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The value of online measures – a processor perspective

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Abstract

In the past the adoption of objective online technologies has been low amongst Australian red meat processors. The aim of this work was to obtain a greater understanding of Australian processor views on the value of online measurement technologies by understanding what they think of current and future technologies. Based on processor consultation key important traits for online measurement technologies were identified for each species (cattle – meat colour, tenderness; sheep – tenderness, pH, age, meat colour, GR and SMY%; goat – lean meat, fat, carcase conformation and meat colour). The responses indicate that overall there is support for online measurement technologies with 80% saying that online objective grading systems have a role in the Australian meat processing sector now and 88% see these having a role in the future. Much can be learned from the implementation of previous online measurement technologies in terms of commercialisation and adoption strategies. The development and adoption of objective online measurement technologies is challenging and complex. However, increased adoption of online measurement technologies has the potential to achieve whole of industry benefits and needs continued support coupled with new approaches to enhance adoption.

Executive Summary

As part of the strategy to meet consumer demands and increase the consumption of red meat, the need to change from subjective to objective evaluation of carcass yield and quality traits has been identified over the past 20-30 years. Although, scientifically a number of online objective technologies have proven to be successful, the adoption of these technologies is low amongst Australian red meat processors. The aim of the work reported here was to obtain a greater understanding of Australian red meat processor views on the value of online measurement technologies by understanding what they think of current and future technologies. The ultimate aim of this work was identify ways to increase adoption of old and new online measurement technologies for the red meat industry in Australia. To achieve this data were collected during face to face interviews with 65 processors representative of the Australian red meat industry.

Meat colour and meat tenderness were ranked as the top two most important traits (respectively) by beef processors for an online objective measurement technology and purge (described as an indication of water holding capacity) was ranked the least important. Meat tenderness, pH, animal age, meat colour, GR and Yield predict of SMY% were ranked as the most important traits respectively and marble score, purge, EMA, muscle score and IMF% were all ranked as the least important respectively amongst sheep processors. Lean meat, fat, carcase conformation and meat colour were all identified as important traits by goat processors. These rankings for each species help identify which traits are most applicable to processors and their business. These rankings should be taken into consideration in the development of any new technologies.

Currently all meat quality measurements are assessed subjectively with the exception of pH amongst Australian processors. This is despite the fact a portion of industry had previously measured some meat quality traits objectively and some technologies have been scientifically proven able to measure both meat quality and yield traits objectively. Only one of the five commercialised online objective measurement technologies that have been used in the Australian red meat processing industry is still commercially used.

Surveyed results showed that there was adequate awareness of each of the technologies with 86% and 79% of beef processors being aware of the VIAScan® beef carcase system and VIAScan® beef chiller assessment system respectively and 50% and 71% of sheep processors being aware of the VIAScan® sheep carcase system and AUS-MEAT Sheep Probe respectively and 75% of all processors were aware of the Hennessy Grading Probe. Initial adoption rates of each of the technologies were reported as 17% for the VIAScan® beef carcase system and 9% for the VIAScan® beef chiller system. Amongst sheep processors one processor adopted VIAScan® sheep carcase system and 27% had used the AUS-MEAT Sheep Probe. Adoption for the Hennessy Grading Probe was represented by 32% of beef processors and this is the only technology still been commercially with no change in the percentage of processors currently using it.

No beef processors surveyed use an online technology to measure SMY% or LMY% despite the science supporting the capabilities of VIA to achieve this. Further to this over 70% of processors said they would use an online measurement to measure SMY% and LMY% if it had a high level of accuracy.

Of the processors surveyed 80% agreed that online objective grading systems have a role in the Australian meat processing sector now and 88% see these having a role in the future. Enhanced systems of capturing meat quality and yield data were given significant support so as to: "make real time decisions on market suitability (77% of processors), and just over half the processors surveyed said they would "market product differently", "provide feedback to suppliers" and "derive and payment system". The majority of industry wants the payback of online measurement technology costs to be 2 years or less.

