Final report Phase 2

Project code: **A.TEC.0100**

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Date published: June 2014

PUBLISHED BY
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Quantifying the benefits of developing a CT marbling solution (Phase 2)

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

This project has been conducted to gain an understanding on the feasibility of estimating total fat and lean from hot boned out beef primals and the estimation of intramuscular fat.

The assumptions in this report include:

- processor cost to purchase a CT machine (i.e. initial capital outlay) could be $500,000;
- current error rate on carcase yield measurement is approximately 1 mm at the P8 site.

Study indicates a potential:

  - reduction in the error rate of estimating fat to fall from 70 to 40%
  - the benefits of hot boning: reduction in moisture loss, improving the accuracy of grading cattle and reduction in grading error could produce benefits of $4.4M per year (based on ~500 head/day)

Executive summary

This research project conducted by Agriculture NSW, NSW Department of Primary Industries, has investigated a "cost benefits analysis of estimating intramuscular fat from CT images". To conduct this work Terrance Farrell and Garry Griffith were contracted to do the economic analysis.

Experimental studies conducted in Phase 1 (final report submitted to MLA) indicated:

- ✓ That it is feasible to measure fat under hot-boning conditions.
- ✓ Confirmed the large variability that exists within primals for Meat Standards Australia (MSA) grade versus chemical intramuscular fat (%). The correlation between MSA grade and chemical intramuscular fat (%) ranged from 0 to 0.94 across 20 primals.
- ✓ Developed an equation ($AdjR^2$ = 0.84) to estimate intramuscular fat in a primal but this equation still needs an independent evaluation.

Subsequently this cost benefit analysis (CBA) study was conduced (i.e., phase 2).

This study found that if a processor were to purchase a $500,000 CT machine (assumption) and if the current error rate on carcase yield measurement was approximately 1 mm at the P8 site then abattoirs processing > 500 head of cattle/day would benefit from installing a CT machine. Hot boning carcasses and the utilisation of a CT machine at a grading station on the slaughter floor has the potential to increase profitability.

Based on the assumptions reported, this study found that the benefits of hot boning beef primals i.e., reduction in moisture loss, improving the accuracy of grading cattle and reduction in grading error could produce financial benefits in the order of $4.4M (~500 head/day). Future studies are required to estimate the value of the MSA index and examine if the prediction error rate for low and high quality muscles is similar over and above the index range. The provision of MSA estimates on the number of bodies that fall into each MSA index grade has the potential to increase the precision of this CBA.

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Background

Computerised axial tomography (CAT or CT) scan machines produce slices of a scanned image enabling the operator to look inside an object. Post processing of images (i.e., the slices) can then produce three dimensional images of body or muscle segments. The images can then be interpreted by software to estimate the weight and dimension of various components. Research in phase 1 (MLA Phase 1 final report) of this project was aimed at scanning hot or cold boneless beef primals in an abattoir environment with the intention to estimate intramuscular fat by a non-destructive technique. The potential also exists to estimate a CT scanned retail beef yield.

At present carcase yield is estimated from age, weight and fat levels. (Carcase yield should not be confused with dressing percentage which correlates the carcase weight to the animal's live weight). Cattle producers are paid according to the levels of these weight and fat attributes and other factors including dentition and sex. The current weight and fat measures are affected by trimming and dressing percentage at the abattoir. Subcutaneous fat is measured on the rib and or P8 site over the rump. Fat tissue on these sites can be removed by hide pullers and where a significant amount of fat is removed from a carcase it will affect the value of the carcase, the subsequent payment back to the producer and the Meat Standards Australia (MSA) eating score prediction. Researchers using other technologies have tried to estimate the carcase yield with Video Image Analysis (VIA) and Digital Image Analysis (DIA). These technologies have been reasonable in predicting live weight, muscle and fat weights for sheep, and dimension and area measurements in beef (Ross et al, 2014). However, intramuscular fat measurements are still in their developmental stage.

