of the beef deboning process, which have emerged during the study.
The objectives agreed between MLA and DMRI have been completed.

Contents

1 Parties

On behalf of the meat industry members in Australia, New Zealand, Norway and Denmark, a feasibility study of Deboning Beef has been established. The international Feasibility Deboning Beef project group consists of meat technology members, engineers from Australia and Denmark along with automation subsuppliers from New Zealand.

2 Project objectives

Deboning of beef is strenuous, labour-intensive work. In many countries, labour costs are high and there is a shortage of labour supply. These countries have a strong incentive to apply technology to reduce the labour content in their production.
The purpose of this project is to identify technical solutions for more cost-effective deboning of beef by finding more efficient automated methods. This will provide economic benefit, and will improve the working environment and product safety. A proposal for a joint development plan funded by the partners with support from public subsidy programmes for automated selected tasks may also be an outcome of this study.

The project is aimed at evaluation of ideas, with close contact with all the partners. Based on identified ideas and recommendations from the project group, the results may be taken further into development projects for specific machines.

The objectives of the study are:

- to analyse the operations and process requirements of a representative number of deboning departments at the project participants' plants and, if relevant, at other international plants
- to identify operations that may be automated with a short payback time
- to conduct a technical/economic evaluation of the possibilities of developing more efficient and automated processes
- to conduct market interviews with three major suppliers of boning room technology
- to investigate the possibilities of subsidies from national programmes, the Nordic Innovation Centre, the EU 7th framework programme or similar programmes
- to investigate the possibilities of a joint development cooperation between the Nordic partners (possibly including Finland), Ireland, Australia through MLA and other relevant partners
- to draw up a proposal for a development plan and budget

3 Activities

This section includes the main activities which have been performed during the study and explains the ideas.
Many proposals have been subject to discussion, and up to nine ideas have been evaluated.
Of these ideas, five have been subject to further discussion, and finally three preferential ideas have been further detailed and analysed.

The direct benefit of each project contribution in terms of workforce savings is a key parameter. Also, the workplace environmental benefit and reduction in the harsh and strenuous workload each operator is exposed to are benefits of automation which will eventually have a large impact on the conclusion.

Furthermore, the complexity of each task is graded with respect to the complexity of development and the cost of an operating unit installed at the deboning plants. These general considerations form the basis of the final conclusion of the project.

Although many similarities exist among the participants' present plant operations, there are also some crucial differences, such as the significant variation in throughput and traditions in primal cuttings (e.g. pistola and forequarter/hindquarter and sides) or operation methods for deboning (e.g. table vs. line or pace boning).

There follows a brief explanation of all five ideas to identify the different tasks to be automated.
- Shoulder Removal
- Tenderloin Removal
- Back Boning
- Robot Cell
- Leg Deboning

3.1 Shoulder Removal:

The desired objective is to separate the shoulder, also expressed as the Banjo, from the forequarter and attach a hook into the shank followed by a suspension on the rail. The remaining carcass will stay attached to the hook and will be further processed.
The processing unit will be capable of processing both sides. Differences in method, e.g. slung or hook position at the breastbone, as well as determination of the hook position at the shank can be a challenge. Cutting precisely along the desired seams is a significant challenge, but is feasible, according to the project group.

3.2 Tenderloin Removal:

After location of the pelvic bone, a horizontal cut determines the start of the tenderloin. The tenderloin is further processed along an adaptive trajectory path.
During this process, the entire tenderloin is extracted from the carcase and included in a processing tool, imagined as a cup. The tenderloin will finally be pulled and delivered in suitable trays or on a conveyor. The cutting tool (cup) will most likely exist in different sizes according to variations in carcass weight, but the design will initially be similar to shapes known from equivalent pork tool.
The processing unit will be capable of processing both sides. The variation in both cup sizes and shape will be the main target for the first development step in this project as well as the location of the pelvic bone.

3.3 Back Boner:

After separation of the belly and flank from the back, the back piece is supposed to enter an automatic machine with the vertebrae facing upwards and will be fixated by a moving and gripping chain. The featherbones will be loosened and cut away by a set of knifes and saws. An additional set of four knives successively loosens the ribs from the loin as the meat proceeds along the path of the chain.

