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Caprine and Ovine "cubing" characterisation and automation feasibility

FINAL REPORT

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The input from Scott Technology, Midfield Meat and McPhee as well as Western Meat Exporters is gratefully acknowledged.

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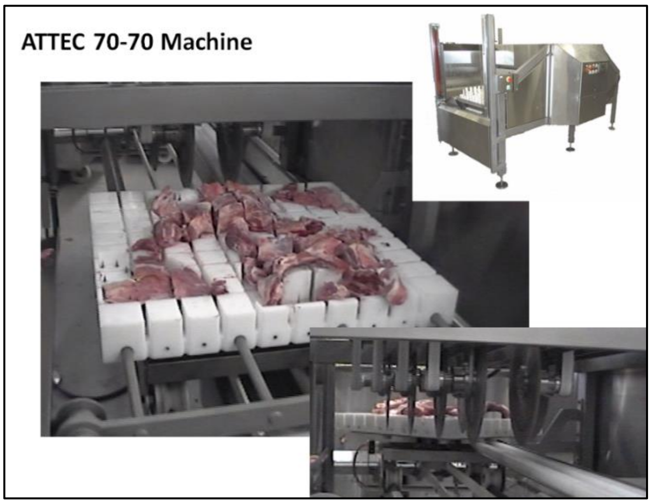
1.0 Executive Summary

This project has considered the feasibility of automation to meet the requirements of carcass cutting into cubes, assessing also current commercial solutions.

The 70-70 machine from ATTEC Danmark A/S is the only solution reported for fresh meat. "Cube" sizes are approximate, given the natural profile and variability of carcasses.



In Australia, primal cut meat is generally compacted into frozen blocks and cut into "cubes" for bulk packaging or in bags of fixed weight for export. Tests conducted indicate that cutting frozen by band-saw results in over 3 times the loss compared to cutting fresh.

The cubing process is influenced by the variability of the carcass shape, size and weight, which determine the number of whole cubes that may be extracted against a given specification. The cutting scheme and control in the handling processes are more dominant factors.

Against a given target cube size and quality, there exists an optimum cutting scheme for extracting the highest number of conforming cubes. In the range 25-25-25 mm and 50-50-50 mm, the evaluations suggest loses of 1.89% and 0.9% respectively from the process when cubing fresh meat by band-saw. These are mapped into specific losses for goat, lamb and mutton carcasses in the respective weight ranges.

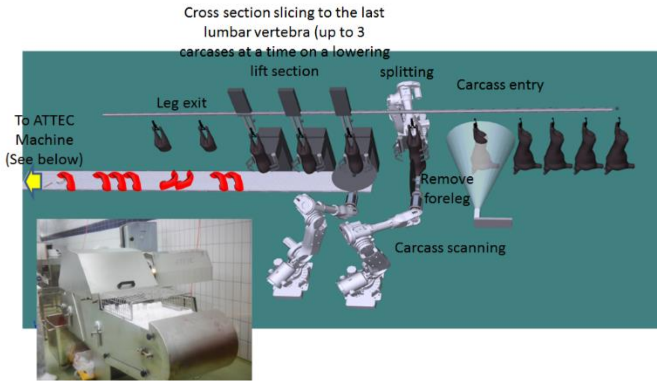
Efficiency performance has been examined using a theoretical approach, but using measured data from practical time and motion of band-saws operations and associated handling. The process of production is based on current known approaches to cubing and options for minimum labour lines of production pointing to the key developments. Qualitative approach to defining relevant quality measures have been considered and described in a systematic manner.

The overall impact of automation has been assessed and benefits quantified, including assessment of investment opportunity and returns against different production line design scenarios. It is estimated that automation can potentially contribute to a A$7 per carcass saving, relating to losses from band-saws and labour. In a 300 carcasses per hour operations labour savings approaching 15 heads is estimated combined with the elimination of operator contact with band-saws. Significant quality and presentation benefits may also be expected with the use of knife-blades for a large number of cuts.

Evaluation of the technologies such as band-saws and knife blades (or a combination) as possible technologies for the cubing process as well as automation solutions has been made. For cubing, band-saws are generally used with frozen meat leading to losses greater than 7%. Cutting unfrozen into cubes is not a current practice in the Australian industry, but use of knife blades can reduce such losses by, at least, a factor of 3.6.

Automation solutions have been evaluated and a range of currently adopted techniques are considered suitable, but require integration in a form that allows flexibility and throughput capacities that meet processor expectations. **During the course of this study, it has become apparent that a single stand alone machine for performing cubing of a whole carcass is not a practical proposition**. Furthermore, using multiple knife blades adjacent to each other poses significant complications for cutting primal pieces with hard bones such as those in legs or shanks.

The feasibility of automation to meet the requirements of carcass cutting into cubes has been revealed to be practical using a systems approach. A systems drawing of a solution with estimated costs resulting from initial tendering or consultation with specific suppliers has been reached. The approach provides a flexible solution that also supports primal cutting of whole carcasses as it is based on a robotic system already developed for ovine cutting.



The final approach to the solution recommends the separation of the foreleg, leaving the main carcass to be cubed from the neck or breast of the carcass to the top of the last lumbar vertebra, with the carcass hanging from the legs. The remaining long leg and the forelegs are not to be cubed as this will generated a high proportion of diced meat rather than bone in cubes, especially with smaller size cubes (25 mm). The forelegs and hind legs may be retailed separately as primal pieces or main joint for higher price than cubes.

EVALUATION OF CUTTING FROZEN 17th March 2016	All in Kg ±0.1
16.9	Kg carcass weight in frozen form
15.7	Kg net weight of cubes after band-saws
1.2	Kg loss in bandsaw dust that did not end in finished bags
7.6%	**loss into band-saw dust (X)**
100	carcasses per hour
100	$/carcass
5	days/wk
48	wks/year
7.5	hours per shift
1,800	total hours
180,000	carcasses/year
6%	yield saving estimate based on latest evaluation X/3.6
9,936	equivalent carcass savings in repect of yield improvement
993,631	a) AU$/year possible gain in yield
4	people saving based on observations of current practice
50,000	per person/year
200,000	b) AU$ labour saving opportunity
1,193,631	**Total potential saving (a) +(b)**
7	**AU$/carcass**

The solution for automation is based on the Scott Technology goat 6 way cutting system with adaptations to produce slices from the carcass. The slices may be cubed using the ATTEC 50-50 machine, which, despite its limitations for breaking leg and shank section, would cube rib sections from the main carcass once presented in strips as generated by the proposed robotic system.

Significant reduction in the use of band-saws, typically 6 may be eliminated, will result in better work environment and reduced insurance payments. The main benefits would be in labour saving and reduction of yield loss in the process by avoiding band-saw dust, which is equivalent to 6% of weight of carcass sections cut into cubes. The initial tendering places the cost of the proposed system at A$1.5m with potential return on investment less than 18 months.

2.0 Introduction

Current cubing operations observed involve the freezing of the meat into manageable blocks and then cutting into cubes of specific size using band-saws operated by people, with significant risk to operators making multiple passes against the moving blade. The Australian meat industry processing goat, mutton or similar products and breaking carcasses into cubes requires new automated machines to eliminate operator contact with band-saws for economic high volume production, servicing existing markets as well as opening new markets. Cost of production continues to be a major constraint.

Band-saw cutting requires multiple passes to break up the carcass into small cubes and Band-saw cutting generates bone dust, compromising quality and resulting in significant losses. Cutting a block into 25 min slabs has a loss of 1 mm in 25 (4%). Cutting slabs into 25 mm strips results in another 4% loss and when a cube is produced from the strip, there is a potential for a further 2% loss per cube. The overall result could be a minimum of 10% loss.

Cutting Caprine and Ovine carcasses into cubes is an Australia meat industry requirement. A cost effective and technologically demonstrable solution has been sought, but unavailable, except for the 70-70 machine from ATTEC Danmark AIS, used by Nortura, Norway. No other industrial solutions have been openly reported.

Establishing the understanding that will result in a validated technical requirements specification, a technical engineering automation specification has been necessary.

Accommodating for anatomical variability, machine specifications for achieving cubing in the range 25-25-25 millimetres to 50-50-50 is a requirement. The 70-70 machine by ATTEC is specified as a 2D machine, whilst the process needs to consider breakup in cubes in 3D.

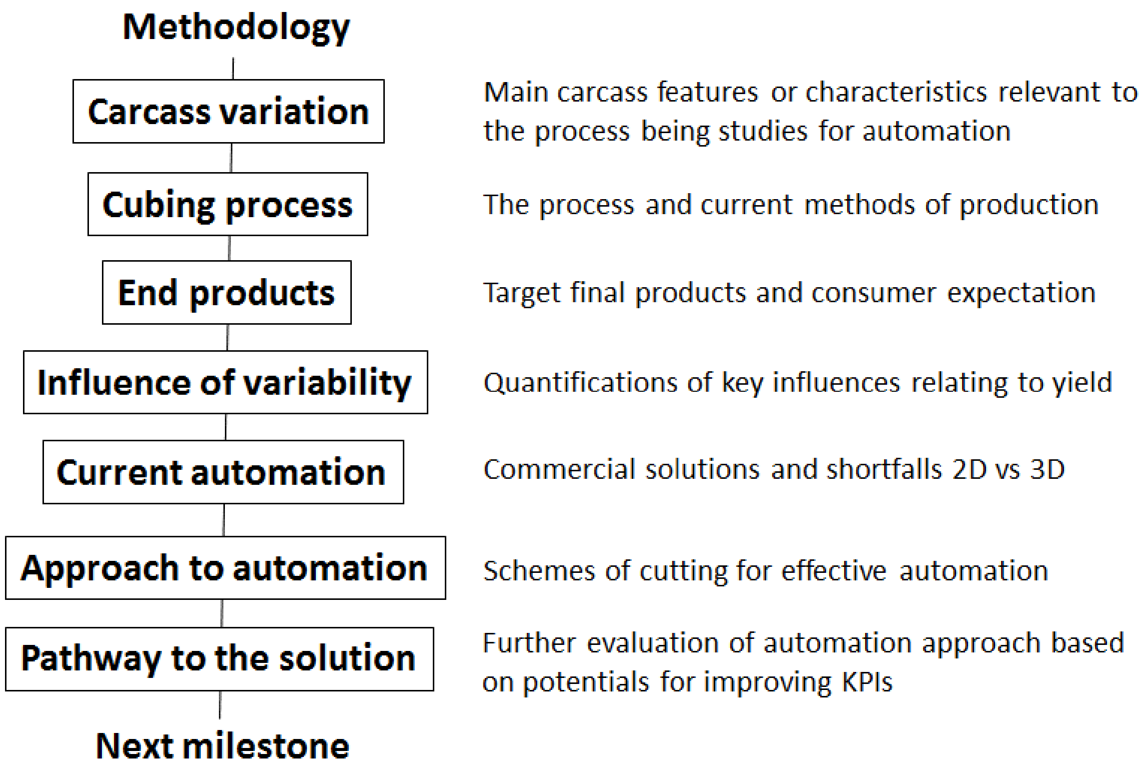
The need for the project has been established during past communication involving Australian meat processors, including McPhee, JBS, F1etchers and Thomas Foods.

3.0 Project Objectives

- Evaluation of specifications for cubing against variability and variations in carcass anatomy for different target products
- Yield modelling and calculation of benefits against different operating schemes including band-saws
- Evaluation of cutting performances including band-saw and knife blade cutting (this would be using available test rigs from machine manufacturers including ATTEC, Freund, AMC (UK), Marel, etc.)
- Machine design for manufacturing follow up or tendering.
- Reporting on finding including detailed specification of automation technology for performing cubing supported by cost estimations for implementation and benefits calculation leading to the next steps, which would develop and test the machine in production in an in Australian plant.

4.0 Methodology

The project has followed a step by step procedure to examine the requirements for ”cubing”: the industry and machine processes in use and attempted and the constraints imposed by the process and anatomical variability. Variability of the profile of carcasses and primal sections influence the optimum “cubing” given a target “cube” size, which require examination before embarking on approaches to define automation solutions. The steps and considerations in the methodology of the project as executed in 4 milestones are listed below:



The key drivers are:

- Yield performance
- Operating performance
- Quality performance
- Safety in operation including the case for automation

In order to establish performances, cutting trial have been performed to establish the supporting methodology for assessing and benchmarking the process.

Figure 1, shows the approach in the process of breakup, a fresh lamb at 17.1 Kg was cut in sections. The tests were conducted by separation the Banjos (Both foreleg) as a one piece, before band-cutting. The forelegs were then split into two longitudinally. The remaining whole carcass was then broken up in section of 100mm as shown and each section split to reveal the images in Figure 1 (right). A theoretical analysis of the cuts into 25x25x25, 25x25x50, 25x50x50 and 50x50x50 has been made to calculate KPI related figures. For safety reasons, the staff operating the band-saw during trials did not wish to make cuts of smaller dimensions than what is presented in Figure1.

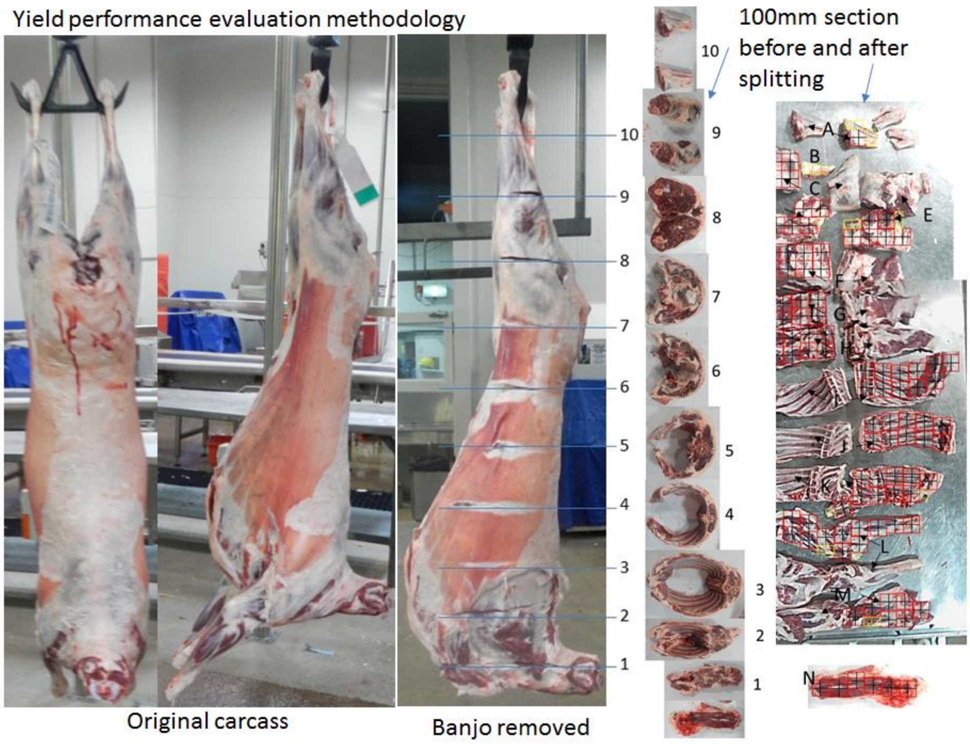


Figure 1: Methodology to assess yield performance.

