MLA and Predictive Microbiology

AN EVALUATION OF THE INDUSTRY WIDE IMPACTS

Prepared for:
Meat and Livestock Australia

Prepared by:
Centre for International Economics

30 June 2006

Contents

Boxes, charts and tables

Foreword

The Centre for International Economics has been commissioned by Meat and Livestock Australia to evaluate MLA's Predictive Microbiology project. The evaluation applies the Framework developed for MLA by CIE. The evaluation draws on information from MLA, consultation with stakeholders (including processors, regulators and researchers) and the Australian and international literature on the costs and benefits of food safety regulation.

Highlights

- ❒ Consumers of red meat are demanding ever-higher standards in food safety both in Australia and overseas. MLA has responded to these demands, in part by investing $2.1 million in the Predictive Microbiology project (equal to $3.2 million in 2006). Other organisations have put $0.4 million towards predictive microbiology (equal to $0.6 million in 2006).
- ❒ MLA's investment in Predictive Microbiology has paid off. Microbiological quality has improved almost four-fold since 1993, with this program being an important driver of this change. MLA has found that food safety and integrity are an important driver of demand for red meat in international and domestic markets.
- ❒ The costs of achieving higher food safety standards have been small, in part due to MLA's Predictive Microbiology project, which has provided a cheap, effective and flexible method of validating processing techniques.
- ❒ MLA's investment in predictive microbiology produced a Refrigeration Index that has become part of Australia's export regulations. It is required to be used by export processors in beef, sheepmeat, pig meat and goat meat. Use of this tool goes beyond the regulatory requirements. Export processors are using the Refrigeration Index more intensively than required and domestic processors are also using this tool.
- ❒ MLA's investment in predictive microbiology has paid off for the industry (table 1). The red meat industry is expected to increase its value added by $44.4 million over the 30 years since the project began having an impact. These benefits are more than 11 times as great as the cost of the project to MLA and partners. The internal rate of return on the project is 37 per cent.
- ❒ MLA's investment has had positive flow-on effects for the broader economy. Australia's economy is expected to receive an additional $162 million over the 30-year period. This reflects the gains to the red meat industry, to the pig meat industry and flow-on effects from cost savings to processors. Benefits to Australian consumers are estimated at more than $60 million.
- ❒ Predictive microbiology has reduced the risk of illness and death from listeriosis, contributing to saving the equivalent of four lives every year.

1 Economic results from Predictive Microbiology (net present value 2006)

	Red meat industry value added	*Costs*	*Industry benefit-cost ratio*	*Internal rate of return*	*Total value added*	*Consumer surplus*
Unit	A$m	A$m	Ratio	%	A$m	A$m
Predictive Microbiology	44.4	3.8	11.5	37.4	161.7	61.4

Source: CIE.

MLA and Food Safety

Food safety is an important driver of demand for red meat. On an ongoing basis, perceptions in food safety have been linked to demand for red meat products (Leading Edge 2004). In addition, food safety scares or incidents can drive significant changes in demand for red meat or lead to loss of market access for individual companies or entire countries. Demand for food safety is rising in the industrialised world (World Bank 2005).

MLA has played an important role in recognising and facing the challenges posed by higher consumer demand for food safety, both in Australia and in key export markets such as the US, Japan and Korea. The Predictive Microbiology project has been one part of this effort. Predictive microbiology provides a tool for assessing the microbiological growth of pathogens at each point in the processing chain. It has had broad implications for the red meat industry, impacting on markets for sheepmeat and beef, domestic and export and across a range of different production types.

Predictive microbiology has been accepted by both regulators and industry participants. Exporters of meat products are required to use the refrigeration index, an output of predictive microbiology. Many exporters began using such tools before they were legislated, recognising their usefulness in improving profitability and performance. In addition, some domestic processors use predictive microbiology.

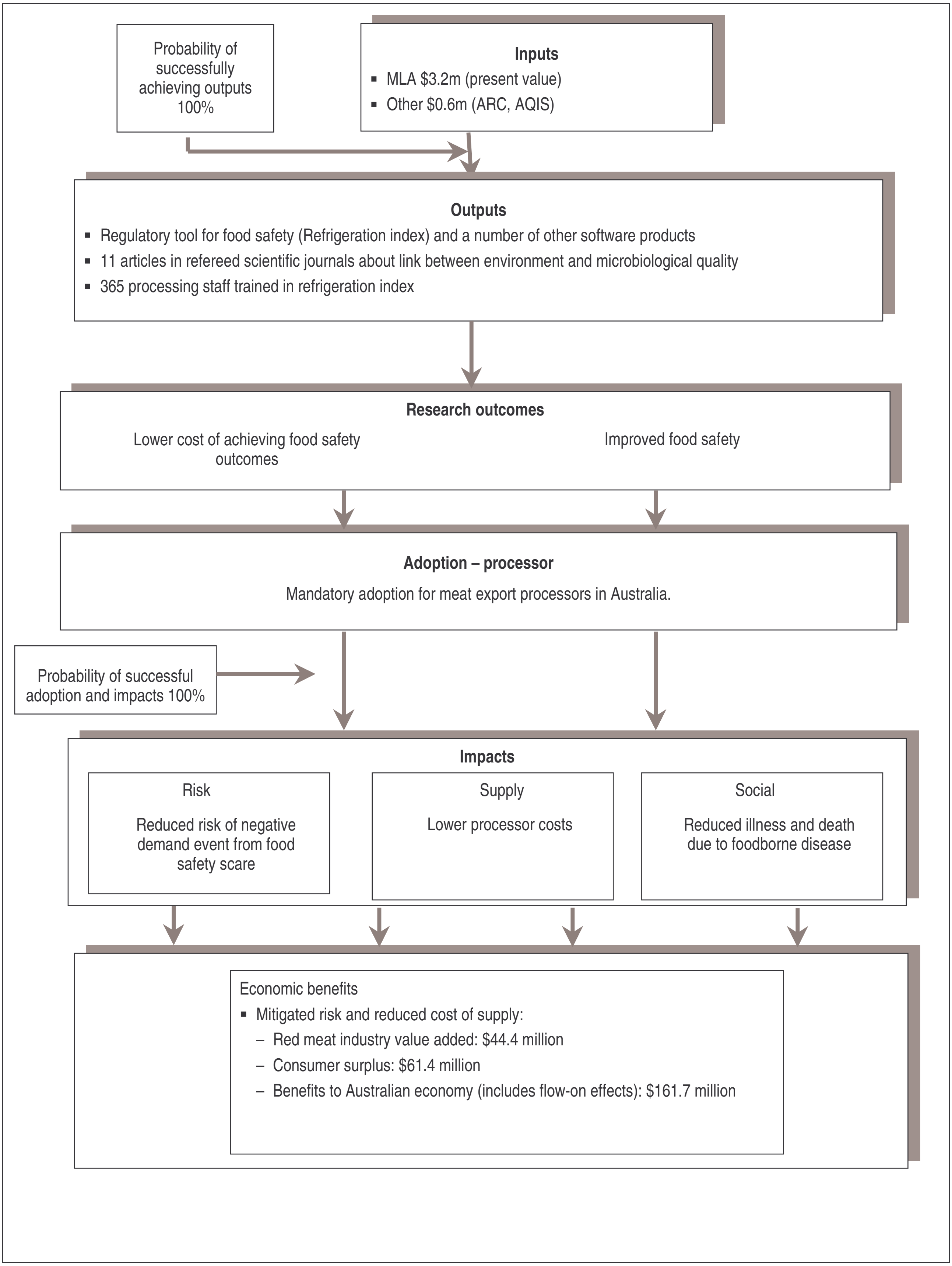
Predictive microbiology has led to improvements in food safety and has helped to lower the cost of compliance for the Australian industry. This study estimates the impact of MLA's investment in predictive microbiology on the red meat industry, the Australian economy and consumers.

The following sections outline MLA's investment in the predictive microbiology project. They discuss the costs of the project, what the project produces and has achieved and how this has impacted on the red meat industry and Australia.

Tracing Inputs to Impacts

The pathways through which MLA is contributing to food safety and industry value added through the Predictive Microbiology project are outlined in chart 2. This traces the project's inputs and outputs to their outcomes and impacts and finally to the economic and other benefits.

2 Tracing the impact of Predictive Microbiology



Inputs

The predictive microbiology project has cost $2.5 million in total (table 3). Of this, $1.7 million was through MLA contract funding, primarily to researchers at the University of Tasmania in the Australian Food Safety Centre of Excellence. Total MLA funding has been $2.1 million. Funding has also been provided to the Centre through Australian Research Council (ARC) research grants. Other funding has been provided by AQIS for training processors in how to use the outputs of predictive microbiology (this includes AQIS time and costs of venue hire, catering and production of handouts).

In present value terms (using a 5 per cent discount rate), the total funding of the Predictive Microbiology project has been $3.8 million.

There will also be costs to the industry of having to implement changes that have resulted from predictive microbiology. These are evaluated as supply impacts later in this report.

3 Funding of Predictive Microbiology

Cost category	*Funding amount*	*Funding in present value*
	A$'000	A$'000
MLA contracts	1 725	2 740
MLA funding for training	179	193
MLA time	214	300
Other funding	410	615
Total	2 528	3 849

Source: Evaluation questionnaire.

What did the program do?

MLA's Predictive Microbiology project involved research, direct collaboration with industry and transferring and developing knowledge to minimise product exposure and regulatory compliance costs.

Essentially, the predictive microbiology project has aimed to understand the link between temperature/environment and microbiological growth through time. This allows industry and regulators to see how different temperature paths change the final outcome of microbiological growth. From this understanding, models provide information on whether particular temperature paths through time provide an appropriate level of food safety.