There is no suitable method to measure Intramuscular fat (IMF) at an abattoir at present; however, it can be measured on muscle samples which are tested in labs. Two methods: (1) near infrared mass spectroscopy; and (2) chemical extraction are widely used to measure IMF samples in research labs. There is a low correlation between the fat sites measured in abattoirs which include P8, Rib and US Marbling and AusMeat Marbling with IMF. These fat measures are also poor predictors of eating quality but are currently used by the industry as a proxy measure for IMF. Intramuscular fat has a quadratic influence on meat eating quality and the effect plateaus above 17 % IMF (Thompson, 2004).

Preliminary research data on muscles from 36 head of cattle show that CT scanned images using a mixed model technique rather than a boundary method can repeatedly predict the lean and fat tissue percentage in hot or cold beef primals. Software has also been developed that can estimate CT scanned IMF with an accuracy of r = 0.71; caution needs to be applied because of the small sample size and an evaluation using a larger data set is planned. The scope of this analysis is to ascertain the economic cost benefit of installing a small CT scanner into a beef processing plant to measure IMF and retail beef yield.

Objectives

Phase 1

1. Determine if differences exist in the estimate of kilograms of total fat from CT scanning images at a range of temperatures.

2. Determine the relationship between the MSA marbling score, chemical intramuscular fat (IMF) (%), and the CT scanning image of IMF (%) of the 10 mm slices.

3. Develop equations to estimate IMF (%) in primal cuts

Phase 2

Perform an economic cost benefits analysis to determine the profitability of implementing a CT scanning technology into an abattoir. Detailed costs of placing CT scanning equipment into the supply chain will be collected. Data by a senior economist will fully evaluate the cost benefit.

Phase 2. Economic cost benefit analysis to determine the profitability of implementing a CT scanning technology into an abattoir.

Introduction

A significant amount of research has been applied to carcase yield prediction. Wallace *et al.* (1997) used scan data of rib fat measurements to predict meat yield to an accuracy of up to 60 per cent. Perry *et al.* (1993) estimated that carcase yield could be predicted from live weight, P8 fat depth and muscle score with up to 62 per cent accuracy. Afolayan *et al.* (2002) obtained similar results and slightly improved the model by including stifle width (diameter) but the prediction accuracy level remained at around 62 per cent. McKiernan *et al.* (2009) showed variation in yield due to cattle breed particularly in traits including Rib Eye Area (REA) and IMF percentage. Adding breed also improved the model slightly for a number of traits but the increase in yield prediction accuracy was small.

VIA Scan yield prediction models for beef are still very inaccurate. Ross *et al.* (2014) reported that the correlation of VIA to beef EUROP scores was only 0.52. EUROP scores are primarily associated with muscle distribution and subcutaneous fat depth and this information is used to predict carcase composition. The correlation between VIA Prediction and IMF is improving in sheep carcases but has not been tested extensively with beef carcases.

Kruk *et al.* (2002) examined the relationship between marbling and IMF. VIA Scan data was compared to IMF for animals grown on two different weight gain paths. The VIA Scan results did not detect a significant difference for animals on either growth path; however, the group of animals on the “fast” path was detected with IMF chemical analysis. This result indicated that the VIA Scan could not detect the variation in monounsaturated fat levels and that yield may be better predicted with X-ray technologies.

Computerised Tomography (CT) X-ray machines have the capacity to scan individual beef muscles and predict IMF composition. The machine would measure IMF rather than P8 or Rib fat and would provide a marbling score if required. Carcase yield could be estimated by measuring the fat and lean percentage in each primal or a selection of primal and eating quality could also be estimated by the IMF percentage following Thompson (2004).

Improvement in carcase yield estimation could reduce variability in payments to producers that result from errors in fat measurement associated with hide pulling, carcase trimming, and muscle shape. In the Japanese market there may also be premiums associated with more accurately predicting marbling, fleck and the distribution of IMF within various primals.

Meat Standards Australia has a retail cuts grading system that could be enhanced with a cuts based yield analysis system. At least one processing plant in Australia has the capacity to pay producers on a cuts based model; however, that model is not used at present.

To develop these cuts based market mechanisms beef primals would need to be CT scanned at some point in the boning room prior to the point where carcase identification is lost. Often carcase identification is lost at the commencement of boning when identification tickets are removed. Carcase identification issues are complex in multi-line and multi-market boning rooms but these issues can be addressed with other tracking technologies.