Note that the analysis that follow and in the remainder of this report uses the data from the band-saw process focusing on 25x25x50mm cubing. However, calculations are presented for other piece sizes. Support for trials from Mr. Dean McKenna and colleagues at Midfield Meat, Australia, is gratefully acknowledged.

The evaluation has focused on determination of solutions as part of adopted automation that can be transformed or further developed into an integrated machine or a line to meet: throughput; yield performance, and quality expectations of the leading processors in Australia currently engaged in cubing meat.

It has been confirmed that automation opportunity can target a gain approaching than A$ 7.00 per carcass with a potential yield improvement of 6% based on observation of frozen carcass cubing. Carcass cubing is generally performed at 100 carcasses per hour average using 9 people in the process. The savings estimated is based on carcass value of AU$ 100 per carcass and a labour saving of 4. The figures are based on conservative calculations.

Knife cutting for significant portion of cuts will result in better quality and automation can bring consistency and performance in delivering to specification, resulting in greater savings than what is estimated. Increasing market share and selling products at higher value.

5.0 Project Outcomes

The following sections describe the work performed under the main 4 milestones of the project leading to the presentation of a systems solution that would provide the automation capability for the Australian meat industry for cubing. It is important to emphasise that a single machine solution for performing the task from the whole carcass has not been considered feasible.

5.1 Overview of products and dependency on carcass variation

Figure 2 shows typical cube pieces of meat from a primal sections of a carcasses. The pieces have been cut by band-saw and knife-blade. Surprisingly, it is noticeable that the cut surfaces are almost fee of bone bust. In the case of frozen products such is not the case. Although bone dust does not pose major issues in the case of frozen, its presence can compromise pack presentation if it were to spread over retail packaging material or bags.

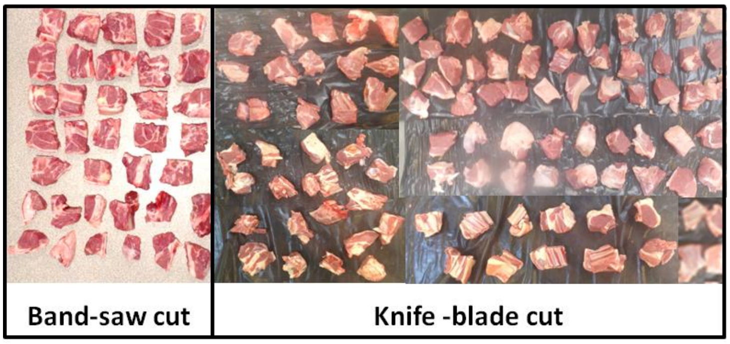


Figure 2: Typical "cube" pieces cut by band-saw and knife blade.

The key consideration for the project is how many pieces of a given cube size could be extracted from a carcass efficiently, with minimum under size pieces (unsuitable to be sold in the mix of cube cut pieces), and with minimum losses in the cutting process (by band-saw or knife blade).

5.1.1 Carcasses variation

Figure 3 shows images of typical carcass profiles in the cases of Goat, Lamb and Mutton.

Figure 3: Photos of carcasses in the range 8Kg (smallest goat) to 50Kg (large mutton).

It is important to highlight that, in the context of cubing, carcass profile influences the overall size of pieces that may be extracted as a cube. It is generally understood that the term cube refers to a piece that is of approximate shape, as a natural piece of meat conforming to an overall size. A 50-50 piece could be acceptable as piece that is 43 mm in length, 55 mm in width and 20 mm in thickness. No real specifications, except customer specifications as "a guide" are used. Clearly, when cubing frozen products more consistency is expected, however this also is a function of the primal piece shape and overall dimensions as well as the effectiveness of compact freezing groups of primal cuts into uniform blocks. In the case of fresh, the 70-70 machine as used in Norway, cuts pieces that could be 100 mm deep.

5.1.2 "Cube" size and geometric fit into carcass profile

Figure 4 shows the mapping of 25x25x25mm cubes onto a typical carcass (small ovine carcass approximately 1,200 mm in length and 16Kg in weight). It should be noted that the dimensional specification is an approximation as meat pieces are not uniform.

The most important requirement in the cubing process is the extraction of the highest number of cubes, conforming to size and customer quality expectations, at minimum loss due to cutting process. and lowest reject quantity of non-conforming pieces.

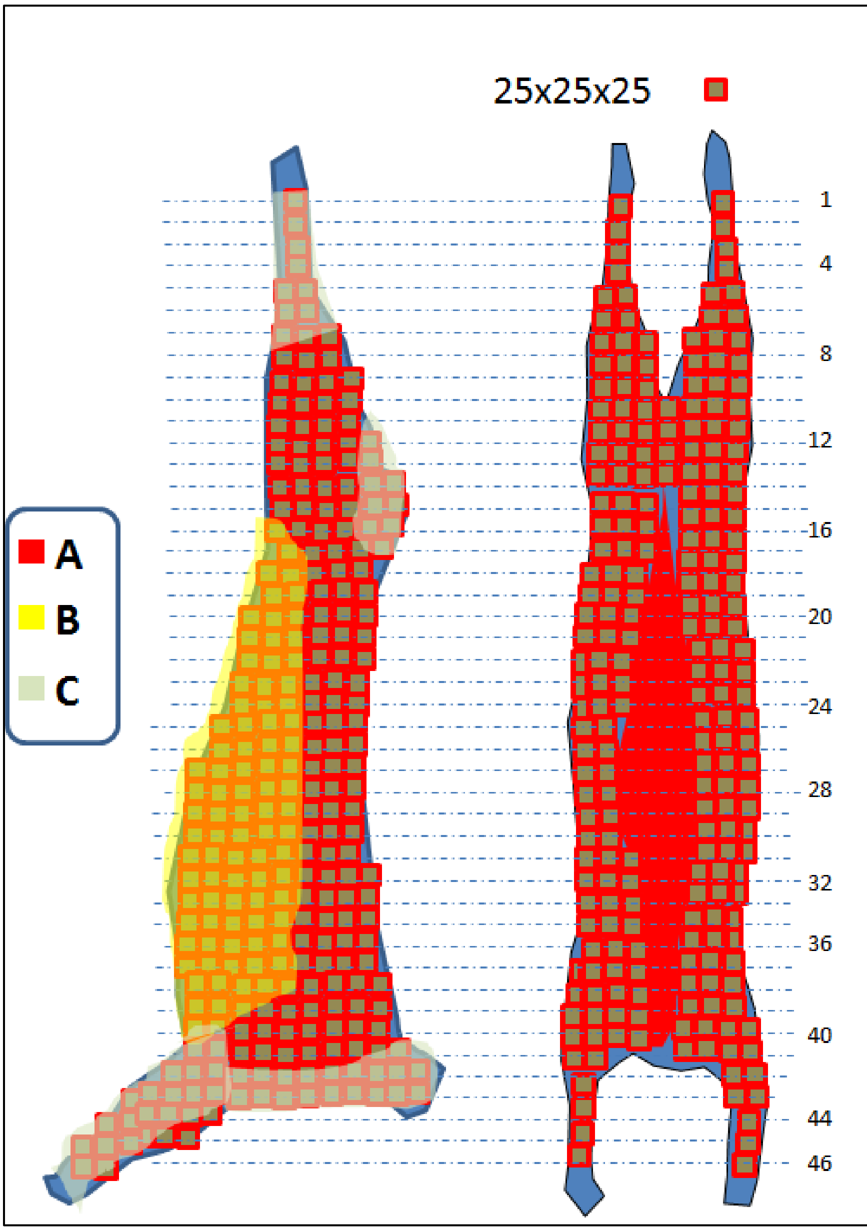
A complication in the process of 2D cubing fresh meat carcasses is that the cube dimensions, such specified (e.g. 50-50), leave ambiguity in the thickness of the piece being unspecified and thus a cut may be produced that is more 50mm thick. This may be as high as 100 mm from the shoulder regions of the carcass.

3D definition of the cube has other complications as the carcass has regions that are not deep enough (Figure 4 marking B) for the thickness to produce the cube to the full dimension specified. The chest and belly meat are generally too thin for full cube pieces of say 50X50 by 50 mm deep, as the thickness of the carcass section, especially in smaller, thinner lambs is less than 25 mm.

The thicker, meatier sections (Figure 4 marking A) provide for 3D cubes of various dimensions and the complication here is how many whole pieces can be extracted. In other words, how many exact cuboid pieces of say 50x50x50mm can one extract from a given carcass. The leg and shoulder regions are generally thick enough for a wide range of cubes of a given to be extracted from the carcass. There still remains the complication that several cut pieces close to the boundaries of the carcass surface may not conform to exact size. This then becomes a matter for quality specification and sorting if pieces, not meeting dimensional specifications, are to be separated.

It is also important to note that some regions may be bonier than others and a cube may end up being just bone (Figure 4 marking C). This poses challenges for packaging as sorting as well as grouping may be require, especially for retail, where pieces of different meat and bone composition (and potentially also fat) may need to be mixed in appropriate numbers to balance the distribution between meaty, bony or fatty cube pieces.

It is estimated that a 16 Kg carcass would generates 711 cubes of 25x25x25 mm based on cube size and cube weight evaluation that have been performed using a band-saw.



AW			
LW	15	Kg	
OIs	0.8	Kg	
TCW	14.2	Kg	
Ls	1.89%		
CW	20	g	
	no of cubes		
Tot	711		
1	4		
2	4		
3	4		
4	4		
5	4		
6	4		
7	14		
8	14		
9	18		
10	18		
11	24		
12	24		
13	24		
14	24		
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31	16		
32	19		
33	19		
34	19		
35	19		
36	19		
37	28		
38	28		
39	28		
40	28		
41	32		
42	32		
43	12		
44	12		
45	6		
46	4		

Figure 4: 25x25x25 cube mapping giving 711 pieces as a theoretical estimate.
A-meaty cubes B-thin bony cubes (15-25mm thick) C-bony cubes.

It is important to note that quality specifications could eliminate a portion of the cubes as non-conforming. If 50mm cubes were to be produced, almost all cubes from the carcass marked B in Figure 4 would be non-conforming. However, a 50x50 by 20mm to 30mm thick, would increase the number of pieces from the carcass in marked sections A and C, making the pieces from the belly and rib cage to conform at much higher "cube" numbers.

5.1.3 50 x 50 or 25x25 – optimum size "cube"

The evaluations of the process and the broad overview considerations of the target end meals for which Caprine and Ovine meat as cubed pieces may be used for, reveals useful indications. Targeting a product size of 50x50 by 25 mm or 25x25 by 50 mm size of cut giving meat piece for a verity meal, may be considered optimum.

Figure 5: Meat pieces targeting meals.

Figure 5 elaborates on this by showing the progression of cutting to a finished meal. Note that cutting 25mm cuboid pieces can result in too smaller pieces of meat, which, in the case of frozen, appearing in a final meal. Also, if cutting is to be performed on a band-saws, the process poses considerable risk as an operator using the band-saw needs to place fingers in a closer proximity to the saw blade when cutting 25 mm pieces. This is less so when cutting 50 mm pieces.

Automating the process would eliminate the risks to the operator; however, the assessment of typical meals suggests that bone in pieces of 25mm cube would not be appropriate for the type of dishes utilizing high volumes of such meat.

Meat pieces are typically in the size envelope of 50x50 by 25mm, but smaller pieces would naturally emerge in the cutting process given the profile of carcasses. As may be seen in photo of Figure 5, smaller pieces are also used, as may be seen in the saucepan to the right of Figure 5. Smaller pieces in a 50x50 by 25mm thick production process poses less complications for quality sorting in so far as smaller pieces would be nominally half the size and considered reasonable and acceptable in a final meal.

5.2 Alternative "cube" cutting schemes and influence of carcass variability

The process of cubing as currently performed generally involves:

- the breakup of a whole carcass into manageable primal pieces,
- packing compactly the resulting meat into boxes or a holding tray as blocks of fresh meat, with minimum air gaps between the primal pieces,

- freezing the meat, typically using plate freezers,
- retrieving and unpacking blocks and cutting on a band-saw,
- bulk or retail packing cut "cubes".

The alternative is breaking up the fresh primal cuts into smaller pieces in a manner that generates the resulting cubes.

Around the world, meat cubes from Caprine and Ovine carcasses are sold fresh and frozen. On the whole, Australia supplies such products frozen and hence there is an advantage in 'pre-freezing' before "cubing". An important consideration would be the evaluation of fresh vs frozen and options for automation in respect of both approaches towards the market.

The following sections elaborate on the alternatives and the influences of carcass variability.

5.2.1 Pre-freezing before "Cubing"

Figure 6 presents the process by which carcasses may be cut into manageable pieces and then cut into cubes after freezing.

Figure 6: Overall process – cubing from frozen blocks.

The important factors are:

- Structured cutting generating groups of cut pieces, which can be assembled in a most compact form to give the best cubing result with minimum undersize pieces.
- Optimisation of yield, which would require the placement of primal cut positions relative to each other in manner that maximizes the generation of whole cubes to specified dimensions. As an instance for 50 mm cubes the cut positions would be best arranged for multiples 50 mm cubes, from an assembled set of primal pieces when together as a compact group, taking into account the subsequent cutting lines and allowing for changes in dimension during the process of compression (in plate freezers) and the freezing itself.

The anatomical variability: shape, size and cutting possibilities, as related to positioning of primal cut lines, in a manner that give the highest number of conforming cubes requires significant judgment. Furthermore, a conforming cube should meet the specification of the cube size to the expected tolerances, but this in itself is not clearly specified, if indeed achievable. It is observed that there are no specific guidelines of specification for cubing and that quality standards or benchmarks are yet to be defined. Clearly, with loose specifications cubes may be produces to a wider specification of tolerance, providing less constraint and greater opportunity for optimising cube yields. However, if the end product tolerances were to be specified in a restrictive manner, a significant portion of cubes, not meeting dimensional or weight specifications, would be considered non-conforming, compromising the KPI in yield.

5.2.2 "Cubing" fresh

The process by which unfrozen meat may be cubed from carcass to the end product requires the breakup of the whole carcass into manageable pieces if the task is to be performed on band-saws.

The influences of carcass variability still remain, unless the tolerances in the cubing process are broadly accepting of size variations that do not pose severe losses where non-conforming pieces are to be separated from saleable cubes. An overview observation of the products used in meals indicates that the market is open to variation of piece sizes. Therefore, the impact of yield losses due to the use of cutting or cubing mechanisms (band-saw or knife blades) become more significant considerations. Two specific studies have been conducted to quantify loss factors compare cutting fresh and frozen meat and influence of carcass variation.

The results of the first study are summarized in Figure 7, which provides the results of a trial cubing 50-50-50 mm pieces using an ATTEC knife blade. A whole carcass was separated into manageable pieces using the ATTEC vertical cutter and then the ATTEC Whole Barrel Machine and the shoulder machine. The leg primal and other resulting pieces where cut into cubes using a standard manual circular cutter at ATTEC.

The original weight of the carcass (prior to removal of fat and kidney and other surface tissues) is recorded and the remaining weight estimated as "cubing weight", 21.044 Kg. This is the weight of the carcass from which cubes are expected without further losses, except those attributed to the use of the knife or cutting blades in the total process from whole carcass to end cubes of near 50 mm cubes. All the resulting cubes weighed 20.717 Kg. A loss of 327g attributable to circular blade cutting.