Via this method, an orthogonal processing direction is followed, which is different from manual deboning. The cut along the bones, and to a suitable extent also between the bones, can be achieved via an adaptive construction. Finally, the vertebrae are cut free and can therefore be removed onto a suitable disposal tray or transport conveyor belt, and the loin and breastbones are ready for further processing by automatic placement on a suitable medium.

The processing unit will be capable of processing only the left or right side. This project is espected to result in a substantial benefit in terms of operator savings. The main challenge will be to prove the adaptive cutting technology known from pork.

3.4 Robot Cell:

Several ideas for automation will obviously be more suitable for plants with a large processing capacity. However, if the capacity of robotic equipment could be used more efficiently, e.g. by performing several different deboning operations implemented within the same unit, automation may still be viable in smaller processing plants. A basic Robot Cell concept therefore covers several individual tools operated by only one robot.
The carcass, side or quarter is basically fixed only once. Primal cuts could be performed sequentially by a circulating movement.

Examples of processes which could be included in the robot cell could be scribing, shoulder removal as well as the tenderloin removal. The preconditions are that the mentioned operations are all developed which to some extent already exist. For example, scribing is well known from the pork industry and is also under way in relation to beef.

From a financial perspective, it is also recommended that a positive economic benefit exist even if a partial investment is selected. This option includes one processing operation from the start, followed by a second operation when developed, rather than waiting for the total development to be finalized.
The processing unit will be capable of processing both sides.

3.5 Leg Deboning:

From inside the belly, the Tibia is cut free halfway with a bent knife. Separation of the topside and the muscle is performed by cutting between the 2 segments. This operation requires good trimming to expose the division line between the 2 muscles. Simultaneous to the division, pulling on the topside and pressing on the knuckle ease up the operation.

Cutting underneath from outside the tibia and between the muscle, passing the elbow and along the femur exposing the bone from the inside is a complex, yet realistic process. Scribing of the femur from the elbow towards the aitchbone elbow and angling the knife while returning towards and around the elbow joint exposes both bones enough for them to be removed with a sufficient yield result.

Although advantages exist and automation is feasible, it is also considered to be fairly complex and involves some of the most expensive pieces of meat.
On this basis, it is classified as low priority and is placed in a category for future development.

4 Results

Identification

This section covers the identification of the extracted ideas and provides a brief explanation of the reasons for their selection. It also provides an economic analysis from of an end-user perspective and finally comments on the other objectives.
Based on the five proposals, three basic ideas have been selected and subjected to detailed calculation.
The three listed projects express the priority recommended by DMRI.
The following are relevant for the initial automation recommendations:

- Shoulder Removal
- Back Boner
- Tenderloin Removal

The **Shoulder Removal** proposals reflect the environmental benefit and the creation of less harsh workplace conditions, resulting in an increase in the potential available workforce.

The **Back Boner** project gives a substantial benefit both in terms of direct operator savings and a reduction in occupational injuries.

The **Tenderloin Removal** proposal reflects a proven technology from pork and can be implemented in a robot cell suitable for production with a lower throughput.

Depending on whether the capacity is 50 head/hour and one daily shift or two shifts, the payback time of the machines may vary from an average of approx. one or more years to approx. eight years. A payback time of one year is a highly interesting investment for the beef industry operating in this capacity range. For operations with smaller capacity, the payback time and associated risk may be a barrier to development and implementation.
Furthermore, the significant focus on the working environment encountered at meetings with international meat operations is a recurring issue. Also, softer values regarding workforce accessibility must be taken into account when a final decision is taken. These factors have not been included in the calculation here because of uncertainties in achieving and evaluating data in this area, but a tentative estimate of a 25% increase in cost is considered realistic.

The outcome of this study recommends that all three projects be carried out, either in a parallel or a sequential approach.
A parallel approach will clearly result in a quicker evaluation. Using a sequential procedure, knowledge from the first to the last idea will remain, resulting in a better comparison.
DMRI suggests a parallel approach to minimize the time.
A joint R&D effort will minimise the risks to R&D costs and will ensure international market match and market penetration of developed technology.