As a research based activity, the predictive microbiology project has produced eleven papers in refereed scientific journals and a book *Predictive Microbiology for the Meat Industry*. In addition, results from the predictive microbiology project have been presented at numerous international conferences. In these forms, predictive microbiology has influenced the literature on processor activities and food safety.

The research has translated into improved knowledge of the impact of temperature, acidity, salt content and other environmental factors on microbiological birth and death rates.

Improved knowledge has been converted into products used by industry. The key product is the refrigeration index. This is a simple tool that processors use to map temperature/time paths to microbiological growth.

Predictive microbiology has also created a number of other models for specific parts of the industry linking environmental factors and microbiological growth/death. Five predictive microbiology software products had been produced as at 1999 (Ross 1999).

What did the program achieve?

Predictive microbiology has changed the behaviour of processors and regulators. It has enabled new markets and it has become part of regulations. For regulators, predictive microbiology offers increased certainty about food quality. For industry, the flexibility allowed has reduced compliance costs and enabled the continued use of processing techniques that were under pressure from regulators as well as the development of new and less costly processing techniques.

Specific examples of the achievements of predictive microbiology have been well documented in Sumner and Krist (2002). They include:

- the mandatory use of the refrigeration index by export processors (through the Export (Meat and Meat Products) Orders 2005);
- contributing to continued use of hot boning;
- validating processing at higher boning room temperatures;
- developing and verifying processing techniques for weekend chilling of carcases;
- lowering the costs to regulators and industry of events with potential food safety implications such as refrigeration breakdowns;
- developing and verifying processing techniques for cooked meats such as hams; and
- contributing to removing listeria contamination that can result in illness and death.

The broader outcomes of predictive microbiology have been improved safety of meat products and lower compliance costs for industry.

Adoption

Meat export processors have been required to use predictive microbiology under the Export Control (Meat and Meat Products) Orders 2005.[1] Some domestic processors are also using predictive microbiology more proactively to manage their product safety and to ensure that they have documented evidence of the temperature profile of the product in the event of a failure in refrigeration.

Two export processors, Australian Meat Holdings and Nippon, were using predictive microbiology prior to the regulations coming into place. In addition, many export processors use predictive microbiology more intensively than is required under the legislation.

In addition to ongoing use, predictive microbiology has been used on an ad hoc basis to justify particular processing techniques.

[1] There are 25 large processors involved in exporting beef, sheepmeat and goat meat. The majority of these are beef processors.

Impacts

The predictive microbiology project has changed the food safety landscape significantly through bringing scientific rigour to processing standards. In doing this it has had two key impacts, as outlined below.

1. For industry, predictive microbiology has lowered the cost of compliance through providing a cheap and easy to use means of verifying that processes are safe and of evaluating outcomes of particular events.

2. For consumers (domestic and export), predictive microbiology has improved food safety standards. Industry has also benefited from this through higher demand for red meat.

The balance between these impacts is unclear, as the level of food safety that would have occurred without predictive microbiology cannot be determined. In this case, these impacts have typically been evaluated on the basis of the costs of achieving the required food safety standard in the absence of predictive microbiology. This reflects the lack of information on the linkages between microbiological quality and illness and death. The method used is likely to underestimate some of the less easily defined benefits of the project.

The exception to evaluating on a cost of compliance basis is for listeriosis, because predictive microbiology has directly changed illness and death resulting from listeriosis and this can be quantified. This evaluation reports the reduced illness and death resulting from predictive microbiology and estimates the reduced risk of a fall in demand following wider public awareness of listeriosis.

Impacts that initially affect consumers and processors will find their way to other parts of the supply chain. For instance, reduced processing costs will likely feed through into lower prices for consumers and greater on-farm output. These second and subsequent round impacts are traced out later in this report.

Supply

Predictive microbiology has impacted broadly on the processing sector but has had major impacts for particular methods of processing and product segments. This is documented in Sumner and Krist (2002). The following section values these major impacts.

In valuing these supply impacts, the relevant question is 'What would have occurred in the absence of the predictive microbiology project?' Processors and regulators have indicated that, in the absence of predictive microbiology, they would most likely still have been able to use the same processing techniques but the cost of regulatory compliance would have been substantially higher. Because of this, the evaluation has focused on the additional costs that would have occurred in the absence of the predictive microbiology project. The exception is for hot boning where predictive microbiology has been pivotal in allowing its continued use.

Cost of implementation

All export products categorised as meat and meat products must use predictive microbiology through the refrigeration index, as set out in the Export Control (Meat and Meat Products) Orders 2005. This includes beef, sheepmeat, pig meat, goat meat and a number of other less important meat exports. This imposed some small costs on processors through training to understand the refrigeration index and installing data monitors. The cost of this is estimated by AQIS at $50,000 per processor, which is about the amount paid by Australian Meat Holdings and Nippon to Food Science Australia to get their process validated. This is a high range estimate for two reasons. First, these processors chose to validate their process over a short period of time. Secondly, Australian Meat Holdings was subsequently able to apply this validation to a number of its other plants.

For this evaluation, costs are assumed to be half the level attributable to AMH and Nippon on average, at $25,000 per processing plant. These costs apply to 50 export processing plants, as a once off increase in costs. This equates to a 0.087 per cent increase in costs in 2005.[2]

Predictive microbiology allows processors more flexibility in meeting refrigeration targets through the use of the refrigeration index. This flexibility has been used by a number of processors to date, even before the legislation came into effect. In addition, predictive microbiology has been used to solve particular issues as they arise. The benefits of each of these uses is summarised in table 4 and discussed in turn below.

4 Key qualitative supply impacts of predictive microbiology

Processing method	*Consequences if no predictive microbiology*	*Measure of impact of PM*	*Products affected*	*Markets affected*	*Year of first impact of Predictive micro*	*Temporary or long lasting impact*
Hot boning	No hot boning	Share of benefits of hot boning	Hot boned beef	Export	2001	Long lasting
Weekend chilling of beef	Higher cost of validating processing technique	Cost of alternative measures to reduce food safety risk	Beef that is chilled over weekend	Export and domestic	1998	Long lasting
Refrigeration breakdowns	More product rejected Higher cost of compliance	Cost of proving product is safe	Beef and sheepmeat that is subject to refrigeration events	Export	2001	Long lasting
Boning room temperatures	Production time lost	Additional yield from greater production time	Beef and sheepmeat	Export	2006	Long lasting
Cooling of cooked meats	Higher refrigeration costs	Cost of greater refrigeration	Cooked meats	Domestic	2004	Temporary and ongoing

Source: Various.

Hot boning

Hot boning is a method of processing that saves labour time, training time and has occupational health and safety benefits. Predictive microbiology played an important role in establishing that hot boning of beef was not compromising food safety at a time when it was coming under increasing scrutiny by regulators. This affected approximately 5 processors and 10 per cent of Australia's beef export market.

The impact of predictive microbiology has been evaluated as a part of the benefits of hot boning. The benefits of hot boning, from MLA (2005a) are:

- reduced carcase shrinkage - 2% of carcase weight; and
- reduced labour – 25% reduction in the requirement for boning room staff.

The reduction in boning room staff is estimated to amount to a 10 per cent reduction in total labour in processing plants. This is because approximately 40 per cent of the labour costs for processing are from boning room staff (Smith and Jahan 2003, MLA 2005a and CIE model data).

MLA's technical adviser and two major processors confirmed the estimate of the carcass weight saving and that hot boning could provide labor savings.

[2] Data from IBIS World (2005) are used to determine the per cent changes in costs across each market of relevance throughout this section of the report.

The major hot boning processor also indicated that there were savings in training time, with hot boning requiring only 20 days compared to 90 days for other boning room operations. That is, hot boning saves 10 weeks of training or 20 per cent of the year for each new staff member. Assuming that beef processing has the average staff turnover rate in Australia then 13 per cent of staff will be new each year and require training (ABS 2004). Employees will be less productive when they are being trained. If, on average, employees are 25 per cent less productive during training, then labour productivity would rise by 0.6 per cent due to hot boning.[3]

Predictive microbiology has only been one factor that has allowed hot boning to operate and to be profitable. Other important factors include the technical developments, market and cost analysis, training, and overcoming tenderness considerations (less important for low-grade meat for US burger trade). As such, all the benefits of hot boning could not be reasonably allocated to predictive microbiology. Researchers stated that predictive microbiology was pivotal for the continuation of hot boning over the past five years, while a major hot boning processor thought it was not so important. Food Science Australia indicated that while attribution was difficult, 20 per cent was not unreasonable. For this study, it has been assumed that 20 per cent of the value created by hot boning can be attributed to the predictive microbiology project. The sensitivity of results to this assumption is considered later in this report.

Allocating the changes due to hot boning to predictive microbiology (i.e. multiplying by 20 per cent) gives:

- reduced carcase shrinkage — 0.4 per cent increase in yield;
- reduced labour costs — 2 per cent reduction in labour costs; and
- reduced training — 0.12 per cent increase in labour productivity.

Allocating a portion of the benefits from hot boning to predictive microbiology is the most appropriate method of evaluation as long as the alternative methods of validating hot boning are likely to be prohibitively expensive. One alternative to predictive microbiology would be to test for Salmonella. Two to three thousand tests would be required per processor per day to detect Salmonella with any degree of confidence, according to the American Meat Science Association. Using industry estimates of $200 per sample, the total sampling costs per processor per day to detect would be in the order of $500 000. At such a cost, hot boning would no longer be profitable. Food Science Australia also indicated that hot boning was unlikely to have been viable under the likely regulatory scheme in the absence of predictive microbiology. This does not imply that all the benefits of hot boning should be allocated to predictive microbiology – while predictive microbiology might be necessary for hot boning it is not sufficient in and of itself for hot boning to be profitable.