The overall process in the cubing trial generated over 98% of the meat in cubes of different sizes capable of sorting and packing with in the overall range of 25mm to 50mm cubes. This is significant as the cubes may be sorted into categories and sold against different specifications.

The estimated loss is calculated at 1.55% of carcass weight after trimming ready for cubing. 176 cubes were generated in the weight range 37g (a small cut 25mm cube from the rib section-see Figure 6 bottom left) to 153g (a 50mm cube from the rack). It must be highlighted that in a normal meal this piece would be considered too large and hence the proposed approach for a 50-50-25 scheme for cutting.

The second trial has been conducted in two parts.

Part one of the trial has examined how the cubing of a shoulder primal into 50-50-25 pieces. Figure 8 shows the results of this trial. Photo A is the original shoulder piece 1.59 Kg and B is the same after cutting in 25mm thick sections on a band-saw of 1mm in effective cutting width. C is shows the cutting lines for 50mm square cuts intended and D shows the position of the cuts if 25mm cubes were to be cut. 25 mm cuts were not done as the band-saw operator considered it unsafe to perform the cuts, beyond the ones actually performed resulting in the cuts shown in Photo E.

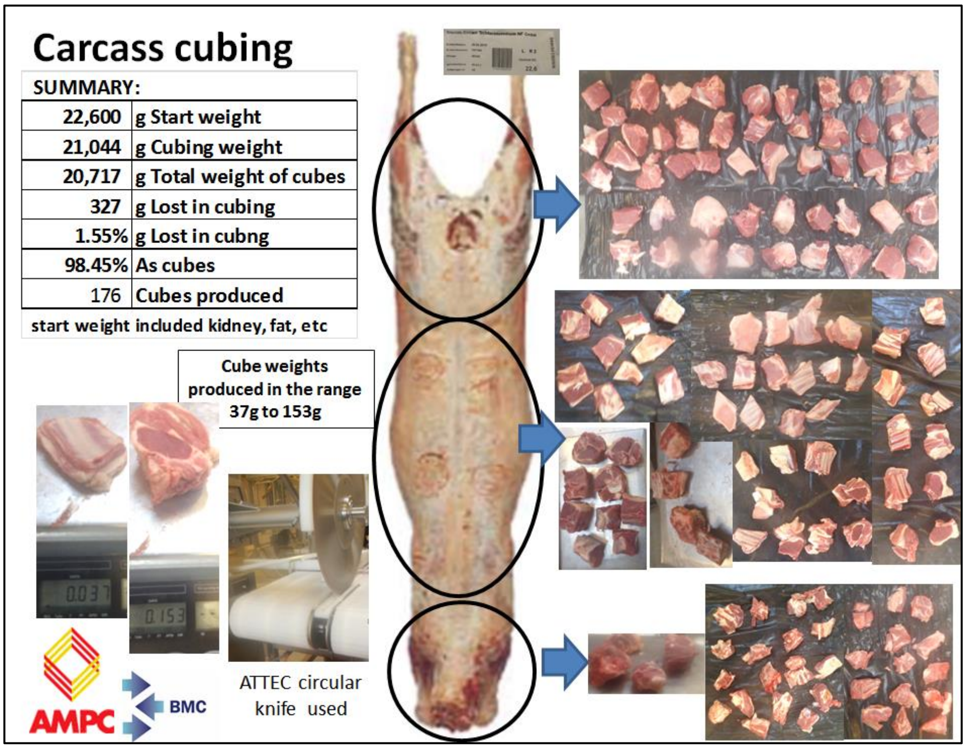


Figure 7: Cubing lamb using knife blades on various ATTEC equipment.

The cut pieces in photo E, Figure 8, are labelled 1, 2 and 3 corresponding to D1, D2 and D3 respectively, showing the additional cuts that could have been made to produce 25mm cubes.

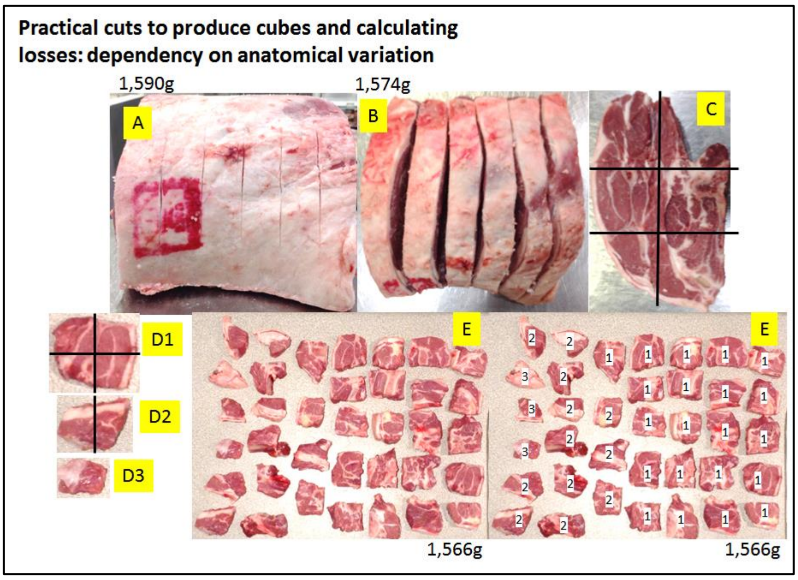


Figure 8: 50-50-25 pieces from a shoulder sub-primal cut on band-saw.

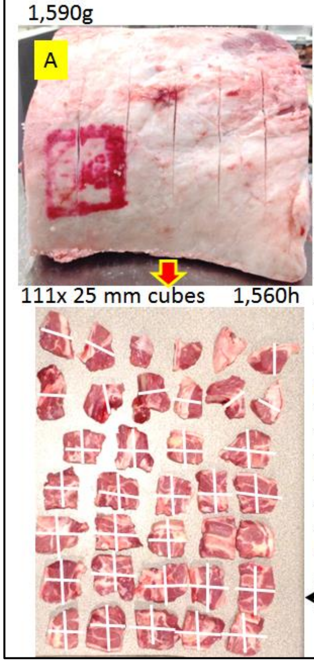
From the weight measurements and counts as presented in Figure 8, the following results may be noted (see Figure 8).

- 21 50x50 by 25 mm pieces were generated and if 50 mm cubes were to have been produced, then the total number of cubes would be 10 whole pieces of 50x50x50 (half the number of piece labelled D1 in Figure 8), with many smaller pieces that would not conform.
- The estimated loss due to the bad-saw (as in Figure 10) would be 0.9% based on the resulting cuts of Figure 8 for 50mm cubes.
- The number of pieces that would have been close to 25 mm cubes would have been 111 (see Figure 9, calculations for D1, D2 and D3) from which that 70 cubes per Kg would have been possible with an estimated band-saw loss of 1.89%.
- Based on the evaluations the losses and cubing performances in respect of carcass variation has be derived as in Figure 11, accounting for different carcass weights quantifying the relationship between carcass variation and losses, which is considered to be the overriding influence in the process.

It may be observed that the percentage losses from the knife blade trial at ATTEC is comparable with the losses estimated in the band-saw trial. This is important as it points to the possibility of combining saw and knife blade cutting in the automation options to be considered, without concerns over losses attributable to saws when processing fresh meat. Indeed, a concern identified with knife blades is bone shattering when cutting thick bones such as the leg or shank bones, which may be overcome by using a saw edged, but thin circular blades.

Yield loss calculation on fresh 25mm cubing process using a band-saw

1,590g

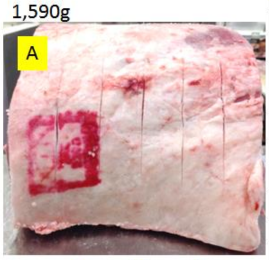


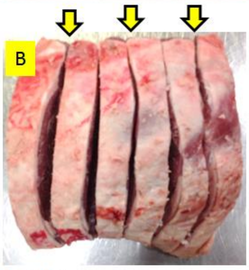
Calculation of loss % on fresh meat				
A	1,590	g Original weight of the shouder chop primal		
B	5	cuts performed		
C	6	shoulder chops produced		
D1	21	4	84	50x50 by 25 requiring 2 more cuts for 25 mm cube
D2	12	2	24	50x25 by 25 requiring 1 cut for 25mm cube
D3	3	1	3	25 mm cube
E			**111**	**Total 25mm cubes from shoulder chop primal**
wgt estimation of			**14.3**	**gs per cube**
		or	**70**	**number of 25 mm cubes per Kg**
B	1,574	g after chop cuts		
	16	g loss after chop cuts		
	0.2%	loss on the cuts performed per cut		
E	1,566			
Losses	**24.0**	g	Overall loss actual on bandsaw loss measured	
	57	g Estimated weight of 50x50x25 cube D1 droup		
	1,203	g Estimated total weight of all 50x50x25 cube D1 Group		
D1 loss	**4.9**	g loss after cutting 50x50x25 pieces into 25mm cubes		
	28.6	g Estimated weight of 50x25x25 cube D2 droup		
	344	g Estimated total weight of all 50x50x25 cube D2 Group		
D2 loss	**0.7**	g loss after cutting 50x50x25 pieces into 25mm cubes		
	30	**g Total overall actual and estimated losses for 25mm cubes**		
←	**1.86%**	**percentage loss**		

Figure 9: 25mm cubes per Kg of meat and estimated band-saw losses.

Yield loss estimation on fresh 50mm cubing process using a band-saw

1,590g





1,574g

Calculation of loss % on fresh meat		50mm cube estimation
A	1,590	g Original weight of the shouder chop primal
B	1,574	g after 5 chop cuts 25 mm thick
X1	16	g loss on 5 cuts
X2	5	cuts
X3	3.2	loss per cut
X4	2	cuts that would have produced 50 mm chops
X5	6.4	loss on 2 chop cuts 50 mm thick
C	1566	Weight of pieces after 50 mm cutting of chops
X6	24	g loss on cuts giving 50 mm cuts
X7	8	g losses after adjustment for 3 chop cuts at 25 mm
X8	14	g losses if the cuts were for 50mm cubes
X9	0.9%	estimated loss on 50 mm cube cuts

1,566g

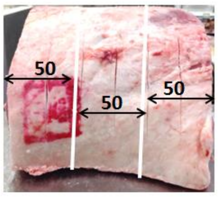
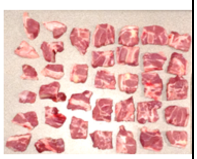


Figure 10: 50 mm cubes- estimation of loss based on results of Figures 8 and 9.

The data presented in Figure 11 provides the estimates of loss per carcass and carcass type based on the percentage losses calculated in the trial results of Figures 9 and 10. The derived estimates for lamb, goat and mutton of variable carcass sizes in the range shown (see Figure 11 top left) for 25mm and 50mm cubes are given. Note that the tables in the lower part of Figure 11 account for the typical population of carcasses in the weight range that may be seen for each carcass type.

Summary of loss estimations against carcass types and variation

Evaluation of carcass variation, cube size and losses					
Band-saw		Carcass Kg		Kg losses estimated	
		wgt range		25 mm	50 mm
1	Goat	8	24	0.30	0.15
2	Mutton	26	50	0.60	0.29
3	Lamb	12	36	0.43	0.21



Carcass variation			KG	KG
	Goat-assessment		Losses	Losses
		Cube size	50 mm	25 mm
	Kg	Population	0.91%	1.86%
	8	0.5%	0.0004	0.0007
	10	7.0%	0.0063	0.0130
	12	10.0%	0.0109	0.0223
	14	17.0%	0.0216	0.0443
	16	30.0%	0.0435	0.0893
	18	15.0%	0.0245	0.0502
	20	10.0%	0.0181	0.0372
	22	7.0%	0.0139	0.0287
	24	3.5%	0.0076	0.0156
Loss/carc		100.0%	0.15	0.30

Carcass variation			KG	KG
	Lamb-assessment		Losses	Losses
		Cube size	50 mm	25 mm
	Kg	Population	0.91%	1.86%
	12	0.5%	0.0005	0.0011
	14	5.0%	0.0063	0.0130
	16	8.0%	0.0116	0.0238
	18	15.0%	0.0245	0.0502
	20	25.0%	0.0453	0.0931
	22	20.0%	0.0398	0.0819
	24	15.0%	0.0326	0.0670
	26	7.5%	0.0177	0.0363
	28	4.0%	0.0101	0.0208
	30	3.0%	0.0082	0.0167
	32	2.0%	0.0058	0.0119
	34	1.0%	0.0031	0.0063
	36	0.5%	0.0016	0.0033
Loss/carc		100.0%	0.21	0.43

Carcass variation			KG	KG
	Mutton-assessment		Losses	Losses
		Cube size	50 mm	25 mm
	Kg	Population	0.91%	1.86%
	26	1.0%	0.0024	0.0048
	28	5.0%	0.0127	0.0261
	30	18.0%	0.0489	0.1005
	32	20.0%	0.0580	0.1191
	34	20.0%	0.0616	0.1266
	36	15.0%	0.0489	0.1005
	38	8.0%	0.0275	0.0566
	40	6.0%	0.0217	0.0447
	42	3.0%	0.0114	0.0234
	44	2.0%	0.0080	0.0164
	46	1.5%	0.0062	0.0128
	48	0.3%	0.0013	0.0027
	50	0.2%	0.0009	0.0019
Loss/carc		100.0%	0.29	0.60

Figure 11: Estimation of losses for goat, mutton and lamb when producing 50 or 25 mm cubes.

On average, cubing carcasses using a band-saw could result in the loss of 150g in the case of 50mm cubes from a goat carcass and 600g in the case of mutton for 25mm cubes. The carcass variation considers the population and the tables (Figure 11) correspond the variation to the expected losses if cubing were to be done on band-saws. Whole carcasses will need to be cubed in structured KPI trials, one of each type, which would complement the estimated data from the trials conducted under this study.

The second part of the aforementioned trial has been the cutting of fresh and frozen meat using the same band-saw which generated the meat piece in Figure 8. In this trial 3 cuts have been made on two shank piece of similar weight, but one frozen and the other fresh. The results are shown in Figure 12.

The trial was aimed to quantify losses due to band-saw cutting fresh and frozen meat in terms of grams lost per square centimetre.

In addition to the measurement of weights before and after cutting, the effective area of the cuts performed on each shank has needs to be determined for each shank. Figure 12 gives the results.

Loss estimation: fresh vs frozen on band-saws wrt cubing

Frozen 3 2 1

Fresh 3 2 1

Calculation of loss per square cm from a 1 mm band-saw				
Comparison: ratio of frozen to fresh wgt losses				3.6
Frozen				Ftprt
Weights:		gs ± 2	Slice	sq. cm
	At start	318	1	29.39
	After 3 cuts	310	2	23.11
	Loss	8	3	17.17
	gs/sq.cm	0.1148	Tot	69.67
Fresh				Ftprt
Weights:		gs ± 2	Slice	sq. cm
	At start	338	1	28.51
	After 3 cuts	336	2	22.00
	Loss	2	3	12.58
	gs/sq.cm	0.0317	Tot	63.08
Note fresh cut after cutting- scale flickering between 336 and 338				

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Figure 12: Trial with band-saw cutting fresh and frozen shank for estimation of loss/unit area.