Processors most commonly responded (48%) that new technologies should be implemented pre-rigor on the slaughter chain. Thirty eight percent of processors said new technology could be implemented either pre-rigor/pre-chiller or post rigor chiller. Fourteen percent said that they would prefer implementation to be based post rigor in the chiller.

The majority of processors wanted technologies to achieve a level of accuracy either greater than 90% or greater than 95%. Seventy percent of processors surveyed indicated they had concerns over supplier faith and accuracy in measurement. Accuracy and consistency were the two main factors processors indicated were needed from technology to deliver a consistent quality to consumer.

On the basis of the results generated through extensive processor consultation, several strategies have been identified. These strategies have been developed to ensure maximum adoption of new online measurement technologies using processor views for future focus areas and strategies based on key learning from previous online measurement technologies.

Considerations to maximise adoption:

- Identified important traits for online measurement technologies for each species (cattle – meat colour, tenderness; sheep – tenderness, pH, age, meat colour, GR and SMY%; goat – lean meat, fat, carcase conformation and meat colour).
- Implementation pre-rigor pre chiller
- Target chain speeds of 200-250/hr (cattle), 11-15/min (sheep) and 10-12 (goats)
- Payback of 2 years or less
- Accuracy levels greater than 90-95%.

Key strategies based on learnings from previous online measurement technologies:

- Manage expectations and roles of industry (processors) during commercial technology development "don't oversell" till scientifically proven under commercial conditions.
- Ensure that the technology is 100% commercial ready for use before showcased to industry, so customer faith is not lost in the technology.
- Ensure business models of the technology manufacturer are viable.

- It would be advisable that any new online measurement technology should be incorporated and/or accredited by our national grading systems (AUS-MEAT and MSA), like has occurred in Europe and the USA. Early engagement recommended.
- Considerations for how equipment will be serviced and maintained (in-house or external) need to be incorporated at initial stages of the project and developed as necessary. These considerations may include;
    - Have a preventative service and maintenance plan (like a motor vehicle).
    - Scientifically determine optimal calibration periods.
    - Develop formal training packages, so knowledge is not lost with staff turnover.
    - Include these initiatives in future business models and cost benefit analysis.
- Considerations should be made to building on existing technology concepts (ASP) and engage existing reputable manufacturers to get greater critical mass to ensure; sustainability of the manufacturing business, resources for technical support and quality.
- Increase awareness of current successful technologies (eg Hennessy Grading Probe) to targeted groups (eg medium to large beef plants).
- Use descriptive information to future proof the longevity of technology (eg chain speed) and think ahead with targets.
- Continued financial support from industry such as Plant Initiated Projects and Meat Donor Company projects are critical to the development of any new technology to mitigate risk.

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1 Background

In general Australian producers sell cattle and sheep either on liveweight (e.g. through the saleyards) or on a carcase weight basis (e.g. livestock sold over the hook). The price paid for animals sold on based on liveweight is derived from a predetermined c/kg rate (cattle) or $/head (lamb/sheep). This rate is based on the buyer's subjective judgement of traits that are exhibited in the live animal such as; frame size, muscling/shape, age, estimated weight and fatness and any additional background information that may be obtained such as breed. The price paid for animals that are sold on a carcase weight basis is generally determined by price grids. Cattle grids have various rates (c/kg) depending on grade (vealer, yearling – heifer/steer, grown steer, cow, bull, MSA yearling - heifer/steer), dentition, muscle score (subjective), fat score (objective- determined by fat depth at P8 site mm) and carcase weight (objective). Similarly sheep grids have various rates based on category (sheep, hogget, lamb) (Merino, crossbred), carcase weight (objective), fat score (objective determined by fat depth at GR site mm, if measured or subjectively by palpation) and skin value. Irrespective of selling method sheep and cattle are predominately sold on indicators of meat yield as it is a major component of carcase value.