Weekend chilling of beef

Weekend chilling of beef was resulting in higher microbiological counts than achieved for other meat. This left the industry in a position where it was facing higher regulatory costs unless it could find a simple method of changing its chilling regime and proving that this was safe. Predictive microbiology provided the means to develop and validate new weekend chilling regimes. This allowed industry to achieve compliance without additional refrigeration costs and occupational health and safety issues from colder and harder meat.

The possible alternative to predictive microbiology would have been greater refrigeration costs. Food Science Australia indicated that accelerated chilling regimes can increase refrigeration costs by as much as 50 to 70 per cent. This is a maximum of the potential costs that predictive microbiology could have avoided. In reality, regulators may have imposed much lighter standards than an accelerated

[3] Increase in productivity is calculated as 13 per cent of staff * 20 per cent of new staff time each year no longer in training * 25 per cent loss in productivity when training (approximately).

chilling regime. Because of this, this evaluation assumes that Predictive Microbiology could have avoided a 10 per cent increase in refrigeration costs.

Electricity for refrigeration makes up approximately 60 per cent of electricity costs and electricity costs make up 5 per cent of processing costs (Scheurmann 2005). The predictive microbiology project therefore reduced overall costs by 0.3 per cent relative to what they would have been under a faster cooling scenario. This is only for the 15 per cent of production accounted for by weekend chilling (both domestic and export beef).[4]

The possible reduction in occupational health and safety costs has not been quantified in this study. This reflected the lack of stakeholder agreement on whether predictive microbiology had been an important driver of OH&S costs.

Refrigeration breakdowns

Predictive microbiology has improved the ability of regulators and industry to judge food safety after events such as refrigeration breakdowns. This has allowed industry to easily verify the quality of meat to help determine whether it is allowed to enter the food supply chain. Food Science Australia has estimated that there were between 3 and 9 major refrigeration breakdowns per year since 2001-02, with an average of six events per year. These involved meat value of between $88 000 and $223 000 per year. AQIS indicated that there were many more minor refrigeration events — around one per processor per year. Both major and minor refrigeration breakdowns would have required greater testing costs prior to the use of predictive microbiology.

For major events, predictive microbiology's role is to make the process of verification quicker and cheaper. Product can be verified as safe at almost no cost. Product that may not be safe is often condemned, as a high refrigeration index means that the chance of finding that the meat is safe through microbiological testing is small and the value of additional testing is therefore less than the cost.[5] In this case predictive microbiology saves the costs of testing the meat and storing it while it is being tested. AQIS has indicated that between 30 and 120 samples would have been required in the past (depending on the type of meat) for a selection of recent events. Assuming an average of 60 samples, avoided testing costs per event would be in the order of $12 000 ($200 per sample). FSA indicated that there was an average of six major events per year over the past five years. Total costs avoided by predictive microbiology are therefore $72 000 per year.

For minor events predictive microbiology reduces the time required by industry and AQIS to verify carcass product by six hours per event, based on discussion with AQIS and industry. This time is valued at an annual salary of $120 000. Assuming that there is one event per processor for 50 export processors gives an overall estimate of avoided costs of $17 000 per year.

The combined impact of predictive microbiology in lowering the testing costs of refrigeration breakdowns is a 0.007 per cent reduction in processor costs. However, there would also be cost savings through reduced need for storage. A major processor indicated that these would be at least as large as the savings through less testing. This is because storage requirements can reduce the ability of the business to continue processing at maximum capacity. Exact quantification of the avoided storage costs was not possible, so this is conservatively assumed to be equal to the avoided testing costs. The combined effect of MLA's investment in Predictive Microbiology is therefore to avoid a cost increase of 0.014 per cent for beef and sheep processors.

---

[4] Previous estimates of chilling over the weekend were 20 per cent although MLA's technical adviser indicated that this was likely to have fallen to 15 per cent due to changes in processing hours worked.

[5] A high refrigeration index means that microbiological growth is predicted to be greater.

Boning room temperatures

One processor used predictive microbiology to validate processing at a higher temperature. This has the advantage of allowing production to continue on extreme days when refrigeration systems may not be able to reach required temperatures.

This value has been previously been arrived at by MLA through valuing continued production for four hours per year where it would otherwise be stopped. If a processor ran for eight hours, 365 days per year, this would equate to a 0.14 per cent increase in production. This increase in production would apply to the 7.8 per cent of the beef export processing sector that is using this technique. Variability in boning room temperatures is a new application of predictive microbiology. While it is likely that the proportion of processors using his technique may rise in the future, this evaluation focuses on benefits that have been realised to date. As such, the benefits of this application of predictive microbiology are based on 7.8 per cent of the beef export processing sector continuing to use this technique.

Cooling of cooked meats

Predictive microbiology has been used to develop an alternative standard for cooling cooked meats such as hams, roast beef and large processed meats. This has subsequently been incorporated into the Australian standard. The development of a new standard followed the finding that large cooked products were not achieving the previous standards, though the implications for food safety were unclear. In the absence of predictive microbiology, regulators may have enforced the stricter cooling regime in the previous Australian Standard. This might have required processors to put in place accelerated chillers. Food Science Australia has indicated that the capital costs of accelerated chillers could be in the order of $260 000 to cool approximately 20 tonnes per day. MLA has estimated that large products would account for 28 000 tonnes per year. This would mean additional refrigeration capital costs of $1.4 million.

For large smallgoods, we estimate that approximately 86 per cent is from pig meat and the remaining 14 per cent from beef.[6] This means that pig meat processors can avoid capital costs of $1.2 million and beef processors can avoid capital costs of $185 000.

These dollar changes are equivalent to:[7]

- a 13.5 per cent reduction in machinery and equipment investment costs for pig meat processors; and
- a 0.7 per cent increase in machinery and equipment investment costs for beef processors.

Processors would also avoid electricity costs. As noted earlier, accelerated chilling would increase electricity costs for refrigeration by 60 per cent. Refrigeration makes up 60 per cent of electricity costs and electricity makes up 5 per cent of processing costs. Processing costs would therefore fall by 1.8 per cent for the 0.5 per cent of beef processing devoted to large smallgoods and the 5.8 per cent of pig meat processing devoted to large smallgoods.

Additive to lower listeriosis

Predictive microbiology has indicated that an additive could be used to lower the risk of listeriosis. The benefits of this are discussed under the social and risk impacts below.

---

6 This was calculated by using total domestic beef production multiplied by 5 per cent diverted into smallgoods (see MLA Market Information at www.mla.com.au). From this we estimate 37 100 tonnes of beef is diverted into smallgoods. Ross et al. (2004) estimates total smallgoods volume to be 263 000 tonnes. Beef therefore makes up 14 per cent of volume. The remaining amount is assumed to be pig meat. These proportions are assumed to be the same for large smallgoods.

7 This uses CIE's model data on machinery and equipment investment in beef and pig meat processing.

Such an additive could cost as little as 3.5 cents per kilogram of finished weight or as much as 7.5 cents per kilogram (estimate from Myosyn Industries). This evaluation uses the high-point of this range, of 7.5 cents per kilogram finished weight, as a conservative estimate of the additional costs to processors.

Only 5 per cent of beef is diverted to smallgoods (MLA Market Information) or 37 100 tonnes. The rest is assumed to be pig meat. This means that approximately 55 per cent of pig meat used for domestic consumption is for smallgoods.

The average retail price of pig meat in 2003/04 was $10.19 and the average retail price of beef was $13.90 (IBIS World 2005). This study assumes similar prices for retail smallgoods. Non-livestock intermediate costs in the processing stage of production comprise 2.3 per cent of the retail price for pig meat and 1.8 per cent of the retail price for beef (CIE model). Using the above retail prices these costs make up 23.5 cents per kilogram and 25.7 cents per kilogram for pig meat and beef respectively.

The increase of 7.5 cents per kilogram only applies to 5 per cent of beef and 55 per cent of pig meat that goes to the domestic retail market. The domestic retail market makes up only 25 per cent of beef production and 31 per cent of pig meat production (CIE model).

Combining the above figures gives an increase in non-livestock intermediate costs of:

- 0.35 per cent across the beef processing sector; and
- 5.33 per cent across the pig meat processing sector.[8]

Uncooked Comminuted Fermented Meat (such as salami)

Following the Garibaldi outbreak, a new standard was introduced for uncooked comminuted fermented meat (UCFM) in 1996. By using a predictive model, MLA showed that this standard was not enforceable and was not being met by industry. In addition, MLA offered predictive microbiology as a tool to implement and enforce an appropriate standard for UCFM.

The ability to evaluate processes, using the predictive model, resulted in a marked improvement in the number of processes that achieved the required reduction in E.coli (FSANZ 2002). The improvement in health outcomes is less certain, as even a single E.Coli organism can cause illness in some cases. No study has yet quantified the public health risk due to E.coli in UCFM, nor the effect of changing E.coli levels. As such, the value of Predictive Microbiology in lowering E.Coli in ICFM was unable to be calculated

Other impacts

Stakeholders have indicated that predictive microbiology has also been used to:

- validate the rewarming of carcases to reduce occupational health and safety costs; and
- validate transportation arrangements.

The benefits of predictive microbiology in these areas are not clear. In particular, whether predictive microbiology changed behaviour or regulation or simply allowed behaviour to continue but with a firm scientific underpinning.