The calculation of cross section area for the cuts 1, 2 and 3 in both cases of frozen and fresh meat as in Figure 12 is presented in Appendix 8.1. The grams lost making three cuts and the calculation of loss per square centimetre from band-saw reveals that cutting of frozen meat losses over 3 times more than the same when cutting fresh meat: the ratio of grams per square cm 0.1148, in the case of frozen, over 0.03137, for fresh (3.6 times). It is thus envisaged that automation for producing cubes from unfrozen meat provides a greater yield return.

An important consideration will be the cutting of carcasses into primal or sub-prima pieces to avoid non-conforming pieces that could results when subsequent breakup into cubes is to follow. With automation, the option can be considered to cut whole carcasses directly into end cubes, without the need for primal cutting as an intermediate step.

Figure 13, presents the concept for alternative approach to cubing as a new scheme of cutting fresh or frozen carcasses. The scheme requires further consideration and trial among others that may be revealed during the period of the project. Automation approaches against the cutting schemes will follow the KPI evaluation selecting the most appropriate avenue, which may be based on the use of knife blades as well as saw cutting as options.

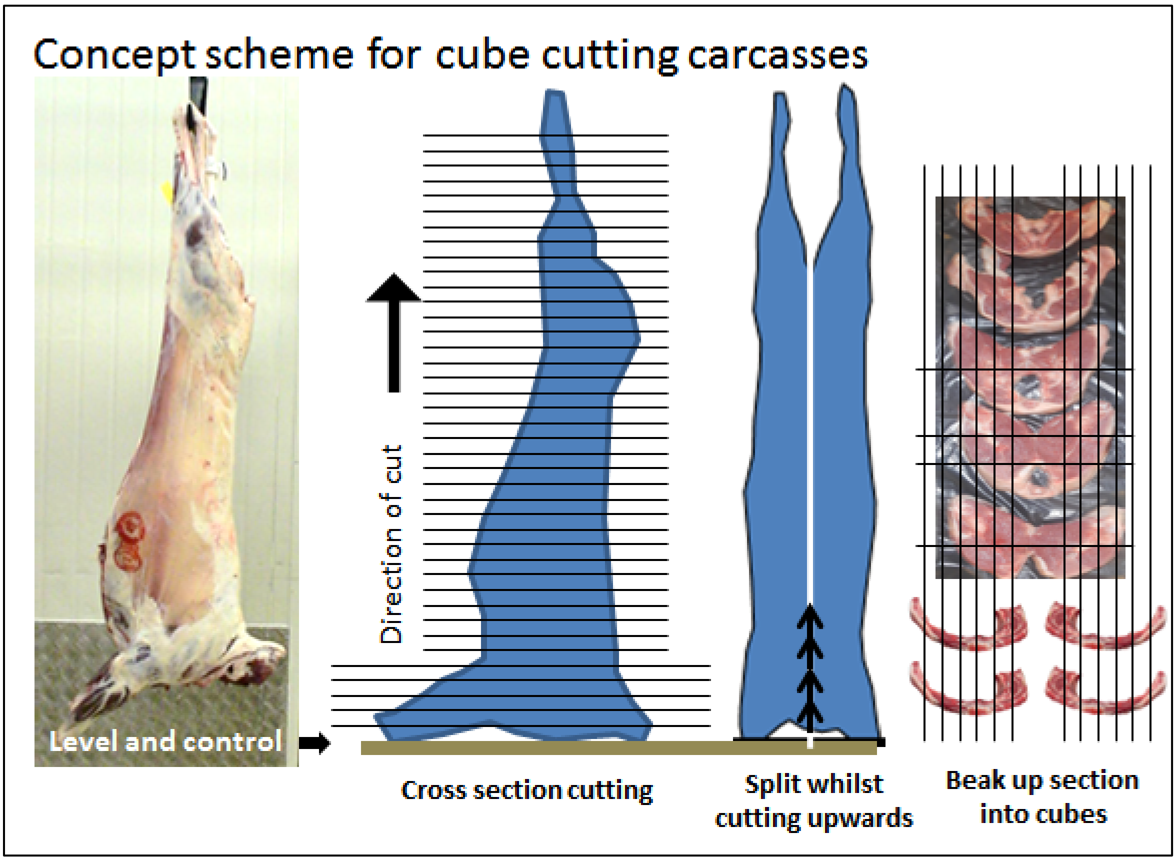


Figure 13: Cube cutting a whole carcass – conceptual scheme.

5.2.3 Automation approaches

The ATTEC 70-70 machine is the only commercial automation solution available commercially to assist with the process of cubing. Figure 14 shows the machine. The machine has been in use in

Norway in the production of Furikol. The machine is operated by loading a primal piece, previously separated from a carcass.

The placement of the primal piece on the "cutting bed" is critical. The cutting bed has slots cut out at a pitch of 70 mm in two perpendicular directions. Once the piece is loaded, the grooved carrier (in white, Figure 15) travels into the machine from the loading point automatically, which is initiated by the operator loading the "cutting bed" and activating the process. Several parallel located cutting blades (knife edge, rather than having a saw tip) at 70mm pitch are in rotation, cutting the bone in meat section as it travels into the machine.

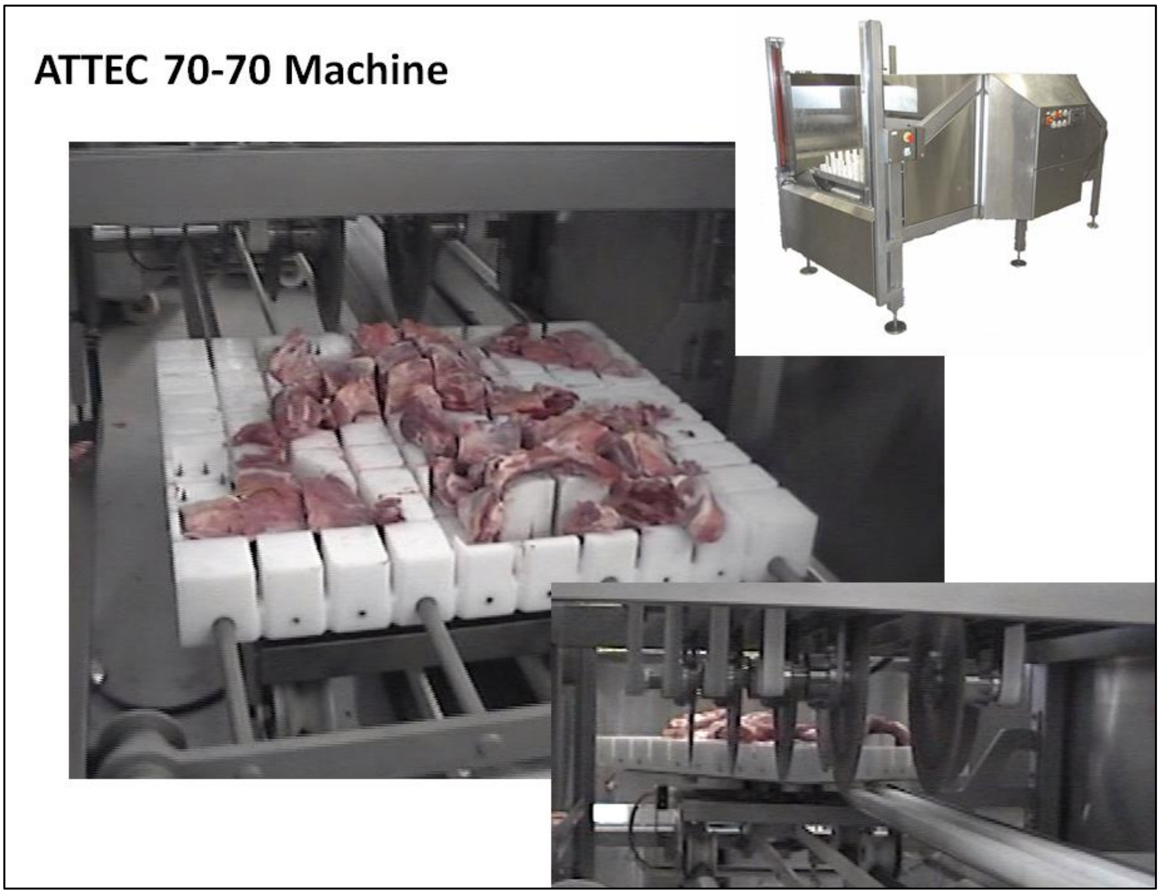


Figure 14: ATTEC 70-70 machine for cutting fresh meat in 2D as used in Norway.

After the first pass the "cutting bed" rotates by 90 degrees in the horizontal plane and travels back making a second cut into the strips of meat cut during the first pass. Once the "cutting bed" is back at the loading points, it tilts to release the pieces cut by the machine, leaving the "cutting bed" free of cubes for another piece to be loaded for cubing. See Figure 15.

The consistency of the machine to produce the desired cube sizes would rely on the correct cutting of the original primal pieces; the anatomical shape and size of the piece itself and the positioning of the piece by the operator.

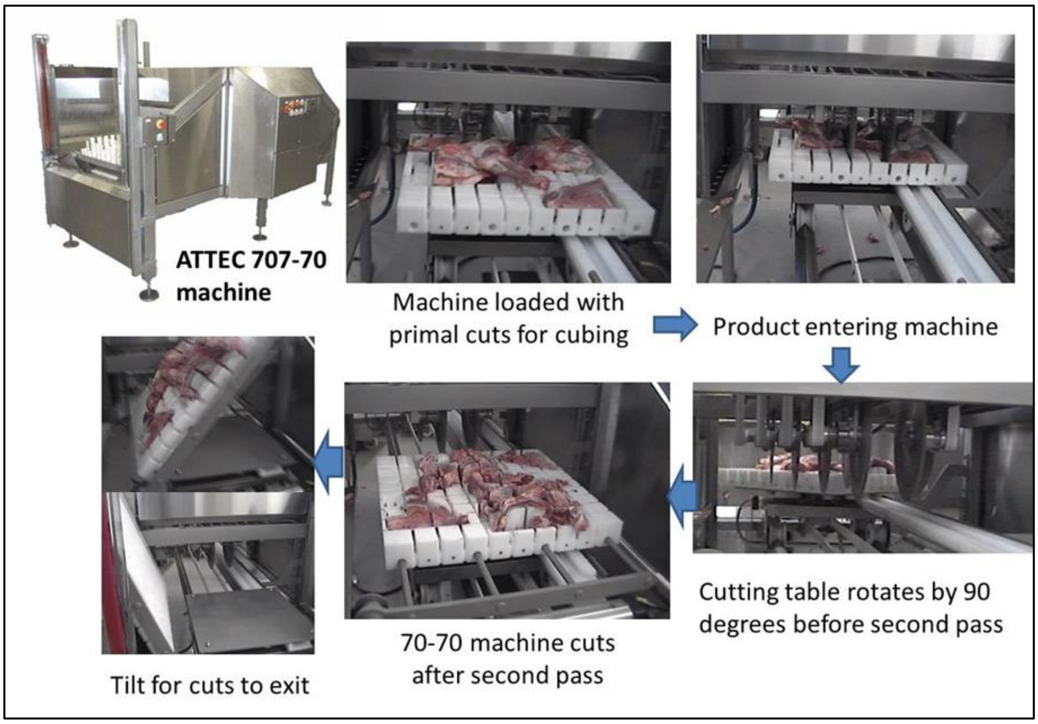


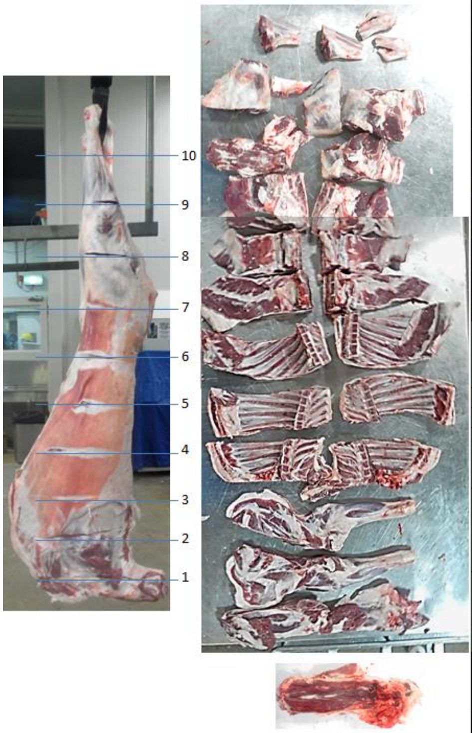
Figure 15: Sequence of the ATTEC 70-70 machine.

5.3 Yield performance

Figure 16 provides estimation of yield loss in the case for Goat, Mutton and Lamb based on loss calculation derived from trials results and analytical extraction of weight loss when performing different size cubes. See Figure 16 bottom right: The table shows 31.6g loss per cut in the 100mm sections produced by Band-saw. Using earlier results, 5.7% of the original carcass weight would be estimated lost when making 50mm cubes from fresh carcasses and 10.1% when producing 25mm cubes as a conservative calculation.

Note that in addition to band-saw losses, certain off cuts may not be used as finished pieces, such as hock tips. It is considered that such losses are the same irrespective of the scheme of cutting.

Focusing on Band-saw related losses and based on OTH, Over The Hock, prices (See Appendix), the loss in value per carcass is estimated to range from A$2.33 per carcass (low value mutton) to A$8.34 per carcass (high value goat). The average for all carcasses as an estimated figure is at A$5.34, when cutting fresh on a band-saw. Figure 17 shows analytically that cutting frozen on band-saw can result in losses that are 3.6 times higher. To this end, the opportunity to expand yield performance using knife blades and automation could be as high as A$19/carcass. Note that the estimates are considered valid as analytical calculations irrespective of cutting scheme, whether it be whole carcasses frozen or as blocks as the numbers are extracted from trials where cross sections of meat have passed over the band-saw edge and the figures are normalized against the actual surface areas that have been subjected to separation in the generation of cubes.



Calculating losses in AU$		17.1	Kg carcass wgt
Goat price/Kg	4.82	From MLA Market price OTH NSW	
Mutton price/Kg	2.40	From MLA Market price OTH NSW	
Lamb price/Kg	4.68	From MLA Market price OTH NSW	
For 17.1 Kg Carcass	25mm cubes	50 mm cubes	50x50x25mm
% loss estimated	10.1%	5.7%	7.9%
Weight lost Kg	1.73	0.97	1.35
Loss/carcass A$	25mm cubes	50 mm cubes	50x50x25mm
Goat	8.34	4.67	6.51
Mutton	4.15	2.33	3.24
Lamb	8.10	4.54	6.32
Average estimated loss/carcass (OTH prices used - all carcass types and cube sizes) AU$			5.35

Cubing yield trials October 2015			
Band-saw Cut losses primary cuts		Estimating losses against further cuts	
17.10	Kg original carcass weight	*13.00*	Kg of meat remaining
3.32	Kg Foreleg weight	50x50x50	5.7%
13.78	Kg remaining	0.90%	for 50mm cubing from M1 report
0.18	Hock weight	0.117	Kg loss etimate for 50mm cubes
13.60	Kg remaining	8	remaining cuts for 50mm cross
10	Number of cuts performed	0.253	additional lossess against expected cross section cuts
7	band-saw split cuts	0.97	Kg Total loss estimate for 50mm cubes
2	longitudenal foreleg cuts	25x25x25	10.1%
13.00	Kg measured after 10 cuts	1.89%	for 25mm cubing from M1 report
0.600	Kg losses on 10	0.246	Kg loss estimate for 25mm cubes
0.0316	Kg loss per cut	28	remaining cuts for 25mm cross
The figures represent estimated losses against caracc original carcass weight using data form Milestone 1 report and additional cutting data for band-saw break up trials at Midfield Meat		0.884	additional lossess against expected cross section cuts
		1.73	Kg Total loss estimate for 50mm cubes

Figure 16: Yield performance consideration.