An alternative point of data capture from a CT machine would be at a point prior to the grading station on the slaughter floor; however, this would require a large machine to handle a carcase or a machine with multiple tubes that pointed toward specific parts of a carcase rather than a whole carcase.

It is estimated that a CT machine that measurers and puts together a 3-D image of the body could cost as much as $60,000 to $90,000 fully installed (Block Imaging, 2014). Taking into account a new technology, this study has assumed that the initial capital cost is $500,000. This is only an approximate value as the operating environment has not been considered nor has labour cost been evaluated. Communication from Niels Toftelund Madsen (Danish Meat Research Institute, Taastrup, Denmark) indicated that they are developing an on line CT scanner that is initially targeting the pork industry (e.g., measuring pork middles). Niels Madsen (Pers. Com.) pointed out that it should be possible to adapt the equipment to beef primals. A footprint space requirement for the machine is approximately 2.5 x 2.5 x 2.5 meters. Measurement speed is aimed at 1000 pork middles per hour. Niels Madsen indicated “that it is too early to determine the cost of implementing a CT machine into production for beef primals. There are too many unknown equipment issues.”

Benefits of measuring carcase fat and yield

The benefit of measuring carcase fat and yield accurately increases as the fat depth of the carcase increases as the marginal cost of fat rises exponentially. It is expected that the measurement error for rib and P8 fat is biased downward as fat is stripped from the carcase with hide pullers or excessive trimming prior to the weigh station. That is, carcases would be more often recorded with lower measurement than higher measurements.

Australian multi-breed carcase data (Afolayan et al 2002) were used to estimate the weight of fat in a wide range of carcases with varying fat scores. The mean weight of carcases reported in the study was 320 kgs HSCW. A cost per kilogram of carcase fat for P8 fat measurements ranging from 0 to 22 mm was calculated from average over –the-hook prices for the past four years (MLA, 2014)

The marginal cost of a 1 mm error in the 7 mm range is $5.54 whereas the cost of a 1 mm error in the 18 mm range is $15.07. Most abattoir price grids have price steps rather than incremental discounts for fat carcases and in many cases the discount step is 20 cents in the lower fat range (domestic) and 30 cents (export) in the upper fat range which equates to $64 or $96 price step per head respectively (based on 320 kg carcase at $3.20 per kg CWT). The cost per carcase and the marginal cost per mm of increasing fat in a 320 kg carcase are shown in figure 1.

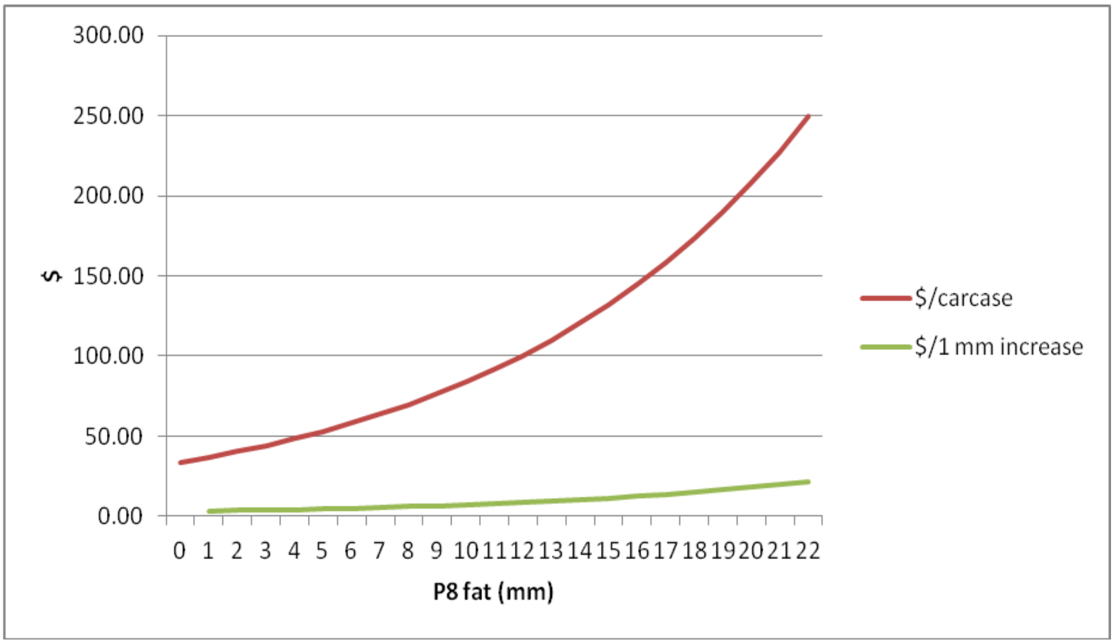

Figure 1. Cost of fat and change in fat cost as measured at P8 site for a 320 kg carcase (HSCW).