The broader value of predictive microbiology is also likely to be underestimated by the assumptions above given that it is used in validation of all processing techniques rather than just the market

[8] Total cost increase = share of production for domestic market that is smallgoods * share of domestic production for domestic retail market * 7.5 cents / Cost per kilogram of non-livestock intermediate inputs.

segments discussed above. These impacts are diffuse and difficult to quantify and many are not yet realised. However, the impacts identified by stakeholders are likely to be the most significant and valuable impacts from Predictive Microbiology to date.

Summary of supply impacts

A summary of the quantitative changes to supply outlined above is shown in table 5. Any changes that have been identified as long lasting are assumed to continue over a thirty-year period. The additional assumption is that there are no other changes in processors' behaviour as a result of predictive microbiology. This assumption has been made because this evaluation is about the types of benefits that have occurred to date. To the extent that additional impacts occur in the future, that have not yet been identified, this study will report a conservative estimate of the benefits of the project.

5 Supply impacts from MLA's investment in Predictive Microbiology

Impact	*Market*	*Part of supply chain*	*Potential production impacted*	*Peak change in processor costs/yield*	*Type of impact*	*Initial year*	*Length of impact*
			%	%			Years
1: Hot boning — yield	Beef — exports	Processing	10.0	+0.400	Yield	2001	30
2: Hot boning — labour costs	Beef — exports	Processing	10.0	-2.083	Labour costs	2001	30
3. Hot boning — training costs	Beef — exports	Processing	10.0	0.124	Labour productivity	2001	30
3: Weekend chilling	Beef	Processing	15.0	-0.300	Costs	1998	30
4: Refrigeration breakdowns	Beef and sheep — exports	Processing	100.0	-0.007	Costs	2001	30
5: Boning room temperatures	Beef — exports	Processing	7.8	+0.137	Yield	2006	30
6: Cooked meats — capital	Pig — domestic	Processing	100.0	-13.537	Investment (mach. & equip.)	2004	1
7. Cooked meats — capital	Beef — domestic	Processing	100.0	-0.670	Investment (mach. & equip.)	2004	1
8. Cooked meats — ongoing	Pig — domestic	Processing	5.8	-1.800	Costs (electricity)	2004	30
9. Cooked meats — ongoing	Beef — domestic	Processing	0.5	-1.800	Costs (electricity)	2004	30
10. Compliance costs	Meat processors — export	Processing	100.0	+0.087	Costs	2005	1
11. Additives for listeriosis	Pig — domestic	Processing	100.0	5.33	Costs (non-livestock intermediate inputs)	2006	30
12. Additives for listeriosis	Beef — domestic	Processing	100.0	0.352	Costs (non-livestock intermediate inputs)	2006	30

Source: Evaluation questionnaire.

Social impacts

Predictive microbiology has been used to model how changes to the processing of luncheon meats, pates and cooked sausages could impact on illness and death due to listeriosis. Current estimates are that 44 people per year in Australia contract listeriosis from these smallgoods. Mortality rates for those affected can be in the order of 20 per cent to 30 per cent. The predictive microbiology project identified that the addition of antimicrobial additives to the meats at the processing stage could reduce the number of cases to around 6 per year.

The health benefits of such an action would be to lower the number of cases of listeriosis from smallgoods by 38, according to modelling undertaken for the MLA (Ross et al 2004). This impact is estimated at saving 290 disability adjusted life years (DALYs) or the equivalent to saving around four lifetimes every year. These estimates are based on the overall DALYs attributable to listeriosis and the share of cases of listeriosis attributable to smallgoods, both as estimated by Ross et al (2004).[9]

There are many studies that have attempted to place values on human illness and death. Such studies use methods ranging from willingness to invest in life saving products such as smoke detectors to the financial costs of healthcare and reduced ability to work. The estimates of the value of a DALY can vary widely using these methodologies. This report adopts an estimate of $60,000 per DALY widely used by government departments (see for example Commonwealth Department of Health and Ageing 2003). This value is in the lower range of the estimates of the value of a DALY.

Using the assumptions above, additives to listeriosis can generate health benefits of $17.4 million per year. Under the assumption that these benefits last for the next thirty years the total benefits to the predictive microbiology project would be $281 million. Achieving these benefits is not costless with additives to the production process being required. These costs are estimated in the section on supply impacts above.

The health benefits could also translate into reduced risk of negative perceptions from a listeriosis event and a subsequent fall in demand. This is considered in the risk section below.

Risk impacts

The predictive microbiology project has contributed to improving the safety of meat and meat products. MLA's surveys of microbiological quality of Australian beef and sheepmeat show that a primary measure of overall microbiological count, mean log total variable count, fell by 47.1 per cent in beef and 35.9 per cent in sheepmeat between 1998 and 2004 (MLA 2005b). This measure also fell between 1993/94 and 1998, although not by as much as in the later period. MLA's technical adviser has indicated that 20 to 30 per cent of this could be due to the activities of the predictive microbiology program.

There are foodborne disease outbreaks that stem from red meat, although not many. Dalton et al (2004) reported 9 outbreaks associated with beef products or meals, resulting in 313 cases between 1995 and 2000.[10] Over the same period there were 2 outbreaks associated with lamb products or meals, resulting in 16 cases and 6 outbreaks associated with processed meats resulting in 97 cases. These figures exclude outbreaks and cases where the food type could not be specifically identified.

However, there is currently no direct quantified link between microbiological count and illness and death. This is partly because any outbreak and illness/death requires a number of failures along the supply chain. Common sense suggests that such a link exists, but the nature of the relationship is not known. For example, a 20 per cent reduction in measures of microbiological count is unlikely to translate into a 20 per cent reduction in illness or death. International evidence confirms the existence of the link between microbiological quality and food safety (Wegener et al 2003).

---

[9] In estimating the DALYs, Ross et al (2004) assumed that 60 per cent of fatal cases are elderly people with 10 years remaining life, 40 per cent of fatal cases are unborn foetuses and neo-nates with 70 years remaining life and that non-fatal cases are responsible for a 75 per cent loss of ability for 20 days.

[10] An outbreak is defined as a food safety event that caused two or more illnesses.

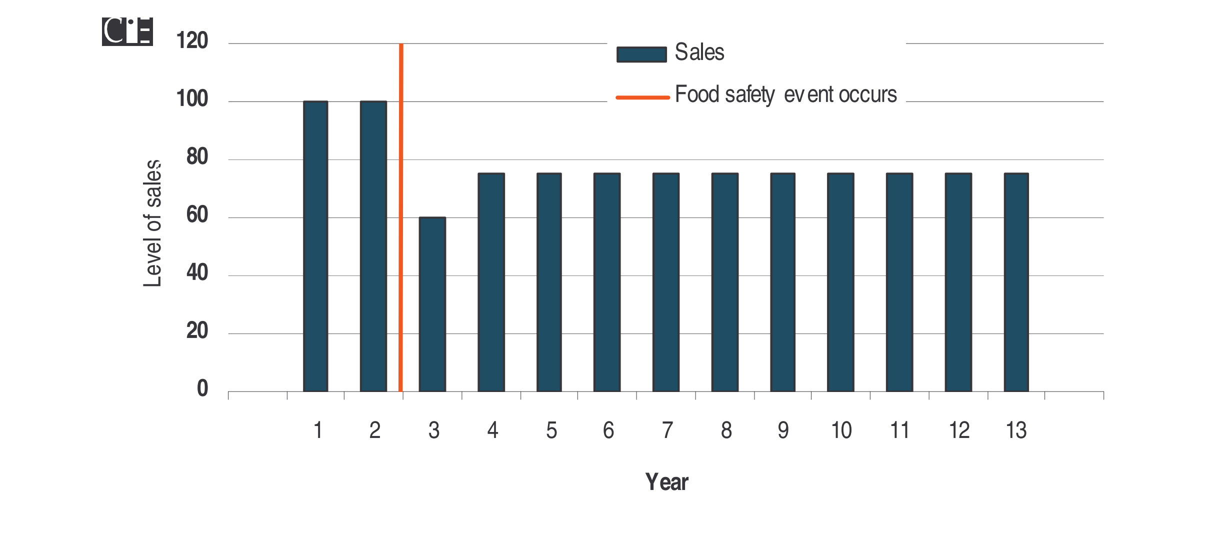
Note that many of the particular improvements in food safety that have been generated by predictive microbiology have already been valued through the alternative costs to achieve this standard. The diffuse effects of predictive microbiology on food safety have not been valued.

There is one area where MLA's investment in predictive microbiology is directly linked to reduced illness and death from food safety. This is valued through both the initial impacts on health (see Social Impacts above) and through the potential for negative demand perceptions.

To value the benefits for industry, this study assumes a similar demand reaction as the one that followed the Garibaldi food poisoning incident in 1995. In this incident one child died and a number of others went to hospital. The impacts on many of these people were permanent. This study does not attempt to value the social impacts of the Garibaldi incident but instead uses this incident as an example of the consumer reaction to unsafe product.

The quantity of smallgoods demanded fell by approximately 40 per cent in the first year following the Garibaldi incident (FSANZ 2002). In the second and subsequent years, demand remained 25 per cent below initial levels (FSANZ 2002). The demand impacts following the Garibaldi incident appear to have been permanent with overall consumption still below initial levels seven years after the event. Chart 6 shows the changes in demand following such a food safety scare.

6 Demand following a significant food safety scare



Data sources: FSANZ (2002), CIE.