Loss estimation: fresh vs frozen on band-saws wrt cubing

Calculation of loss per square cm from a 1 mm band-saw				
Comparison: ratio of frozen to fresh wgt losses				3.6
Frozen				Ftprt
Weights:		gs ± 2	Slice	sq. cm
	At start	318	1	29.39
	After 3 cuts	310	2	23.11
	Loss	8	3	17.17
	gs/sq.cm	0.1148	Tot	69.67
Fresh				Ftprt
Weights:		gs ± 2	Slice	sq. cm
	At start	338	1	28.51
	After 3 cuts	336	2	22.00
	Loss	2	3	12.58
	gs/sq.cm	0.0317	Tot	63.08
Note fresh cut after cutting- scale flickering between 336 and 338				

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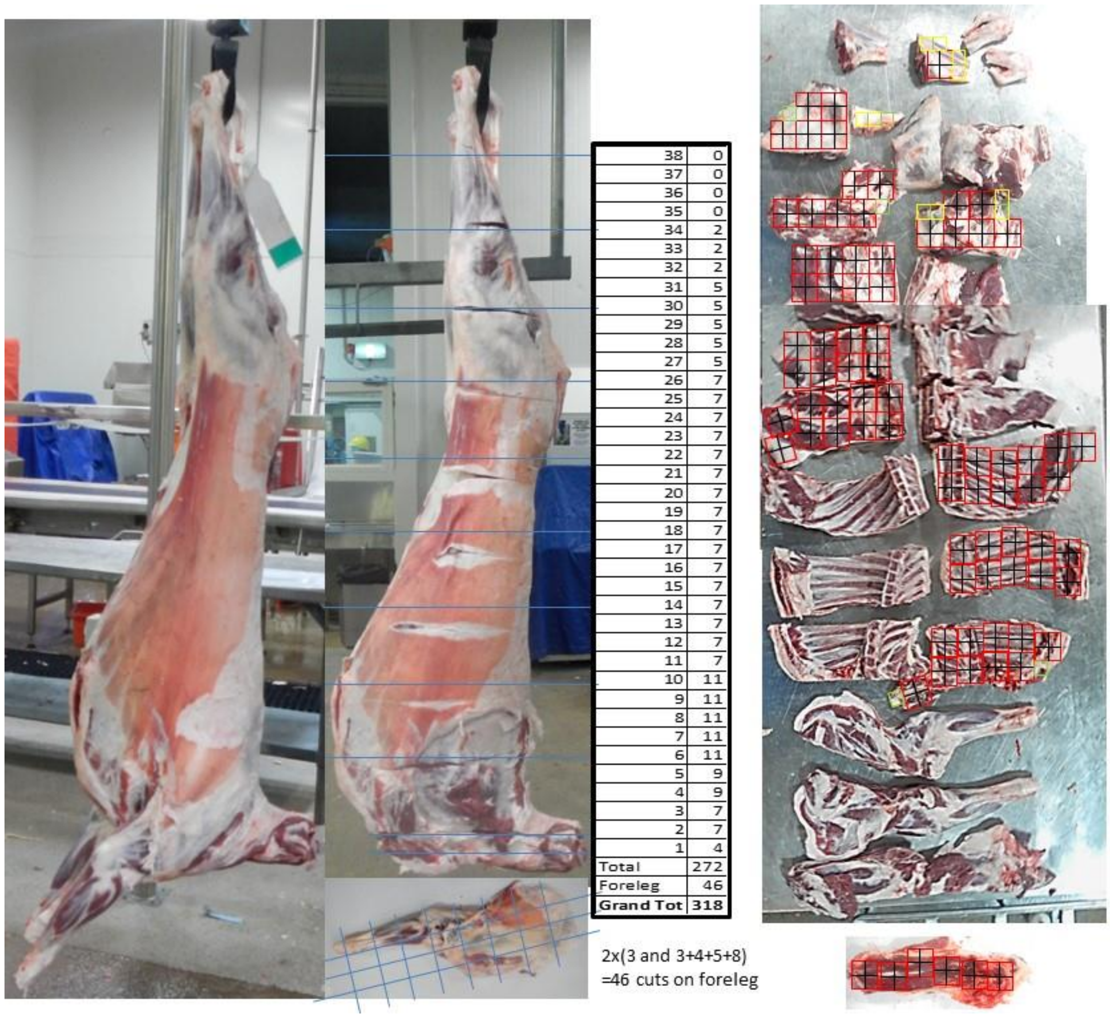
Figure 17: Loss calculation Fresh vs Frozen.

Automation opportunity can target a gain of A$10 per carcass with a combination of saw blades and knife blades. The main reason for combining cutting tip technologies is that during trials it has been revealed that under certain circumstances, thicker bones (mainly leg bones), have a tendency to shatter, causing bone chippings. Equally, the separation of sections with such bones (leg and shoulder shanks) do not require significant number of cuts to become cubes. It is therefore considered reasonable that use of saw-edge blades (generating small degree of bone-dust) would not have a noticeable influence on the magnitude of loss, given that the value proposition is as high as estimated in this study.

5.4 Operating performance

Figure 18 presents, for a 17.1Kg carcass approximately 1050 mm in length, the cutting lines necessary to produce cubes of different sizes. Figure 5 gives the number of cubes in different sizes as an estimation, rather than from actual band-saw cutting, as it has been considered unsafe by band-saw operators to actually perform cuts let than 100mm apart on a normal table band-saw.



38	0
37	0
36	0
35	0
34	2
33	2
32	2
31	5
30	5
29	5
28	5
27	5
26	7
25	7
24	7
23	7
22	7
21	7
20	7
19	7
18	7
17	7
16	7
15	7
14	7
13	7
12	7
11	7
10	11
9	11
8	11
7	11
6	11
5	9
4	9
3	7
2	7
1	4
Total	272
Foreleg	46
Grand Tot	318

Figure 18: Estimation of cubes and number of cuts for 25x25x50mm pieces (see also Figure 19).

Cube count estimation in different categories														
	C1		C2			C3				C4				
	25x25x25		25x25x50				25x50x50				50x50x50			
	C1	Other	C2	C1	Other	C3	C2	C1	Other	C4	C3	C2	C1	Other
A	24	0	10	0	0	8	0	0	0	2	0	4	0	0
B	3	0	1	1	0	0	1	1	0	0	0	1	1	0
C	80	2	40	0	2	20	0	0	2	10	0	0	0	2
D	49	0	24	1	0	12	0	1	0	6	0	0	1	0
E	80	0	40	0	0	18	4	0	0	8	2	4	0	0
F	96	0	48	0	0	24	0	0	0	8	8	0	0	0
G	80	0	40	0	0	20	0	0	0	4	12	0	0	0
H	112	0	56	0	0	24	0	0	0	4	20	0	0	0
I	96	0	48	0	0	24	0	0	0	4	16	0	0	0
J	48	0	24	0	0	12	0	0	0	2	8	0	0	0
K	115	4	56	3	4	28	0	3	4	9	10	0	3	4
L	84	4	44	4	4	38	2	4	4	26	2	0	4	4
M	68	4	34	0	4	16	2	0	4	0	16	2	0	4
N	48	1	24	0	1	12	0	0	1	6	0	0	0	1
Total	983	15	489	9	15	256	9	9	15	89	94	11	9	15
	983	8	489	5	5	256	5	2	3	89	47	3	1	2
		991			499				266					141
		99%			98%				96%					63%

Figure 19: Cube count estimation from a 17.1 Kg carcass based on initial band-saw cutting (see also Figure 18).

Figure 19 places the cubes in four category of size:

C1: 25x25x25 mm overall size,

C2: 25x25x50 mm overall size and focus for the remainder of project,

C3: 25x50x50 mm overall size,

C4: 50x50x50 mm overall size,

Other: which are pieces smaller than those in C1 and potentially non-conforming.

The number of cubes in each section headed C1 to C4 includes cube sizes in the other Categories as smaller pieces are unavoidable given the carcass variability. It is noticeable that when producing 50 mm cubes, only 63% of the pieces are likely to be conforming to size. Based an initial overview of the performance and resulting outcome, it is considered most ideal to target 25x25x50mm cubes as presented earlier, also considering what may be appealing in the resulting meals using such products. See Figure 20 (pieces in the pan), repeated to avoid backtracking. The resulting meal pieces from C2 would better meet expectation than those of smaller or larger.

Figure 20: Meat pieces targeting meals – 25x25x50mm meets expectation (repeat of Figure 5).

Given such expectation, the operating process to achieve the result may be based on either on a band-saw or a frozen "cubing" process see Table 1.

TIMING		**Fresh Whole Carcass by Band-saw**			**Frozen**
1	15	Secs to remove both foreleg banjos	1	18	Cuts before packing in boxes
2	3	Secs to move carcass to Band-saw table	2	2	Secs per cut
3	1.5	Secs to remove hook	3	36	Secs to break up carcass
4	318	No of cuts to be performed on carcass	4	30	Secs to compact pack pieces and Freeze
5	2	Secs per cut	5	20	Secs to unwrap clock
6	636	Secs to make cuts for 25x25x50mm cubes	6	550	mm length
7	656	Total secs to produce cubes from carcasses	7	400	mm width
8	**10.93**	**Total mins/carc for 25x25x50mm pieces**	8	200	mm height
9	**300**	Rate of production - carcasses per hour	9	50	mm cube length
10	**55**	**Number of people required to do the rate**	10	3	passes to make 50 mm slabs
			11	6	sec per pass along 550 mm length
			12	**18**	Secs to produce four 550x400x50mm slabs
			13	4	slabs
			14	25	mm cross section along 550 length
			15	15	passes across each slab to produce strips
			16	60	Total passes to produce 25x50x550 mm
			17	6	sec per pass along 550 mm length
			18	**90**	Secs to produce twenty five 25x50x550 mm strips
			19	25	mm cuts on strips to make 25x25x50 mm pieces
			20	21	passes to make final pieces from strips
			21	525	Total passes to produce 25x25x50 mm pieces
			22	1.5	Secs per pass
			23	**788**	Secs to make pieces final pieces
			24	**896**	Total Secs/ boxed up carcass to make 25x25x50mm pieces on one band-saw
			25	**15**	**Total mins/carc for 25x25x50mm pieces**
			26	**300**	Rate of production - carcasses per hour
			27	**20**	**Number of people required to do the rate**

Table 1: steps and human resource requirements in frozen or fresh cubing processes.

It is estimated that 318 cutting actions would be required to break up a 17.1 Kg lamb into 25x25x50mm pieces (also see Figure 19). This would require 55 staff at 300 carcasses per hour when cutting fresh and if boxed up frozen, 20 staff, most of whom will be operating band-saws. The case for automation is clearly strong and at a first glance it seems cutting frozen could be less labour intensive, however as mentioned earlier, this would compromise yields, with losses that would be 3.6 times greater (close to A$14).

Furthermore, cutting frozen blocks hides the quality issues related to size conformity as cutting lines are hidden, until after de-frosting. This has quality implications, which may be important to end customers.

The approach to automate fresh cutting into conforming sizes, where pieces may be cut more consistently to size with the opportunity for inspection is this important and necessary to explore.

5.5 Quality performance

Size conformance is an important aspect of "cubing". Cutting fresh avoids bone dust and allows for the opportunity to achieve correct cutting lines, avoiding undersize pieces. There also the opportunity to inspect and sort the final pieces.

Figure 19 shows the percentage of undersize pieces that could be expected in each category of "cubing". In addition to size conformance, bone dust contamination may be considered important, which is generally a hidden issue when cutting frozen.

Figure 21: Bone-dust and dust free knife blade images.

As may be seen in Figure 21 bone dust contamination, especially when cutting fresh can be a concern and would influence shelf-life. Using knife blades can eliminate a significant volume of bone dust from band-saw cutting, however certain cuts especially leg bone may shatter when using knife blades. Automatic solutions, may use saw tip blades for certain cuts.

Cutting fresh would allow inspection and sorting following “cubing”, which is not a relevant option, when cubing frozen.

Use of band-saws influence the degree with which high quality may be achieved. Safety of operators is also an important issue, as has become apparent in the trials given the reaction of band-saw operators assisting the cutting trials.

5.6 Safety in operation and the case for automation

It is significant that high number of band-saws would be required to produce cubed products. Work Cover payments as well as exposure of operators already provide the case for automation. Table 2 gives the opportunity for avoiding the use of band-saws, whilst using a much lower number of people in the overall “cubing” process.

Staffing with appropriate automation	
15	Secs to remove both foreleg banjos and load M1
5	Secs to load 25mm carcass cutting machine M2
76	Strips out of the 25mm machine
0.5	per strip to load 50mm cutting machine
38	Secs to make cuts for 25x25x50mm cubes
58	Total secs of operator time to produce cubes
1.0	**Total mins/carc for 25x25x50mm pieces**
300	Rate of production - carcasses per hour
5	**Number of people required to do the rate**

Table 2: Using automation to eliminate band-saws and use fewer people.

The approach is to consider the process as a fresh operation using the steps and equipment as follows:

- Remove banjos (forelegs) from the carcass
- Feed banjo to machine M1, that cuts longitudinally the banjo into the longest 25mm strips
- Feed the rest of the carcass to a vertical cutting machine M2, that cuts the carcass in cross sections of 25mm thick and splits the cut in the spine
- Feed all strips into a final machine M3, cutting the strips into 50mm long pieces

Based on the figures, estimating equivalent of 15 staff at A$40k and A$10/carcass, the value proposition is in excess of A$6m per year for a plant processing 300 carcasses per hour.

5.7 Cutting Technologies

Cubing requires the use of a blade that is capable of cutting both meat and bone.

Band-saws are the most common used with frozen product resulting in significant losses, also posing a risk to operators. See Figure 22 for a typical arrangement.

Figure 22: Typical set up cutting cubes on a band-saw (confidential).

Frozen blocks are cut into strips and strips into cubes. Figure 23 provides estimation of losses and converts the figures, based on a trial in current production facility, into a loss value per carcass. This also confirms the estimated calculations presented earlier.