The annual cost of a 1 mm error in fat measurement to a domestic abattoir that processes 500 animals per day would be $692,500 per year if the animals were 1 mm fatter than measured (Table 1). Similarly the annual cost for an export plant processing 500 head per day would be $1.80 million. The costs for processing plants of higher capacity are much greater (Table1). An export plant processing 2000 head per day could expect a loss of $7.5 million per annum.

Table 1. Annual cost to a domestic or export processing plant by throughput

		Processing head per day*				
		500	800	1500	2000	3000
	Cost	$	$	$	$	$
Domestic	5.54	692,500	1,108,000	2,077,500	2,770,000	4,155,000
Export	15.07	1,883,750	3,014,000	5,651,250	7,535,000	11,302,500

*Assumes 250 processing days per year and a 1 mm measurement error with downward bias.

Costs to purchase and install

The costs to purchase and install a machine in a processing plant at this time are not known; however, the total benefit to a processing operator per year would need to be less than the cost calculated over a 15 year machine life span. Assumed costs are shown in Table 2. It has been assumed that the initial capital cost would be in the vicinity of $500,000. The total costs include the loss of interest on the capital invested in the machine (7 per cent pa), two labourers per machine and an annual service cost of $35,000 (indexed by CPI 3.5 per cent) (Table 2).

Table 2. Assumed CT machine purchase and operating cost per year.

	Machine	Int. on Capital	Labour	Service	Total
Year 1	500,000	35,000	100,000	35,000	670,000
Year 2		35,000	103,500	36,225	174,725
Year 3		35,000	107,123	37,493	179,615
Year 4		35,000	110,872	38,805	184,677
Year 5		35,000	114,752	40,163	189,916
Year 6		35,000	118,769	41,569	195,338
Year 7		35,000	122,926	43,024	200,949
Year 8		35,000	127,228	44,530	206,758
Year 9		35,000	131,681	46,088	212,769
Year 10		35,000	136,290	47,701	218,991
Year 11		35,000	141,060	49,371	225,431
Year 12		35,000	145,997	51,099	232,096
Year 13		35,000	151,107	52,887	238,994
Year 14		35,000	156,396	54,738	246,134
Year 15		35,000	161,869	56,654	253,524
Total	500,000	525,000	1,929,568	675,349	3,629,917

Net Benefits

The net benefits are reported in regards to operating a CT scanning machine on the slaughter floor as opposed to operating it in the packaging area. As mentioned above, the development is only in the early stages and the initial development will be for the pork industry that could be adapted to the beef industry. Therefore cost of production from the Danish Meat Research Institute has not been established and hence estimated values as stated above have been used.

The assumptions in this report are:

- processor cost to purchase a CT machine (i.e., initial capital outlay) could be $500,000; and
- current error rate on carcase yield measurement approximately 1 mm at the P8 site.

Benefits of operating a CT machine on the slaughter floor

Reduction in moisture loss

The opportunity for hot boning would save on moisture loss that is associated with carcase chilling. In some plants this loss can be as much as 2 per cent (McNeil No date, Galka, 2009). (At one per cent loss the cost is $11.20 based on a 320 kg carcase valued at $3.50 per kilogram, which is equivalent to $5600 per day in 500 /day works and $1.4 million in an abattoir of this size over 250 work days per year).

Improving the accuracy of grading older cattle

Additional benefits may be derived from older animals which exhibit higher eating quality scores enabling muscles to be upgraded. On a 4 kg loin this could increase the price from $10 per kilo to $17 per kilogram which is a benefit of $56 per animal (4 kgs x 7 = $28 x 2 loins per animal = $56 per animal). An abattoir processing 300 potential older animals per day may grade up 20 per cent of these which is equivalent to 60 bodies at $56 per body = $3,360 per day or $840,000 per year. There could also be other muscles that could be harvested from carcases that would have been downgraded on the slaughter floor such as the tender loin (eye fillet) and rump which would add additional gains.