Smallgoods comprise about 5 per cent of domestic beef consumption and 55 per cent of domestic pig meat consumption (Ross et al 2004, IBIS World 2005). Not all of this consumption would be affected by a listeria event. In particular, listeria tends to impact heavily on the babies, pregnant mothers and the old. This study assumes that the part of the market affected by a listeria outbreak is equivalent to 20 per cent of the entire smallgoods market. This is the share of Australia's population that is less than 5 years old or older than 65 years (ABS 2006).

For listeriosis, there are a number of negative health events every year. A negative demand event may constitute raising awareness of these health events or an outbreak of such events. Developing a probability for this involves considerable uncertainty. Ross et al (2004) indicated that there were 12 outbreaks of listeriosis in ready to eat meats between 1987 and 2002 across the US, UK, New Zealand, France and Australia. Of these, at least six involved pork and beef products targeted by the predictive microbiology project. Australia makes up about 5 per cent of the total population of these countries. Using this as a basis for an estimate gives the probability of a listeriosis outbreak in Australia in a given year being approximately 2 per cent.[11]

Under these assumptions, the cost to industry that has been avoided through MLA's investment in predictive microbiology has been calculated in the next section. Note that there were also costs to industry of using an additive, as discussed in the supply section above.

Benefits of Predictive Microbiology

The economic benefits of Predictive Microbiology were evaluated using CIE's economic evaluation module and the changes to supply and demand risk that were estimated in the previous section. The economic module calculates the total benefits to the red meat industry, Australia's economy and consumers and shows how these benefits are spread across the supply chain. A key point is that benefits will not remain where they initially occur. For instance, a reduction in processor costs will not wholly accrue to processors. Competition will drive consumer prices down and increase consumption. This will benefit consumers. Increased consumption will drive up demand for cattle/sheep, potentially increasing prices for cattle/sheep and providing benefits to producers. Who finally bears the costs and receives the benefits is determined by how much processors, producers and consumers can respond to price signals in their production and consumption behaviour.

A summary of the results is provided in table 6. All results are net present values calculated over a 30-year horizon using a real discount factor of 5 per cent and presented as at 2006.

The economic analysis shows that the Predictive Microbiology project has been highly successful (table 7). The project as a whole is estimated to increase value added for the red meat industry by $44.1 million over the 30-year period. These benefits compare to funding of $3.8 million (in present value terms), giving a benefit-cost ratio for the industry of 11.5. The internal rate of return on MLA's investment is estimated to be 37.4 per cent.

For Australia, the analysis suggests that predictive microbiology is responsible for a $161.7 million increase in Australia's GDP over the 30-year period. A large part of this is due to impacts on the pig meat industry.

Another measure of welfare is consumer surplus. This measures the change in consumption after adjusting for price and quality impacts. Under this measure, the welfare of Australians rose by $70.9 million as a result of predictive microbiology.[12]

As indicated earlier, social benefits of predictive microbiology were estimated at $281 million over the 30-year period. These benefits should not be added to those calculated above, as the social benefits are already partially captured by the reduced demand risk from a listeria event.

---

[11] Six events divided by 15 years multiplied by 5 per cent.

[12] The three measures of benefits are approximately related in the following way: change in total value added = change in red meat industry value added + change in other industry value added. Change in consumer surplus = change in total value added – change in savings – changes to non-Australian consumers through trade.

7 Economic results from Predictive Microbiology (net present value 2006)

		Red meat industry value added	*Total value added*	*Consumer surplus*	*Social benefits*
Benefits	A$m	44.4	161.7	61.4	281.2
Costs	A$m	3.8	Na	Na	Na
Benefit–cost ratio	Ratio	11.5	Na	Na	Na
Internal rate of return	%	37.4	Na	Na	Na

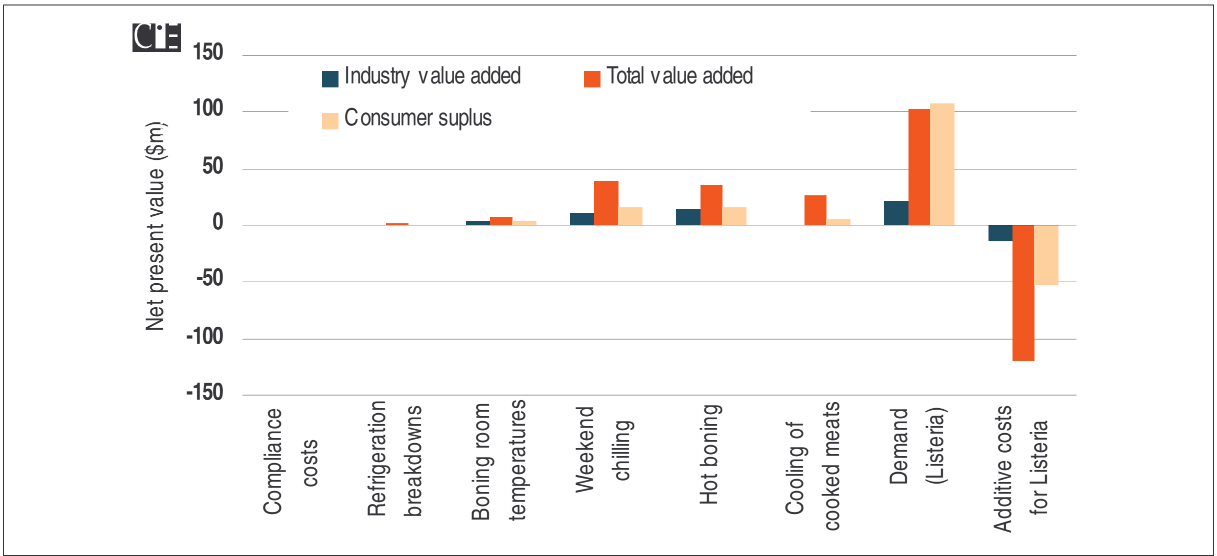
Source: CIE.

Note that the significant benefits of predictive microbiology shown in this evaluation do not include any potential benefits from uses of predictive microbiology that have not yet been developed. Significantly more benefits may accrue in the future as processors learn to use this tool more effectively.

The benefits from each impact of Predictive Microbiology are shown in Chart 8. Compliance costs impose very small overall costs on the industry and economy. Additives to Listeria impose much greater costs on industry and the economy. This particularly impacts on the pig meat sector, which diverts the majority of production to smallgoods.

The reduced demand risk from Listeria brings substantial expected benefits to the red meat industry and the economy. After taking account of the cost impact of having to use additives, the net impact on the red meat industry is much smaller but still positive. Weekend chilling and hot boning are the other two big areas of benefit for the red meat industry, resulting from MLA's investment in Predictive Microbiology.

8 Value added from each impact



Data source: CIE.

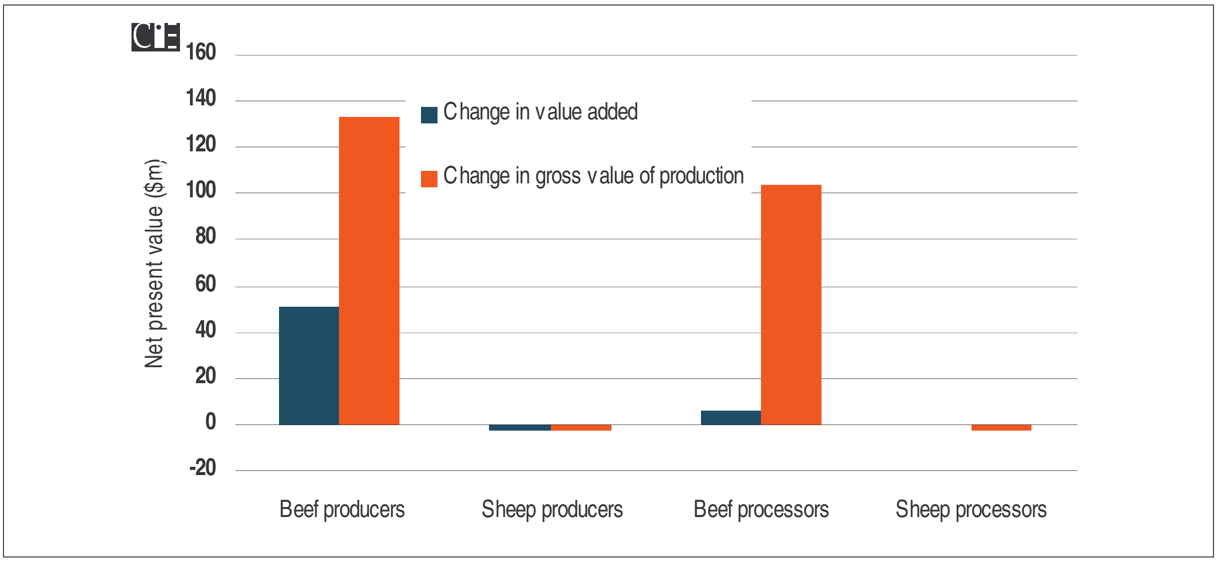
Distribution of benefits across the supply chain

By sector

The economic model uses assumptions about how producers, processors and consumers respond to changes in price to determine which groups ultimately receive the benefits that result from an MLA project. For example, if processors can reduce their costs, competition for consumers will mean that much of this reduction may be passed to consumers through lower prices. Further, at lower prices consumers will demand more. This will increase the demand for cattle and sheep, driving up producer value added.

For Predictive Microbiology, the majority of benefits for the red meat industry go to the beef production sector (chart 9). This reflects an increase in beef consumption underpinned by lower costs for consumers. Value added also rises in the beef processing sector. This is not surprising given that most of the impacts are initially on this sector. Sheep production and processing value added falls slightly, driven by consumer substitution to beef and pig meat.

9 Value added from each sector



Data source: CIE.