EVALUATION OF CUTTING FROZEN 17th March 2016	All in Kg ±0.1
16.9	Kg carcass weight in frozen form
15.7	Kg net weight of cubes after band-saws
1.2	Kg loss in bandsaw dust that did not end in finished bags
7.6%	**loss into band-saw dust (X)**
100	carcasses per hour
100	$/carcass
5	days/wk
48	wks/year
7.5	hours per shift
1,800	total hours
180,000	carcasses/year
6%	yield saving estimate based on latest evaluation X/3.6
9,936	equivalent carcass savings in repect of yield improvement
993,631	a) AU$/year possible gain in yield
4	people saving based on observations of current practice
50,000	per person/year
200,000	b) AU$ labour saving opportunity
1,193,631	**Total potential saving (a) +(b)**
7	**AU$/carcass**

Loss estimation: fresh vs frozen on band-saws wrt cubing

Calculation of loss per square cm from a 1 mm band-saw				
Comparison: ratio of frozen to fresh wgt losses				3.6
Frozen				Ftprt
Weights:		gs ± 2	Slice	sq. cm
	At start	318	1	29.39
	After 3 cuts	310	2	23.11
	Loss	**8**	3	17.17
	gs/sq.cm	**0.1148**	Tot	**69.67**
Fresh				Ftprt
Weights:		gs ± 2	Slice	sq. cm
	At start	338	1	28.51
	After 3 cuts	336	2	22.00
	Loss	**2**	3	12.58
	gs/sq.cm	**0.0317**	Tot	**63.08**
Note fresh cut after cutting- scale flickering between 336 and 338				

Figure 23: Estimating the potential saving with automation cubing 100 carcasses/hour.

The evaluation of cutting reveals that for a small weight carcass, over 1.2 Kg per carcass is lost in the form of band-saw bone dust and a large variation in cube size (See Figure 24).

Earlier evaluation using results from band-saw cutting of frozen and cutting fresh meat by knife-blades (see Figure 23, right), has shown that band-saw losses can be reduced by a factor of 3.6 when using knife-blades.

Figure 24: Band-saw bone dust and variability in cube size.

To follow the approach, examination of potential automation solution(s) have been focused on those that use knife blades as seen in robotic cutting systems and machines such as the 70-70 machine. Figure 25 presents images of such systems.

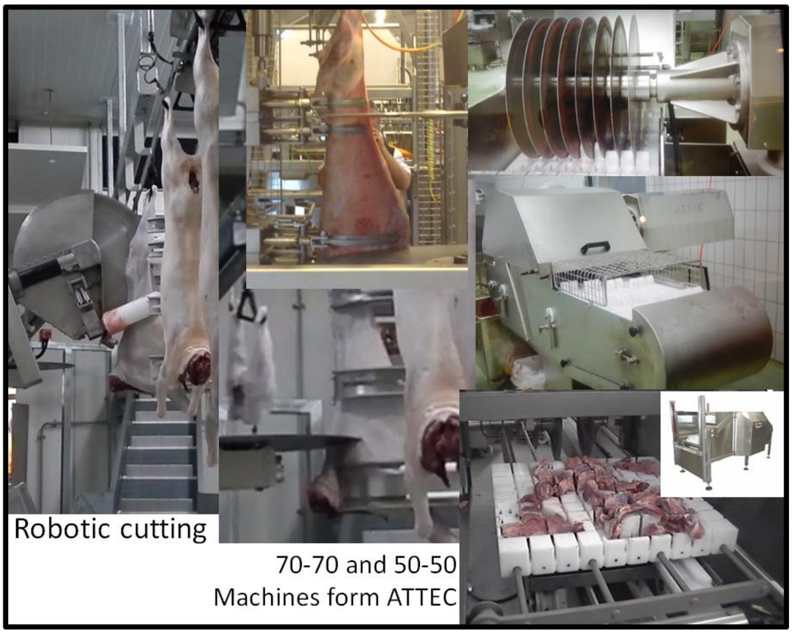


Figure 25: Evaluation of cutting-knife blades with automation including robotics and the ATTEC machines for cubing fresh meat from strips (50-50) and primal pieces (70-70).

5.8 Automation solution

New automation approaches are considered to be required to map the current and future requirements of the industry. Cutting fresh meat with knife blades requires a process that avoids cutting through thick bone such as leg or shank bone. To this end a circular saw blade may need to be included in specific parts of the process that is automated in order to achieve full automation.

The proposed scheme, as illustrated in Figure 26, is based on the separation of the shoulder leg and shank as one pieces (banjo) using a hand knife. Then the banjo pieces are to be placed on a dedicated machine for further cutting. The task of banjo separation and loading the banjo cutter may be performed by one person who would also load the leg from the carcass to produces the strips from the leg and banjo primal pieces for further cutting into cubes. Note that strips may result in too longer cubes, when going through the strip cutter, but these may be re cut on the same machine to give smaller cubes.

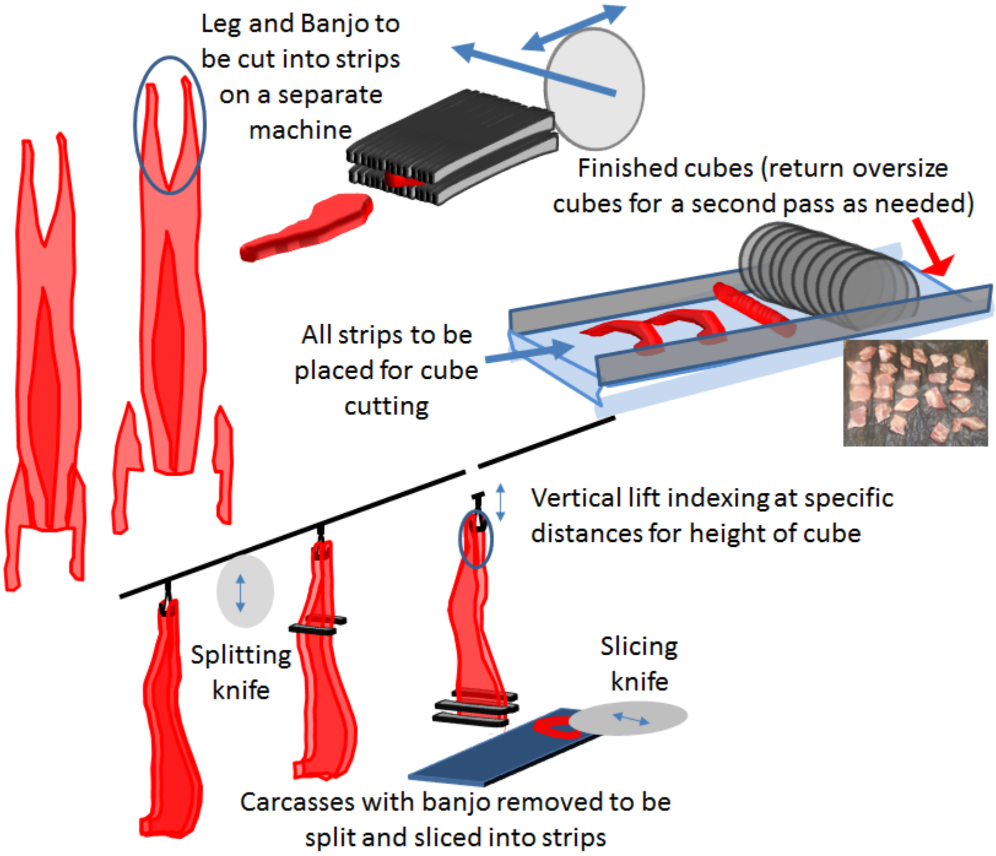


Figure 26: Overall automation approach.

The main carcass, after removing the banjo, whilst still on hanging on the hook, is to be sliced from the neck in an upward direction using an automated system (see slides showing the concept in Figure 26), until the leg primal pair hanging on the hook are reached.

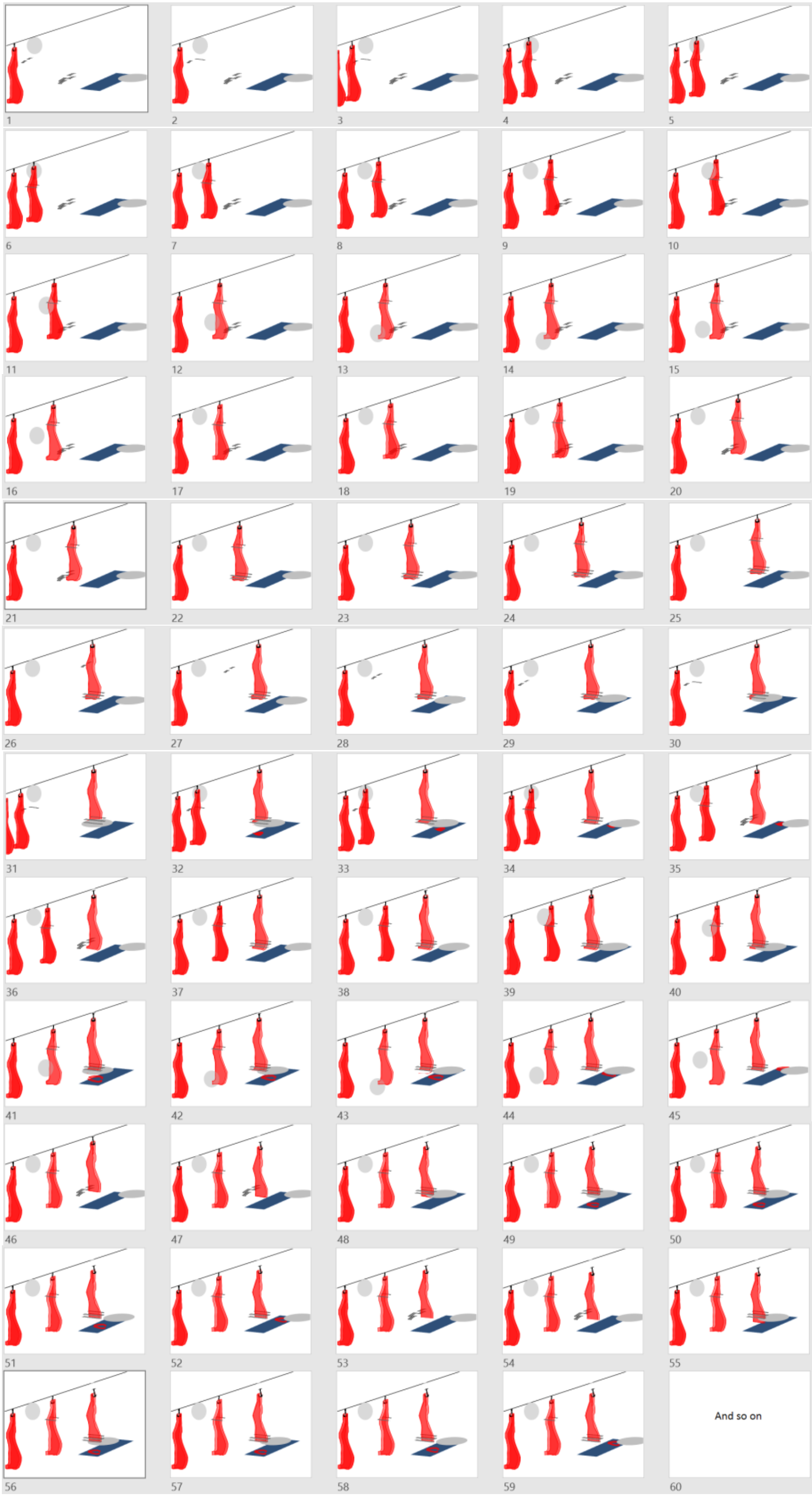


Figure 27: Overall concept for automatic slicing whole carcasses with banjo removed into strips for cutting into cubes (split and slicing may be done by knife blades).

The vertical carcass slicer as proposed and illustrated in Figure 27 has slicing action using a splitting section followed by a vertical lift section and a second knife blade similar to that used in robotic solutions already adopted in primal cutting for horizontal slicing as shown. One advantage of this approach is that the automation may also be used for performing 6 way cuts, when the carcasses are not to be cubed.

The resulting strips may be cut on a machine such as the 50-50 machine from ATTEC to produce cubes, see Figure 28.

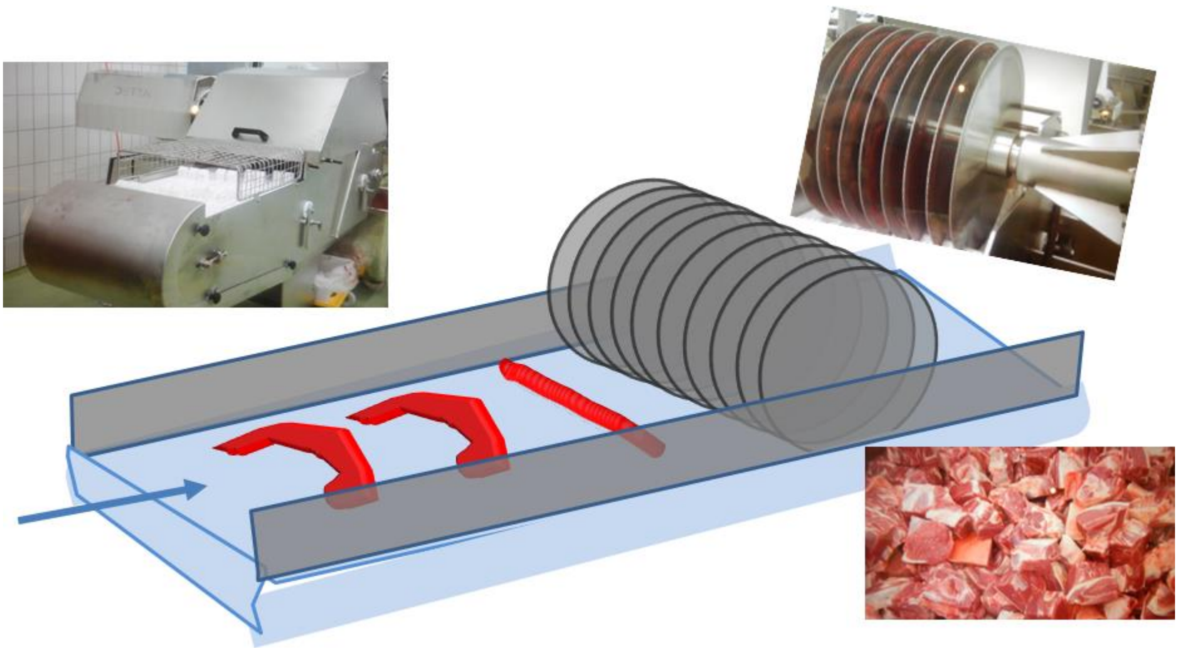


Figure 28: Cutting strips into pieces.

5.9 Requirements and status of automation

Figure 25 presented images of knife blades in action which may be used in the automation development towards an integrated approach for cubing. The throughput requirements per hour poses important considerations in reaching an automated solution. The carcass sliding action would require 3-4 seconds per slice and with the average carcass length of 1,200 mm after removal of banjo and consideration that the legs would have a length of 350 mm, then the remaining slicing length would be 850 mm on average. At 25 mm cube height, the slicing process would require 32 slicing actions at 3.5 seconds/slice, giving 112 second which is just under 2 minutes per carcass (i.e. approximately 30 carcasses per hour). The target of 100 carcasses per hour may be met by 3 slicing stations designed for a cycle of 3 seconds per cycle.

The technologies relevant or in need of development are as follows:

- ATTEC vertical cutter and the ROC systems: The technologies use standard components to perform primal cutting of Ovine. The main features are in the grippers, developed by BMC and Midfield, that can provide the restraining capabilities for handling and fixation of the carcass during splitting and during the slicing actions.