5 Economic analysis of identified ideas

Based on knowledge from similar equipment and development projects, expenses including unit price and installation, refurbishment cost at end-user level and capacity cost have been estimated.
Initially, one calculation was intended, but due to substantial differences two calculations have been performed and represented in the respective executive summaries. Both calculations will be included in the report.

- DMRI table with Nordic numbers.
- MLA table with numbers from Australia/New Zealand.

The capacity of 50 head/hour, at one shift per day, represents a high-end production in the Nordic area and an average production in Australia and New Zealand. There is a miner negative yield improvement associated with the identified ideas. The production speed therefore has no significant impact on the calculation as long as the speed does not affect the locally agreed workload, releasing extra operators.
All ideas have sufficient capacity to fulfil even the highest capacity plant, making all ideas suitable for the industry in all countries.
Due to floatation between Euro and $Aus/$NZ, the exchange rate may also be categorized into uncertainties. The total cost becomes less affected by R&D costs when the potential equipment numbers exceed five pieces.
The calculations in this section exclude the R&D costs. Calculations with R&D are shown later in the report.
The Net Present Value (NPV) calculation expresses the net capital gain in present value when selected equipment is installed at a deboning plant.

[$Aus]	Shoulder removal	Back Boner	Tenderloin removal
NPV	205,000	*1) 3,700,000	290,000

Table 1 MLA table with Capital Value
*1) NPV for both machines

The succeeding steps have also been taken into account and quantified as well as the price estimation of commercialized units, called O-Serie, with additional costs for installation, etc.

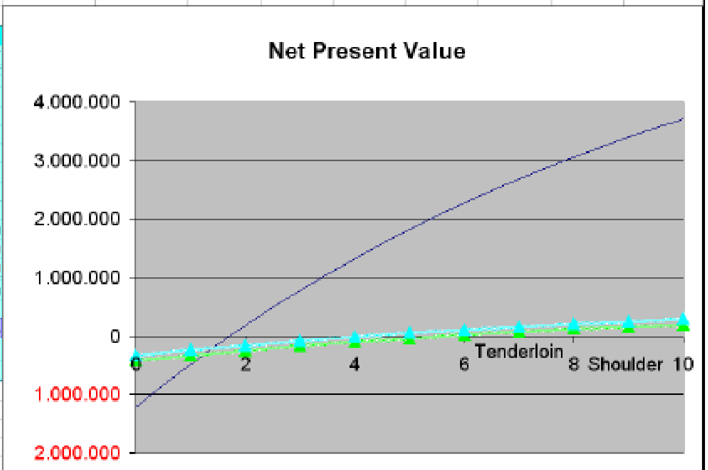
[$Aus]	Shoulder Removal	Back Boner/machine	Tenderloin Removal
Prototype	1,5000,000	3,000,000	1,000,000
O-Serie	415,000	545,000	325,000
Installation	50,000	*1) 70,000	50,000
Rebuilt Cost	50,000	*1) 100,000	50,000

*1) Installation costs for both machines

Precise values and data are shown in the table below.
The **green** range expresses the **Shoulder Removal.**
The **blue** range expresses the **Back Boner**.
The **turquoise** range expresses the **Tenderloin Removal.**
Equivalent to the Net Present Value, the internal rate as well as the payback time is shown.

MLA table, 2 shifts, $AUS 70,000 wages, 50 heads/hour and 10% calculation rate

Capacity /hour	50			
Shifts	2			
Processed beef PA	[pcs/year]	**195.000**		
Currency		(green)	(blue)	(turquoise)
Total Investment/Unit	[$Aus]	414.167	1.214.765	326.667
Total Investment Cost ex R&D	[$Aus]	414.167	1.214.765	326.667
Machine(s) / unit		1	2	1
Depreciation time	10			
Interest pa	10%			
Interest pm	0,8%			
Labour Savings	[pos]	1	6	1
Direct payment	[$Aus]	140.000	840.000	140.000
Capacity cost	[$Aus]	35.000	35.000	35.000
Yield	[$Aus]	4.200	4.200	4.200
Annual cost-saving	[$Aus]	100.800	800.800	100.800
Internal Rate	%	21%	65%	28%
Net Present Value	[$Aus]	205.206	3.705.804	292.706
PayBack Time	[Year]	5,6	1,7	4,1