Sensitivity analysis

There are a number of key inputs that drive the findings of the analysis above. This section tests the sensitivity of the results to these assumptions by putting distributions around key parameters.

The parameters that were varied are shown in table 10. Each parameter was modelled as a triangular distribution between the minimum and maximum and with the mode as the most likely point. Montecarlos simulations were used to derive a distribution of the change in industry value added and total value added under these parameter distributions, using @Risk software.

10 Parameter distributions for sensitivity

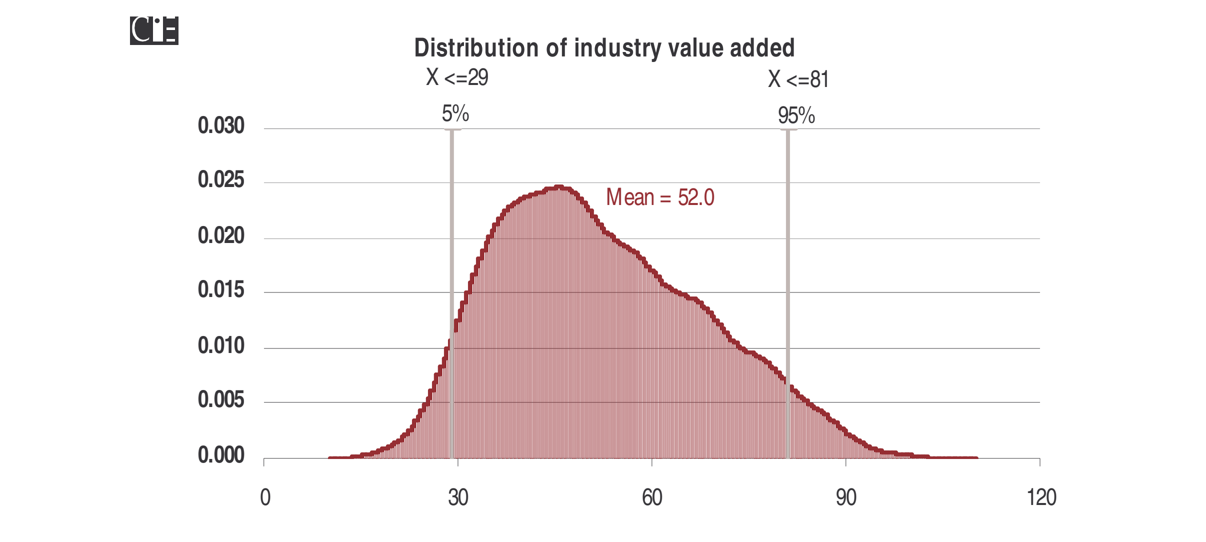
Impact	*Product/market*	*Most likely impact*	*Minimum impact*	*Maximum impact*	*Type of impact*	*Basis of risk estimate*
		%	%	%		
1: Hot boning — yield	Beef — exports	+0.400	+0.200	+0.600	Yield	10% and 30% allocation of benefits of hot boning
2: Hot boning — labour costs	Beef — exports	-2.083	-1.042	-3.125	Labour costs	10% and 30% allocation of benefits of hot boning
3. Hot boning — training costs	Beef — exports	0.124	0.062	0.186	Labour productivity	10% and 30% allocation of benefits of hot boning
3: Weekend chilling	Beef	-0.300	-0.000	-1.800	Costs	Strictness of alternative regulatory regime
4: Refrigeration breakdowns	Beef and sheep — exports	-0.014	-0.007	-0.054	Costs	Uncertainty around storage costs
5: Boning room temperatures	Beef — exports	+0.137	+0.000	+0.270	Yield	Potential for benefits to be allocated elsewhere
6: Cooked meats — capital	Pig — domestic	-13.537	-0.000	-27.075	Investment (mach. & equip.)	Strictness of alternative regulatory regime
7. Cooked meats — capital	Beef — domestic	-0.670	-0.000	-1.341	Investment (mach. & equip.)	Strictness of alternative regulatory regime
8. Cooked meats — ongoing	Pig — domestic	-1.800	-0.900	-0.270	Costs (electricity)	Strictness of alternative regulatory regime
9. Cooked meats — ongoing	Beef — domestic	-1.800	-0.900	-0.270	Costs (electricity)	Strictness of alternative regulatory regime
10. Compliance costs	Meat processors — export	+0.087	+0.043	+0.173	Costs	Highest estimate of compliance costs used
11. Additives for listeriosis	Pig — domestic	5.330	3.390	7.260	Costs (non-livestock inter. inputs)	Lower additive costs and additional investment costs
12. Additives for listeriosis	Beef — domestic	0.352	0.224	0.480	Costs (non-livestock inter. inputs)	Lower additive costs and additional investment costs
13. Demand risk from listeriosis outbreak	Beef and pig meat	2.000	1.000	3.000	Probability of outbreak in absence of project	Uncertainty of outbreak

Source: Evaluation questionnaire.

The sensitivity analysis conducted using the above parameters is shown in chart 11. There is only a 5 per cent probability that the project's benefits to industry were less than $29 million, according to this analysis. The distribution of the industry benefits is skewed heavily to the right due to the potential for a regulatory regime to be imposed on weekend chilling that increased refrigeration costs by 60 per cent.

The sensitivity analysis shows that Predictive Microbiology is highly likely to have been a successful project. Even under significant changes to a number of assumptions, the industry benefits outweigh the costs by a large margin.

11 **Sensitivity of industry value added and total value added**



Data source: CIE.

Verification

A crucial step in the evaluation report is the validation or verification of the information that generates the benefits. One step is peer review of data input, which involves an examination of the outcomes, adoption rates and 5 dimensional impacts that are derived by peers.

A second verification process involves scrutiny of the economic benefits produced by the model and checking these for 'sensible' outcomes by project managers and independent people. By 'sensible' is meant a series of questions such as:

- Do the results line up with prior judgements about expected benefits?
- Do the results imply implausibly profitable new technologies?
- Are private investors putting their dollars behind the technology and behaving in a way consistent with the results?

The advantage of the formal analytical framework is that results can be traced back to the input parameters and adjustments made if necessary.

Many of the assumptions in this evaluation have been sourced from stakeholders in the industry, regulators and researchers. A draft copy of this report was circulated to stakeholders and the report was revised in light of comments received.

References

ABS (Australian Bureau of Statistics) 2004, *Labour mobility, Australia,* Cat. no. 6209.0, February, ABS, Canberra.

—— 2006, *Population by Age and Sex: Australian States and Territories,* Cat. no. 3201.0, ABS, Canberra.

Commonwealth Department of Health and Ageing 2003, *Returns on Investment in Public Health,* prepared by Applied Economics, Canberra.

Dalton, C., Gregory, J., Kirk, M., Stafford, R.J., Giveny, R., Kraa, E. and Gould, D. 2004, 'Foodborne disease outbreaks in Australia 1995 to 2000', *Communicable Disease Intelligence*, vol. 28, no. 2.

FSANZ (Food Standards Australia and New Zealand) 2002, *Review of processing requirements for uncooked comminuted fermented meat products: Draft assessment report,* Proposal P251, December.

IBIS World 2005, 'Meat Processing in Australia', Industry Report.

Leading Edge 2004, *KPI 2004-05: MLA Tracking,* September.

MLA (Meat and Livestock Australia) 2005a, *Innovation Adoption Plans: Meat Quality Science and Technology — Generation One*.

—— 2005b, *Microbiological quality of Australian sheep and beef meat: Results of the third national benchmark study.*

Pointon, D. 1995, 'Wintulichs Pty. Ltd. and marketing environmental disturbance: The 'Garibaldi effect', *Australian Agribusiness Review*, 3(2).

Ross, T. 1999, *Predictive Microbiology Models in the Meat Industry,* MLA.

——, Rasmussen, S., Sumner, J., Paoli, G. and Fazil, A. 2004, *Listeria monocytogenes in Australian processed meat products: risks and their management,* prepared for MLA.

Scheurmann 2005, *Review of Meat Quality, Science and Technology: Beef Electronics Generation 2,* Melbourne University Private.

Smith, P. and Jahan, N. 2003, *Australian food processing industries: Distribution of employment,* Australian Government Department of Agriculture, Fisheries and Forestry, Canberra.

Sumner, J. and Krist, K. 2002, 'The use of predictive microbiology by the Australian meat industry', *International Journal of Food Microbiology,* 73, pp 363-66.

USDA 1982, (Seidernan, S. C. and H. R. Cross), *The economics and palatability attributes of hot-boned beef: A Review*.

Wegener, H., Hald, T., Wong, D., Madsen, M. Korsgaard, H., Bager, F., Gerner-Smidt, P. and Molbak, K. 2003, 'Salmonella Control Programs in Denmark', *Emerging Infectious Diseases,* vol. 9, no. 7, July.

World Bank 2005, *Food Safety and Agricultural Health Standards: Challenges and opportunities for developing country exports,* Poverty Reduction and Economic Management Trade Unit, and Agriculture and Rural Development Department, January.