- ATTEC 50-50 machine that breaks sections of meat strips into pieces using a line array of knife blades. This machine is still in development and needs adaptation to meet the requirements.
- A machine that breaks up the banjo and the leg primal pieces into strips would need to be a new development.
- MAR splitting system for Ovine is already in use in Australia and this module may be simplified for cost using simpler drive solutions compared with a robot

5.10 Line solution

Figure 29 proposes a line approach for meeting the requirement of 100 carcasses per hour in an arrangement that uses several lift and gripping solutions as a concept that uses available technology.

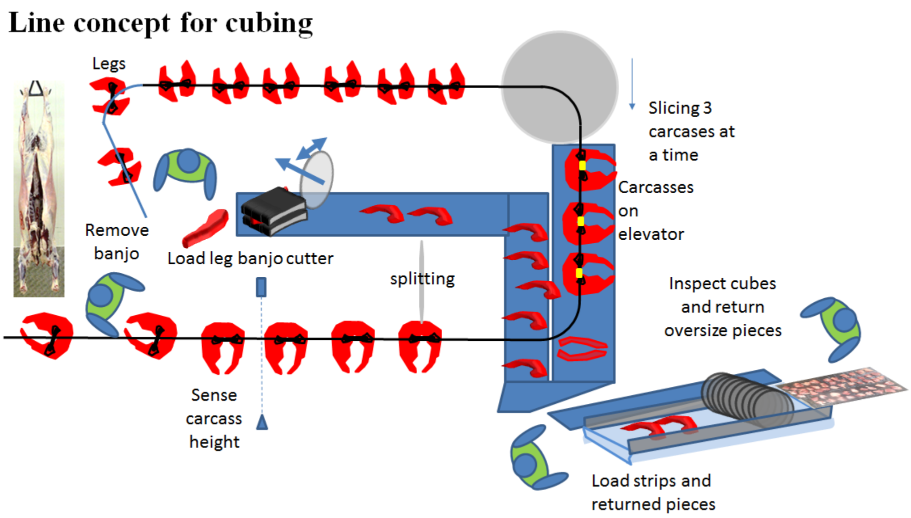


Figure 29: Concept for a line with potential throughput of 100 carcasses per hour.

5.11 Drawings

The 3D drawing in Figure 30 presents the system solution based on the concept of Figure 20.

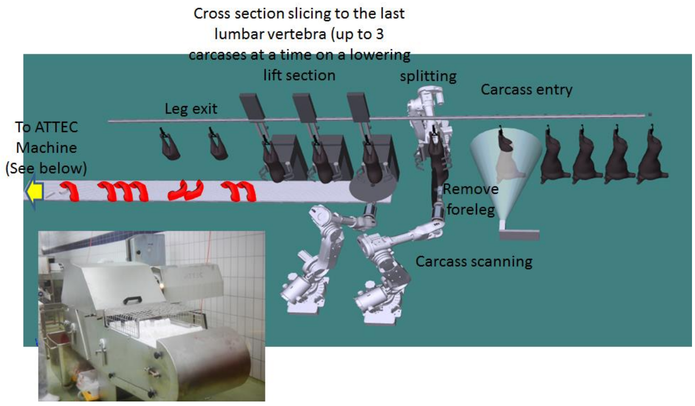


Figure 30: overview drawing combined with standard ATTEC 50-50 machine.

The following 3D drawings of Figure 31 (curtesy of Scott technology) show close up views of the solution including a single station or multiple station lift and cutting stations.

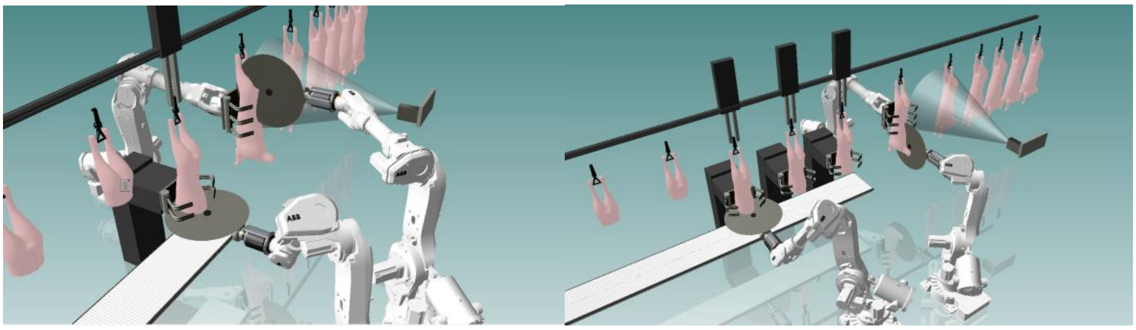


Figure 31: Detailed of single and multiple station for breakup using knife blades prior to final cubing on and ATTEC machine as in Figure 30.

5.12 Returns based on initial tender information

Initial tendering places the cost of the system solution at 1.15m A$ for the robotic set up and a further A$ 350k for the ATTEC for the ATTEC machine. Estimating a further A$ 200k for site changes, installation, training, etc., gives a total of A$ 1.7m.

Based on the estimation of A$ 7 as in Figure 32 (presented earlier) the ROI may be calculated at less than 18 months when processing 100 carcasses per hour 5 days per week for 7.5 hours operating 48 weeks/year.

EVALUATION OF CUTTING FROZEN 17th March 2016	All in Kg ±0.1
16.9	Kg carcass weight in frozen form
15.7	Kg net weight of cubes after band-saws
1.2	Kg loss in bandsaw dust that did not end in finished bags
7.6%	**loss into band-saw dust (X)**
100	carcasses per hour
100	$/carcass
5	days/wk
48	wks/year
7.5	hours per shift
1,800	total hours
180,000	carcasses/year
6%	yield saving estimate based on latest evaluation X/3.6
9,936	equivalent carcass savings in repect of yield improvement
993,631	a) AU$/year possible gain in yield
4	people saving based on observations of current practice
50,000	per person/year
200,000	b) AU$ labour saving opportunity
1,193,631	**Total potential saving (a) +(b)**
7	**AU$/carcass**

Calculation of loss per square cm from a 1 mm band-saw				
Comparison: ratio of frozen to fresh wgt losses		**3.6**		
Frozen				Ftprt
Weights:		gs ± 2	Slice	sq. cm
	At start	318	1	29.39
	After 3 cuts	310	2	23.11
	Loss	8	3	17.17
	gs/sq.cm	0.1148	Tot	**69.67**
Fresh				Ftprt
Weights:		gs ± 2	Slice	sq. cm
	At start	338	1	28.51
	After 3 cuts	336	2	22.00
	Loss	2	3	12.58
	gs/sq.cm	0.0317	Tot	**63.08**
Note fresh cut after cutting- scale flickering between 336 and 338				

Figure 32: Estimating the potential saving with automation cubing 100 carcasses/hour.

6.0 Discussion

There is an important export market for Caprine and Ovine products in small pieces of 50mm approximate cubes or smaller. Such meat products are generally used in soups, stews, curries, and similar meals all around the world. The industry in Australia concerned with producing the raw meat for such foods has been supplying meat in cut pieces or cubes using band-saws.

The process is highly labour intensive and practices vary in processing techniques.

Two machines have been identified from ATTEC, one in use in Norway (the 70-70 machine) and a 2D 50 mm cutting machine, which is a prototype (until recently the information on this machine has been restricted).

The work has considered the capabilities of the processes, both manual and automatic, and identifies the requirements to include a 50-50-50 mm and a 25-25-25 mm cuboid, but a piece size of approximate dimensions 50x50x25 mm, of natural look, is suggested to be a desirable target. A 50x50x25 mm cuboid would meet many requirements with respect to the end use expectations in meals and provides for optimum utilisation of carcasses, which is to be confirmed by the KPI assessment. It is important to note that the natural profile of the belly and rib cage of the carcass results in cube pieces generally in the range of 15mm to 30mm in thickness. Smaller carcasses in the regions of thick muscular sections could also be too thin for extraction of multiple cut pieces 50mm in thickness.

When cubing for 50x50x25 mm target size some of the constrains could be avoided giving higher number of conforming pieces. Nevertheless, many pieces of smaller dimensions could still result, given the anatomical variability constraints, preventing exact multiples of pieces to be fitted into the geometry of the carcass. Analysis shows that the pieces of the smaller size would nominally fall in the 25x25x25 mm size category, which may be acceptable as these would be mixed with larger pieces. However, when targeting 25x25x25 mm cube size, the resulting number of below size pieces may be considered too small.

A common practice for cubing is to compact cut primal pieces into groups for block freezing and then band-saw cutting the blocks into cubes. Observations of the process highlights that clocks are not necessarily uniform and the compacting can still leave air pockets within the blocks. The process of cubing by band-saw, results in higher losses compared to cubing fresh meat, and the presence of air pockets as well as the misalignment of the band-saw cut path not falling exactly along the edges of the primal pieces, compacted in frozen blocks, would leave smaller pieces in the cubes, only to be revealed after de-frosting. “Cubing” carcasses fresh would result in higher quality pieces, facilitating the opportunity for sorting and grading, if premium packs of meat cubes were desired.

Fresh (long life) meat cubes as opposed to frozen cubes is yet to be introduced into world markets at a scale that is significant and compares with existing national markets for fresh in countries such as Norway. An advantage of freezing, prior to cubing is that the product can remain frozen to the end of packing, eliminating the need for freezing cubes after cubing fresh, if so desired. In the KPI assessment under, the option for fresh cubing followed by freezing requires evaluation. Standard plate freezers are available in many plants and normally used to freeze the compacted blocks of primal meat for cubing. Freezing fresh cubes would require additional equipment, unless freezing naturally in retail packs (not subjected to pressure) could be possibility. Freezing also facilitates the packaging process, as the frozen cubes, being rigid and easily to handle, can be feed into a multi-head for fixed weight packing or simply bulk packed using a bulk depositing process.

The key findings reveal that cubing frozen blocks on band-saws gives estimated losses 3.6 times more than when cubing fresh. Using band-saws for cubing fresh is estimated to give losses of 0.9% and 1.89% for 50-50-50 and 25-25-25 cubes respectively. A new approach may be applied in the cutting scheme of a whole carcass when cubing fresh, eliminating the need for primal cutting prior to cubing. There is potential for conceiving automation solutions that remove the need for operators to use band-saws, but using a much smaller crew of people to operate automated equipment to cubes.

Automation opportunity can target a gain of A$10 per carcass with a combination of saw blades and knife blades. Carcass cubing at 300 carcasses per hour may be achieved by a group of machines and 5 operatives to match the capability in cubing by band-saw, which estimated to require over 50 people for fresh carcass cutting and 20 operators in frozen block cubing.

Significant savings in work cover payments and higher quality in product specification and presentation can also be expected.

Based on the figures, estimating equivalent of 15 staff at A$40k and A$10/carcass, the value proposition is in excess of A$ 6m per year for a plant processing 300 carcasses per hour.

Automation solution in the form of an integrated system can provide flexibility, whilst provide a solution for cubing. The attached drawing to this report provide the system as may be considered by processors considering the potential

7.0 Conclusions/ Recommendations

Evaluation of product cubing and dependency on carcass variation: 50x50x50 mm and 25x25x25 mm has been considered in detail and the understanding reached provides for a recommendation that cutting carcasses into approximate 50x50x25 mm or 25x25x25 mm "cuboid" meat pieces provides an important opportunity. This is cross referenced with respect to trend in market towards meat ingredients for meals, such as curries, stews and also premium dishes.

Evaluation of band-saw process has been made resulting in quantified loss calculations. With specific reference to fresh products, band-saw cutting results in approximately 1.89% loss of original weight for 25x25x25 mm cubing and 0.9% for 50mm pieces.

Cutting frozen gives losses over 3 times higher than fresh using a band-saw.

The optimum cutting process for automation requires structured handling, which can be a dominant factor when cutting carcasses of wide variability in size. Quantified the influence of carcass variability on cube production in terms of yield losses that may be estimated for lamb, goat or mutton, based on losses that may be incurred in cutting 25mm and 50mm cubes.

There is opportunity by minimise yield loss to give optimum efficiency in the conversion process of a whole carcass being cut into as many conforming cube pieces as possible, bearing in mind that such pieces are to be used for preparing meals. The following elaborates:

- Measures of yield loss: 0.9% for 50-50-50 and 1.89% of fresh carcass weight using a band-saws and 1.55% of carcass weight using knife blades with the comparison that losses can be 3.6 times higher when cutting frozen meat. Note the calculations are based on carcass weights after trimming and preparation for cube cutting.

- Targeting a 50x50 by 25mm thick cuboid as an approximate size for cubing would be optimum as losses in producing a 25x25 by 25mm cube would result in higher losses.
- The natural form of carcasses would generate under size cubes and a quality assurance process is needed to allow sorting procedure that would need to be adopted in the industry if large export volumes are to be expected.

An integrated automation approach is recommended based on available, partially or to be developed equipment.

Automation solutions for cubing need to provide for correct handling of meat sections for optimum yield in the conversion process of carcasses into cubes.

Automation for Cubing is considered feasible based on the progress of this project. Drawings and initial tendering information suggest that solutions may be achieved based on integration of available and partly proven technologies.

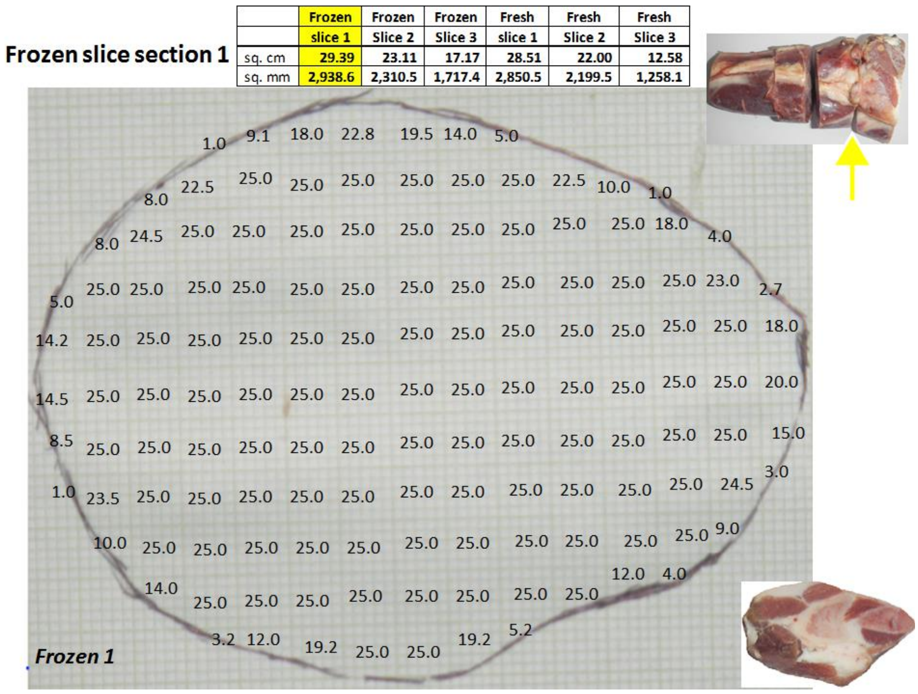
The systems solution as drawings presented may become the basis of a PIP project involving BMC, Scott Technology and McPhee. A potential of $7.00 per carcass has been estimated based on the cutting evaluations. The financial case is strong based on 18 months ROI; however, the technical risks remain until a first production solution as a prototype is developed.