Advantages of Reducing Grading Error

At present graders rely on carcase weight, ossification, hump height, marbling and rib fat to predict the MSA Eating Quality Index value. Research by MSA suggests that the relationship between marbling and the MSA index is low at around 30 per cent accuracy (Pers. Com. Alex Ball MSA Armidale May 28th 2014). CT scanning could increase this relationship to 60 per cent accuracy by predicting IMF percentage. The error rate using marbling and rib fat may cause 70 per cent of carcases to be allocated to the incorrect market group. Assuming a normal distribution over 100 carcases then 35 carcases will be graded up when they should have been graded down, and 35 will have been graded down when they should have been graded up. This leaves only 30 which would have been correctly graded. Table 3, shows a distribution of 10 per cent of carcases falling into the fail grade, 60 per cent scoring 3-star, 20 per cent scoring 4-star and 10 per cent scoring 5-star at an average carcase weight of 300 kgs and if the price difference between MSA Fail and 3 Star is $7 per kg, the price step between 3-Star and 4-star is $12 per kg, and the difference between 3-star and 4 star is $20 per kg then the value of the 100 carcases is $701,550.

Table 3. Value of improving MSA Index Accuracy

Current Grade	Carcases	Fail $10	3-Star $17	4-star $29	5-star $49	Value $ Total
Fail	10	1050	900	1050		$56,250
3-Star	60	6300	5400	6300		$337,500
4-star	20		2100	1800	2100	$190,800
5-star	10			1500	1500	$117,000
	100					$701,550

With CT Grade	Carcases	Fail $10	3-Star $18	4-star $30	5-star $50	Value $ Total
Fail	10	600	1800	600		$56,400
3-Star	60	3600	10800	3600		$338,400
4-star	20		1200	3600	1200	$189,600
5-star	10			1200	1800	$126,000
	100					$710,400

With CT scanning the error rate of carcase allocation would fall from 70 per cent to 40 per cent and assuming a normal distribution we would have 20 per cent grading lower and 20 per cent higher and 60 per cent on the target grade. By improving the distribution consumers could be expected to pay at least one dollar more per kilogram for each Star grade product and therefore the total value of the 100 carcases could sum to $710,400 producing a benefit of $8,850 per day. Over a 250 day work year the benefit would sum to $2,212,500.

Combining the benefits of hot boning cattle i.e., reduction in moisture loss ($1,400,000), improving the accuracy of grading older cattle ($840,000), reduction in error rate of carcass allocation ($2,212,500) could produce benefits for an abattoir in the order of $4.4M ($1,400,000 + $840,000 + $2,212,500 = $4,452,500) for a plant doing approximately 500 head per day. The estimated net benefits are just for one plant and if the technology were to be more widely adopted there might be market repercussions. In particular, some of the cost savings could be passed back to producers and cattle production could become more attractive, supply would increase and prices would tend to fall. Other processors might also adjust their grids and incentives to attract cattle into their works.

Conclusions and future directions

If a processor were to purchase and install a $500,000 CT machine on the slaughter floor and if the current error rate on carcase yield measurement was approximately 1 mm at the P8 site then abattoirs processing more than 500 head of cattle per day would benefit from installing a CT machine. The implications of installing a CT scanner include the potential of estimating retail beef yield of individual beef primals.

A cost benefits analysis in the packaging area after the Cryovac machine needs to be undertaken to compare ‘on the slaughter floor’ *versus* ‘in the packaging area’. This study would be feasible at a later date when production costs are established.

Future studies need to estimate the value of the MSA index and examine if the prediction error rate for low quality and high quality muscles is similar over and above the index range.

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Acknowledgements

Terrence Farrell (CEO of the Charolais Society, Armidale NSW) and Grarry Griffith (Professor of Professor, Faculty of Veterinary and Agricultural Sciences, University of Melbourne) are gratefully acknowledged for conducting the cost benefit analysis.