Questionnaire for project evaluation

Prepared for:

Meat and Livestock Australia

Prepared by:

Ian Jenson and CIE

Date: 30 June 2006

Program name: Food Safety

Project name: Predictive Microbiology

Project code:

Objectives: To improve the safety of Australia's red meat at the lowest possible cost

1. INPUTS

1.1	a) Date of commencement:	1993 (mm/yy)
	b) Expected date of completion:	2006 (mm/yy)
	c) Date(s) of go/no go options:	
i). NA (mm/yy)	ii). _____ (mm/yy)	iii). _____ (mm/yy)
1.2	Costs (cash and in-kind)	

		Is this funded by:			
a) Year	*b) MLA*	*c) Industry partners*	*d) Other RDCs*	*e) Other* [a]	*f) Total*
i) 1993	104145				$
ii) 1994	104145				$
iii) 1995	104145				$
iv) 1996	104145			45756	$
v) 1997	119145			45756	$
vi) 1998	36960			56756	$
vii) 1999	68750			0	$
viii) 2000	166088			0	$
ix) 2001	205808			4575	$
x) 2002	271365			20067	$
xi) 2003	258855			48669	$
xii) 2004	121753			9600	$
xiii) 2005	397278			146044	$
xiv) 2006	52565			8500	$
xv) Year unknown	3430			24000	$
xvi) Total	2118576			306678	$

[a] Source of other contributions (*please list*): a) ARC, b) FSA, c) Postgraduate Awards, AQIS

2. OUTPUTS – No specific KPIs were set for the Predictive Microbiology project

2.1

a) Output description	*b) KPI*	*c) Date of completion*	*d) Means of verification*
i) Papers in refereed scientific journals	Number/quality of papers		Count
ii) Develop software products linking environment and microbiological growth	Number of software products Number of users of products		Count/survey
iii) Train processors in use of software products	Number of users trained Proportion of users trained		Count/survey
iv)			
v)			
vi)			

2.2 At what stage is the project currently at? *Please enter date of current evaluation below ticked box*

i) Yet to start ☐ ii) In implementation ☐ iii) Completed ☒

Date(s) of evaluation(s): a) June 2006 Date(s) of evaluation(s): b) _____ Date(s) of evaluation(s): c) _____

2.3 What is the probability of successfully achieving these outputs? Not applicable as outputs not set at start of project

	Probability of success [a]		
a) Output	*b) Expected*	*c) Expecting during implementation*	*d) Quality achieved* [b]
i)	%	%	%
ii)	%	%	%
iii)	%	%	%
iv)	%	%	%
v)	%	%	%
vi)	%	%	%

[a] Assessments of probabilities are to be made at three stages during the project — at design, during implementation and on completion

[b] Assessment of outputs achieved relative to expectations, 100% equals achieved what was expected, greater than 100% equals achieved more than expected

2.4 Which of the Australian Government's National Research Priorities does this project fit into? *Please indicate 1 to 3, with 1 being the most relevant and 3 least relevant*

An Environmentally Sustainable Australia		**Frontier Technologies for Building and Transforming Australian Industries**	
Water – a critical resource	...	Breakthrough science	2
Transforming existing industries	...	Frontier technologies	1
Overcoming soil loss, salinity and acidity	...	Advanced materials	...
Reducing and capturing emissions in transport and energy generation	...	Smart information use	...
Sustainable use of Australia's biodiversity	...	Promoting an innovation culture and economy	...
Developing deep earth resources	...		
Responding to climate change and variability	...		
Promoting and Maintain Good Health		**Safeguarding Australia**	
A healthy start to life	3	Critical infrastructure	...
Ageing well, ageing productively	3	Understanding our region and the world	...
Preventive healthcare	...	Protecting Australia from invasive diseases and pests	...
Strengthening Australia's social and economic fabric	...	Protecting Australia from terrorism and crime	...
		Transformational defence technologies	...

3. OUTCOMES

3.1	Is this project part of a group of projects under this program?	Yes ☐ *please list (project code)* *a) ____, b) ____ c) ____, d) ____*	No ☒
3.2	Is this project an input to another MLA program?	Yes ☐ *please list* *a) ____, b) ____ c) ____, d) ____*	No ☒
3.3	Does it have a discrete outcome(s) that can be separately identified?	Yes ☒ *please continue to 3.4*	No ☐ *please evaluate as part of the set – ensure all project costs are identified if evaluating impacts.*

3.4 At what point of the program cycle is this project? *Please indicate along the continuum*

i) Strategy/design	ii) Investment	iii) Implementation	iv) Communication	v) Adoption	vi) Evaluation
☐	☒	☒	☒	☐	☐

3.5 What outcomes are expected/achieved as a result of successful completion of the project/set of projects?

	KPIs				
a) Outcome description	*b) Target*	*c) Level reached*	*d) Date expected*	*e) Date achieved*	*f) Means of verification*
i) Lower compliance costs for meat processors					Survey of processors
ii) Improve microbiological quality of product					Microbiological quality benchmarking
iii) Include predictive microbiology tools in regulation					Proportion of processing for which this has occurred
iv)					

3.6 For completed projects (sets), were these outcomes expected? Yes ☐ No ☐

If no, in what way did the outcomes differ from expected? a) ______

3.7 What are the impacts that will/have occur(red) as a result of achieving these outcomes, and how important is the change expected to be?

Please leave blank if there is no change (see manual for mapping project outcomes to the standardised 5-D categories)

i) Demand			ii) Supply			iii) Risk			iv) Environment			v) Social		
Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High	Low	Med.	High
☐	☐	☐	☐	☐	☒	☐	☐	☒	☐	☐	☐	☐	☐	☒
If answered Medium or High, go to section 4			*If answered Medium or High, go to section 5*			*If answered Medium or High, go to section 6*			*If answered Medium or High, go to section 7*			*If answered Medium or High, go to section 8*		

4. DEMAND IMPACTS

Not Applicable to Predictive Microbiology (demand risk is considered in section 6)

5. SUPPLY IMPACTS

5.1 Which products are directly affected?

Beef		Sheep		Type of product	
Beef and veal: grain fed	☒	Sheep meat: mutton	☒	Fresh and chilled	☒
Beef and veal: grass fed	☒	Sheep meat: lamb	☒	Frozen	☒
Live cattle	☐	Live sheep	☐	Dominant cut	☐
Co-products beef	☐	Co-products sheep	☐	*Please specify:*	a)______
Northern beef	☐				
Southern beef	☐				
Cattle feedlots	☐				

5.2 What point on the value chain is the change in supply?

i) On-farm	☒	Go to 5.4
ii) Transport (domestic & international)	☐	Go to 5.5
iii) Processing	☒	Go to 5.6
iv) Wholesale/Retail	☐	Go to 5.7

5.3 Are other investments required beyond the project investment before impacts are achieved? Yes ☒ No ☐

If Yes, are these investments in:

Communication	IP	Trials/prototype	Commercial production	Marketing	Other
☒	☐	☐	☐	☐	☐

What is the investment required? $103 000 (AQIS for training) - already counted

5.4 ***On-farm outcomes** – not applicable to Predictive Microbiology*

5.5 ***Transport impacts – not applicable to Predictive Microbiology***

5.6 ***Processing impacts***

	a) Impact 1	*b) Impact 2*	*c) Impact 3*	*d) Impact 4*
i) Product	Beef, sheep, pig: implementation	Beef: hot boning	Beef: hot boning - training	Beef: weekend chilling
ii) Region	Export	Export	Export	All
iii) Potential volume of this production impacted	100 % of production	10 % of production	10 % of production	15 % of production
Iv) Maximum adoption rate (% of volume reported in 5.5 iii)	100%	100%	100%	100%
v) Year of first adoption	2005	2001	2001	1998

vi) Year of 50% of total adoption achieved		2005	2001	2001	1998
vii) Year maximum adoption		2005	2001	2001	1998
Estimate:					
		a) Impact 1	*b) Impact 2*	*c) Impact 3*	*d) Impact 4*
i) Change in unit cost of production ($/kg finished weight)	i.i) Min	0.043 %	-1.0 (labour only) %	-0.06 (labour only) %	-0.00 (allocated to electricity) %
	i.ii) Most likely	0.087 %	-2.0 (labour only) %	-0.12 (labour only) %	-0.30 (allocated to electricity) %
	i.iii) Max	0.173 %	-3.1 (labour only) %	-0.19 (labour only) %	-1.80 (allocated to electricity) %
ii) Change in yield	i.i) Min	%	0.2 %	%	%
	i.ii) Most likely	%	0.4 %	%	%
	i.iii) Max	%	0.6 %	%	%
iii) Lag between adoption and observing impact		0 Years	0 years	0 years	0 years
iv) Probability of successfully achieving this impact		100%	100%	100%	100%
xvi) Is the change:					
– proportional to the cost per kg; or		☐	☐	☐	☐
– a fixed amount per kg		☒	☒	☒	☒
Is the change (expected to be) permanent?					
Yes		☐	☒	☒	☒
No		☒	☐	☐	☐
If no, how many years until the impact on supply returns to baseline?					
		1 Years	_____ years	_____ years	_____ years
5.6 ***Processing impacts (continued)***					
		a) Impact 5	*b) Impact 6*	*c) Impact 7*	*d) Impact 8*
i) Product		Beef, sheep: refrigeration breakdowns	Beef: boning room temperatures	Pig: cooked meats - capital	Pig: cooked meats - ongoing
ii) Region		Export	Export	Domestic	Domestic
iii) Potential volume of this production impacted		100 % of production	7.8 % of production	100 % of production	5.8 % of production
Iv) Maximum adoption rate (% of volume reported in 5.5 iii)		100%	100%	100%	100%
v) Year of first adoption		2001	2006	2004	2004