8.0 Appendix

8.1: Measurement of area in the calculations presented in Figure 12, giving the loss per square centimetre, against the cuts made on a frozen and a fresh shank.

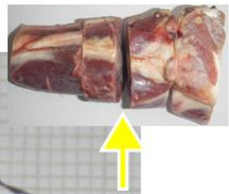
Cut face area neasurement sq. mm count						
	Frozen	Frozen	Frozen	Fresh	Fresh	Fresh
	slice 1	Slice 2	Slice 3	slice 1	Slice 2	Slice 3
sq. cm	29.39	23.11	17.17	28.51	22.00	12.58
sq. mm	2,938.6	2,310.5	1,717.4	2,850.5	2,199.5	1,258.1

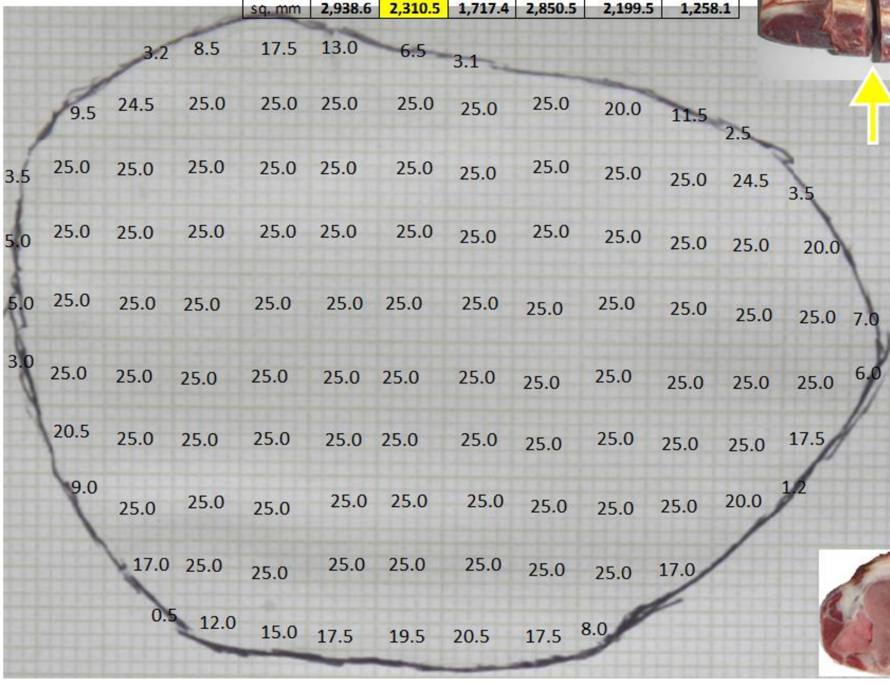
The following figures show the area calculation for each of the cross sections 1, 2 and 3 in the case of the frozen shank trial and the same in the case of fresh shank cutting.



Frozen slice section 2

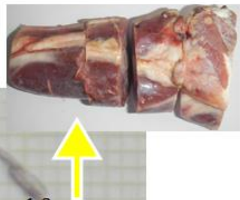
	Frozen slice 1	Frozen Slice 2	Frozen Slice 3	Fresh slice 1	Fresh Slice 2	Fresh Slice 3
sq. cm	29.39	23.11	17.17	28.51	22.00	12.58
sq. mm	2,938.6	2,310.5	1,717.4	2,850.5	2,199.5	1,258.1

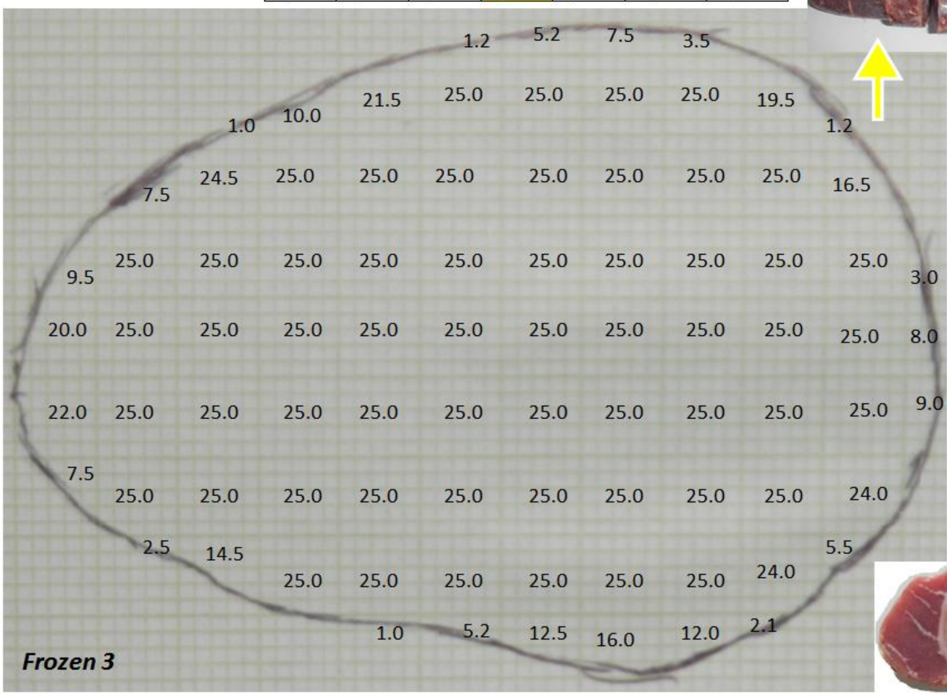




Frozen slice section 3

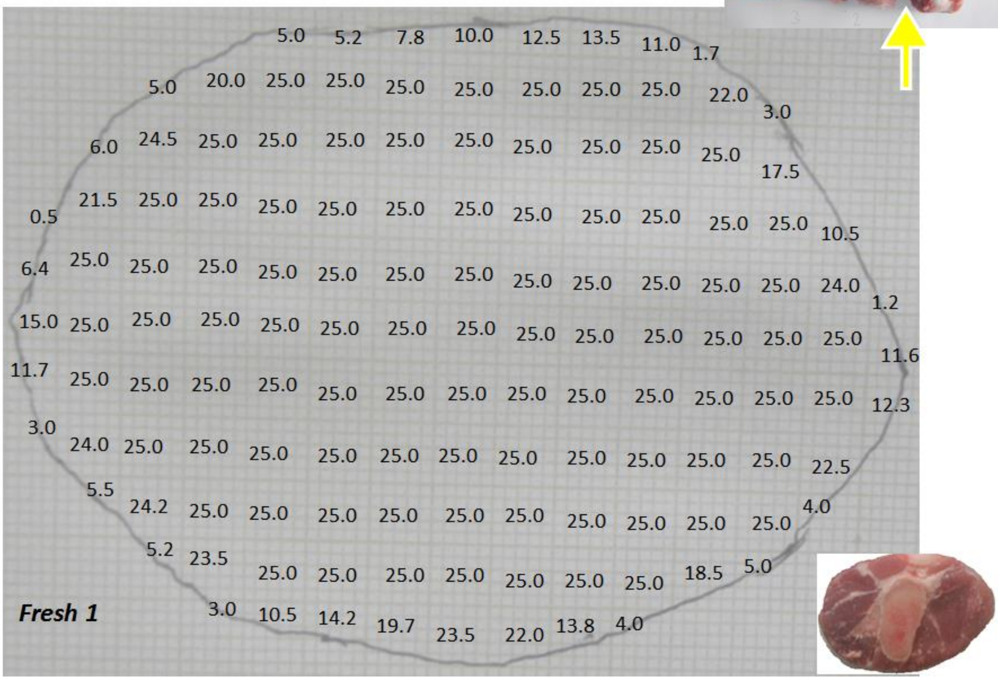
	Frozen slice 1	Frozen Slice 2	Frozen Slice 3	Fresh slice 1	Fresh Slice 2	Fresh Slice 3
sq. cm	29.39	23.11	17.17	28.51	22.00	12.58
sq. mm	2,938.6	2,310.5	1,717.4	2,850.5	2,199.5	1,258.1





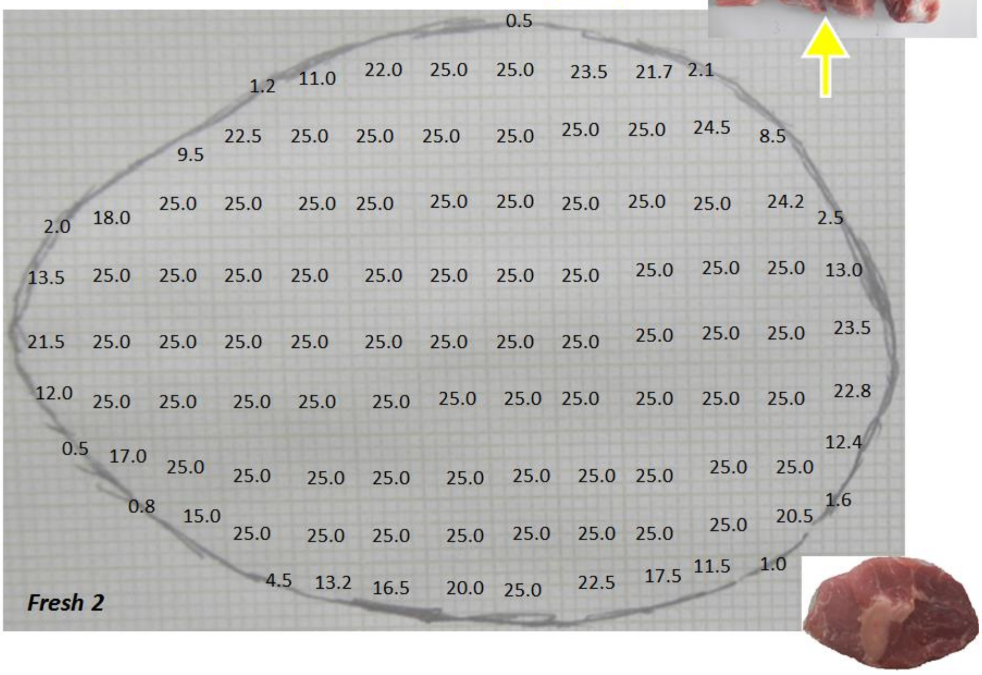
Fresh slice section 1

	Frozen slice 1	Frozen Slice 2	Frozen Slice 3	Fresh slice 1	Fresh Slice 2	Fresh Slice 3
sq. cm	29.39	23.11	17.17	28.51	22.00	12.58
sq. mm	2,938.6	2,310.5	1,717.4	2,850.5	2,199.5	1,258.1



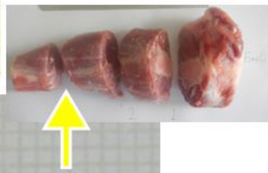
Fresh slice section 2

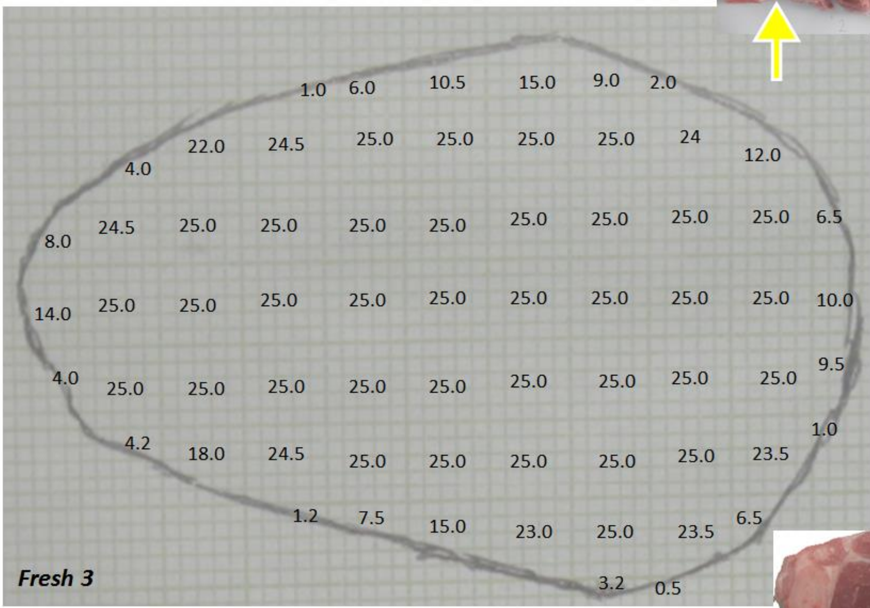
	Frozen slice 1	Frozen Slice 2	Frozen Slice 3	Fresh slice 1	Fresh Slice 2	Fresh Slice 3
sq. cm	29.39	23.11	17.17	28.51	22.00	12.58
sq. mm	2,938.6	2,310.5	1,717.4	2,850.5	2,199.5	1,258.1



Fresh slice section 3

	Frozen slice 1	Frozen Slice 2	Frozen Slice 3	Fresh slice 1	Fresh Slice 2	Fresh Slice 3
sq. cm	29.39	23.11	17.17	28.51	22.00	12.58
sq. mm	2,938.6	2,310.5	1,717.4	2,850.5	2,199.5	1,258.1





8.2 MLA OTH Prices Oct 2015

http://www.mla.com.au/Prices-markets

mla market INFORMATION

Over the hooks indicator - sheep and lamb

Market information provided by MLA's National Livestock Reporting Service

New South Wales

report date 30 Oct 2015

Over-the-hook lamb indicators have firmed this week, following tighter supply and rainfall in some parts of the state last week. Medium and heavy weight mutton lifted, while there is little demand for light weights.

Category	Weight Range	Fat (mm)	Fat Depth	Low Price (c/kg cwt)	High Price (c/kg cwt)	Avg Price (c/kg cwt)	Trend
Lamb	18-20	2 - 4	6 - 20	460	480	468	3
	20-22	2 - 4	6 - 20	470	500	488	10
	22-24	2 - 4	6 - 20	470	500	488	10
	24-26	2 - 4	6 - 20	430	500	482	12
		5	21 - 30	430	500	482	12
	26+	2 - 4	6 - 20	430	500	482	12
		5	21 - 30	430	500	477	13
	Merino 16-22	2 - 4	6 - 20	390	470	417	20
Sheep	14-18	2 - 4	6 - 20	220	280	240	-3
	18-24	2 - 4	6 - 20	260	320	285	12
	24+	2 - 4	6 - 20	240	320	282	8

mla market INFORMATION

Over the hooks report - export goat

Market information provided by MLA's National Livestock Reporting Service

Eastern States

report date 23 Oct 2015

Over-the-hook export goat rates were only marginally higher, with a contributor moving rates in line with others. More producers have been enticed by the high prices with slaughter building.

Category	Low Price (c/kg cwt)	High Price (c/kg cwt)	Average (c/kg cwt)	Trend
8.1-10kg	450	500	482	2
10.1-12kg	450	500	482	1
12.1-16kg	450	500	482	1
16.1-20kg	450	500	482	1
20.1kg+	450	500	482	1

KK/29/08/2016