Net Present Value Acc.	[Year]		0	1	2	3	4	5	6	7	8	9	10
Shoulder removed	[$Aus]	(green)	414.167	322.530	239.225	163.492	94.644	32.055	24.844	76.570	123.594	166.343	205.206
BackBoner	[$Aus]	(blue)	1.214.765	486.765	175.053	776.706	1.323.863	1.820.897	2.272.928	2.683.865	3.057.444	3.397.061	3.705.804
Tenderloin removed	[$Aus]	(turquoise)	326.667	235.030	151.725	76.992	7.144	55.445	112.344	164.070	211.094	253.843	292.706

Table 2 with comparative values

As shown in the table, all recommended ideas produce a positive result and are best shown in the NPV calculation. The numbers are based on a long-term perspective.

5.1 Lower priority ideas

Since three ideas have been recommended, two of them have been given a lower priority:

The **Robot Cell** is mainly based on several ideas which have been recommended in this study. These ideas have to be developed in parallel to gain full advantage, and this will result in greater complexity, longer project duration and therefore concluded to a lower priority. As a concept, the Robot Cell idea still exists and will benefit from the basic development of the other recommended ideas.

The **Leg Deboning** is given lower priority mainly due to technical concerns regarding the detection of the right seams separating several individual prime muscles from each other. The leg deboning will certainly be very interesting to automate. If better technologies become available to determine a more precise trajectory path to follow to separate specified muscles, e.g. On-Line CT.

Markets Interview
Several potential vendors have been interviewed and have also been included in the project group. An extensive interest in developing, producing and supplying exists. The challenging task may well be the collaboration of several partners worldwide and the coordination of intellectual properties.

Funding
A search for potential external public/institutional funding outside the beef industry has been conducted and categorized into national and regional sections. Some potential funding possibilities exist, but, since it is also associated with a substantial application workload and obligation towards formalities, consideration should be taken before applying for any of the suggested funds. The recommendations are not to seek any funds during the conceptual design phase, but rather to wait until the next phase has submitted a case.

6 Perspectives

This section concludes the Executive Summary and proposes that the industry supports:

- All three recommended ideas through an initial conceptual design phase.

It is recommended that this development phase be conducted with a collaborative approach and through joint funding.

The financial cost of the conceptual design phase as well as the time estimation are shown in the table below. A detailed schedule for each idea is included in the report.

$Aus		Shoulder Removal	Back Boner	Tenderloin Removal
Conceptual Design		360,000	1,100,000	290,000
	Travel costs	20,000	40,000	20,000
	Consultancies	35,000	50,000	30,000
Time estimation		12 months	16 months	11 months

Table 3 MLA table with conceptual design phase

The estimation of the Shoulder and Tenderloin Removal reflects the average cost level in the Australian and New Zealand region. MLA and associated partners will be a major presence if these ideas are to be developed, whereas the Back Boner estimation reflects the cost level when the development is accomplished by DMRI.

It must be emphasized that all participants support all ideas, but the Shoulder and Tenderloin Removal costs will be higher if developed by DMRI.

The outcomes of these conceptual designs are very simple manual or semiautomatic pieces of equipment that enable the project group to acquire sufficient knowledge to verify the technical feasibility and update the project's financial risk issues.

This phase will also include visualization and simulation of the new process setups caused by the implementation of new technology..
The outcome shall be controlled at any time, in a safe and documented way. All participants may reject the achieved results from the conceptual design phase and call for a new investigation or alternatively reform the project at any of the agreed milestones.
A stepwise approach (with phases) and milestones attached to the end of each phase is recommended.

The industry is recommended to collaborate on combining its strength and capability in order to achieve significant results that will benefit the industry. Each project participant in the feasibility study must evaluate the outcome of this feasibility report with regard to their specific situation. DMRI will collect the evaluations and facilitate a continuation of the conceptual phase if there are sufficient interested parties. Depending on the evaluation, the structure of the conceptual design phase may be organized differently from the feasibility studies.