vi) Year of 50% of total adoption achieved		2001	2006	2004	2004
vii) Year maximum adoption		2001	2006	2004	2004
Estimate:					
		a) Impact 5	*b) Impact 6*	*c) Impact 7*	*d) Impact 8*
i) Change in unit cost of production ($/kg finished weight)	i.i) Min	-0.007 %	%	-0.0 (only for mach&equip) %	-0.90 (allocated to electricity) %
	i.ii) Most likely	-0.014 %	%	-13.5 (only for mach&equip) %	-1.80 (allocated to electricity) %
	i.iii) Max	-0.054 %	%	-27.1 (only for mach&equip) %	-2.70 (allocated to electricity) %
ii) Change in yield	i.i) Min	%	0 %	%	%
	i.ii) Most likely	%	0.14 %	%	%
	i.iii) Max	%	0.27 %	%	%
iii) Lag between adoption and observing impact		0 Years	0 years	0 years	0 years
iv) Probability of successfully achieving this impact		100%	100%	100%	100%
xvi) Is the change:					
– proportional to the cost per kg; or		☐	☐	☐	☐
– a fixed amount per kg		☒	☒	☒	☒
Is the change (expected to be) permanent?					
Yes		☒	☒	☐	☒
No		☐	☐	☒	☐
If no, how many years until the impact on supply returns to baseline?					
		_____ Years	_____ years	1 years	_____ years
5.6 ***Processing impacts (continued)***					
		a) Impact 9	*b) Impact 10*	*c) Impact 11*	*d) Impact 12*
i) Product		Beef: cooked meats - capital	Beef: cooked meats - ongoing	Pig: Listeria additives	Beef: Listeria additives
ii) Region		Domestic	Domestic	Domestic	Domestic
iii) Potential volume of this production impacted		100 % of production	0.5 % of production	100 % of production	100 % of production
Iv) Maximum adoption rate (% of volume reported in 5.5 iii)		100%	100%	100%	100%
v) Year of first adoption		2004	2004	2006	2006

vi) Year of 50% of total adoption achieved		2004	2004	2006	2006
vii) Year maximum adoption		2004	2004	2006	2006
Estimate:					
		a) Impact 9	*b) Impact 10*	*c) Impact 11*	*d) Impact 12*
i) Change in unit cost of production ($/kg finished weight)	i.i) Min	-0.0 (only for mach&equip) %	-0.90 (allocated to electricity) %	3.39 (only for non-livestock inter. inputs) %	0.224 (only for non-livestock inter. inputs) %
	i.ii) Most likely	-0.7 (only for mach&equip) %	-1.80 (allocated to electricity) %	5.33 (only for non-livestock inter. inputs) %	0.352 (only for non-livestock inter. inputs) %
	i.iii) Max	-1.3 (only for mach&equip) %	-2.70 (allocated to electricity) %	7.26 (only for non-livestock inter. inputs) %	0.48 (only for non-livestock inter. inputs) %
ii) Change in yield	i.i) Min	%	%	%	%
	i.ii) Most likely	%	%	%	%
	i.iii) Max	%	%	%	%
iii) Lag between adoption and observing impact		0 Years	0 years	0 years	0 years
iv) Probability of successfully achieving this impact		100%	100%	100%	100%
xvi) Is the change:					
– proportional to the cost per kg; or		☐	☐	☐	☐
– a fixed amount per kg		☒	☒	☒	☒
Is the change (expected to be) permanent?					
Yes		☐	☒	☒	☒
No		☒	☐	☐	☐
If no, how many years until the impact on supply returns to baseline?					
		1 Years	_____ years	_____ years	_____ years
5.7 ***Wholesale/Retail – not applicable to Predictive Microbiology***					

5.8	If the project has a positive impact, what is the minimum investment in the project necessary to generate beneficial impact? Information not available to answer this

6. RISK IMPACTS

6.1 Does the project aim to:

	Yes		No
i) Reduce the probability of an adverse event?	☒	*Go to 6.2*	☐
ii) Reduce the impact should an adverse event occur?	☐	*Go to 6.2*	☒
iii) Position the industry to take advantage of opportunities should they arise?	☐	*Go to 6.3*	☒
iv) Other type of objective? *Please specify* a) _____	☐		☒
Please specify: b) _____ *Go to 6.2*			

6.2 What is the nature of the adverse event being addressed?

	Minor	*Major*
6.2.1 Demand risk:		
Food safety	☐	☒
Meat labeling	☐	☐
Negative health perceptions	☐	☐
Negative environmental perceptions	☐	☐
Other risk quality	☐	☐
Live trade export ban	☐	☐
Trade barriers increase	☐	☐
Other demand risk	☐	☐
Please specify: a)_____		
6.2.2 Supply risk:		
Supply of industry skills	☐	☐
Occupational Health and Safety	☐	☐
Excessive environment regulation	☐	☐
Animal health regulation	☐	☐
Access to water	☐	☐
Resource degradation	☐	☐
Climate change/variability	☐	☐
Other cost / certainty of production risks	☐	☐
Please specify: a)_____		

6.3 What is the nature of the opportunity that the project is positioning the industry for?

		Minor	*Major*
6.3.1 Demand opportunity:			
Positive health perception		☐	☐
'Clean and green' image		☐	☐
Other perceptions opportunity		☐	☐
Please specify:	a)______		
Trade barriers decrease		☐	☐
Other access opportunity		☐	☐
Please specify:	b)______		
Other opportunity		☐	☐
Please specify:	c)______		

6.4 For the risks/opportunities identified as major in questions 6.2 and 6.3, please complete the following where relevant:

	a) Impact 1	*b) Impact 2*	*c) Impact 3*	*d) Impact 4*
i) Risk / opportunity addressed	Demand risk from Listeria outbreak	Demand risk from Listeria outbreak		
ii) Product affected	Beef	Pig		
iii) Markets affected (demand)	Domestic	Domestic		
iv) Regions affected (supply)				
v) Portion value chain affected (supply)	Processors	Processors	Producers	Producers
vi) Potential volume affected	5 % of market/product	55 % of market/product	% of market/product	% of market/product
vii) How often is this event expected? (months/years)	Min: 1/100yrs Mean: 1/50yrs Max: 1/25yrs	Min: 1/100yrs Mean: 1/50yrs Max: 1/25yrs		
viii) Expected frequency if project is successful (leave blank if no change) (months/years)	0	0		
ix) By how much does the project delay the event (speed up in case of opportunity)?	0 years	0 years	years	years
x) Expected probability of achieving this change	%	%	%	%
xi) In-progress assessment of probability	100 %	100 %	%	%
xii) Assessment of achievement on project completion	%	%	%	%

6.5 For the **'demand'** risks/opportunities identified as major in questions 6.2 and 6.3, use section 4 of this questionnaire, and for the **'supply'** risks/opportunities identified as major in questions 6.2 and 6.3, use section 5 of this questionnaire to fill out the following table:

Effect of adverse event or opportunity if it arises

		a) Impact 1	*b) Impact 2*	*c) Impact 3*	*d) Impact 4*
Without project:					
i) Proportion affected		20%	20%		
ii) Change in demand/supply for area affected (first year)		-40%	-40%	%	%
iii) Change in demand/supply for area affected (second year)		-25%	-25%	%	%
iv) Duration of demand impact		10 years	10 years	years	years
With project (if different):					
i) Proportion affected	i.i) Min.	%	%	%	%
	i.ii) Max.	%	%	%	%
ii) Change in demand/supply for area affected	ii.i) Min.	%	%	%	%
	ii.ii) Max.	%	%	%	%

6.6 Are there additional costs of implementing the risk / opportunity impact (outside of MLA costs and costs entered in other sections)? Yes ☐ No ☒

If yes, please complete the following:

a) Year	*b) Implementation cost*	*c) Who makes this investment?*
i)		
ii)		
iii)		
iv)		

7. ENVIRONMENTAL IMPACTS

Not Applicable to Predictive Microbiology

8. SOCIAL IMPACTS

8.1 Does the project lead to social impacts, such as:

	Minor	*Major*
i) Development of industry skills	☐	☐ *See also supply impacts*
ii) Improvement in industry networks	☐	☐ *See also supply impacts*
iii) Better labour retention	☐	☐ *See also supply impacts*
iv) Improved OHS practices	☒	☐ *See also supply impacts*
v) Greater confidence of industry members in future	☐	☐
vi) Better human health outcomes (*See also impact on demand*)	☐	☒
vii) Rural population retention	☐	☐
viii) Improved community perceptions of the industry (eg. animal welfare)	☐	☐
x) Other	☐	☐

Please specify: a)______

8.2 For the major changes in social impacts, please complete the following table:

		a) Impact 1	b) Impact 2	c) Impact 3	d) Impact 4
i) Social impact		Reduced illness/death from Listeriosis			
ii) Unit of measurement		Disability adjusted life years			
iii) Level at start of project (baseline)		336			
iv) Target	Level	46			
	Year	2006			
v) Probability of success		100			
vi) Current level	Level				
	Year				

8.3 Where possible, fill out the following table:

		a) Impact 1	b) Impact 2	c) Impact 3	d) Impact 4
i)$ value per unit outcome	Min.	$40 000			
	Max.	$80 000			
ii) Units achieved (max. impact)	Min.	200			
	Max.	336			
iii) Year of initial impact		2006			

iv) Year of max. impact	2006			
v) Year when impact falls to zero				
Note: If social impacts are also economic impacts then for 'Demand', go to Section 4, and for 'Supply', go to Section 5				

8.4 Are there additional costs of implementing the social impact (apart from costs accounted for in other sections)? Yes ☐ No ☒

If yes, please complete the following:

a) Year	*b) Implementation cost*	*c) Who makes this investment?*
i)	$	
ii)	$	
iii)	$	
iv)	$	

9. INCOME RECEIVED

Not Applicable to Predictive Microbiology

10. SUPPORTING EVIDENCE

10	What supporting evidence can be provided for the assessments made in this questionnaire? *Please provide quotes and evidence that supports the claims*
Supporting evidence provided in report	