Currently the use of value based marketing is limited in Australia. Value based marketing is in principle where a producer is paid on the inherent value (including quality and quantity traits) of the product to the buyer and the end user. This method provides clear feedback from the customer (processor) to the producer and has pricing systems that support these signals (MLA, 2014). Meat quality traits such as tenderness are currently not used to differentiate price. Over the past few decades there has been extensive research in Australia and around the world into the development of online measurement technology to predict both beef and sheep carcase quality and yield characteristics (e.g. Clarke, et al. 1999; Craigie, et al. 2013; Damez & Clerjon, 2008; Hopkins, 2011). Online measurement technology can be defined as a technology designed to capture carcase yield and/or meat quality traits at production speed, either on the kill floor or in the chiller. The research and development of these technologies has largely been driven by the need to satisfy consumer demands, provide more accurate feedback to producers and reduce labour requirements at the processing level. Although a number of these online technologies have been scientifically proven to be successful it is considered that the adoption rate has been low amongst Australian processors.

An example of minimal adoption rates is shown within the Australian sheep industry where there is currently minimal differentiation between carcases. Carcases are identified as lamb, hogget, mutton or ram and are often only graded according to hot carcases weight with kidneys and internal fat removed and based on the level of fatness (Hopkins, et al. 1995). Fat can be determined via a subjective assessment where a fat score of 1-5 is allocated (with 1 the leanest and 5 the fattest) or by an objective measure of GR (total tissue depth at the twelfth rib 110mm from the midline) (Anon, 2005). The later measure of fat normally only applies to carcases sold over the hooks which is expected to only accounts for a small proportion of sheep carcases processed. A similar approach is taken in different EU countries including the UK where a carcase weight is recorded and a subjective score is allocated for fatness and conformation (Lambe, et al. 2009).

This simplistic approach is the most common among Australian sheep processors despite the development over the past 20-30 years of many technologies for measuring fat - for example AUS-MEAT sheep probe (ASP), (Hopkins, et al. 1995); Hennessy Grading Probe (Hopkins, et al. 2013), Video Image Analysis, NIR reflectance, conductivity, ultrasound and computer tomography (CT) (Kongsro, et al. 2009; Lambe, et al. 2009; Stanford, et al. 1998). The low usage of these technologies seems anomalous given that some technologies have shown to have moderate to high accuracy including the ASP (Hopkins, et al 1995) for GR, and VIA (Hopkins, et al 2004; Rius-Vilarrasa, et al. 2008), and ultrasound (Swatland, 2002) for fat score.

This project was designed to firstly undertake an extensive review of literature on current and developing online measurement technologies to identify how scientifically robust each of the technologies are (Section 1.1 – presented in Milestone 1). Second aim was to gain a comprehensive understanding of beef, sheep and goat processors perspectives on the value of various online carcase measurement technologies. This knowledge is vital to identify any barriers to adoption with respect to current and future online technologies in order to increased levels of adoption in the red meat industry.

1.1 Review: The success and failings of the use of online measures in the red meat industry

1.1.1 Introduction

Measurement of carcase traits and meat quality attributes needs to be reliable and quick and must be able to be carried out during the production process in order to utilise the information in real time and hence maximise economic benefits. The method must ensure the quality/quantity of the meat/meat products and satisfy consumer demands. To achieve this methods/technologies need to be fast, non-destructive (and/or non-invasive), online, accurate, cost-effective and ideally have multi-uses (be able to predict more than one characteristic). There are several imaging and spectroscopic technologies appropriate to evaluate meat properties based on; video Image analysis, spectroscopic methods (UV-visible, Near Infrared, Mid-Infrared, Raman and Fluorescence spectroscopy), optical probes (Hennessy Grading probe, the Swedish FTC lamb probe), mechanical probes (AUS-Meat sheep probe, Ruakura GR Lamb probe), Magnetic Resonance methods (nuclear magnetic resonance spectroscopy, magnetic resonance imaging, magnetic resonance elastrography), X-ray methods (computed tomography, MicroCT, Dual X-ray absorptiometry), Dielectric methods (impedance, microwave) and ultrasound (Damez & Clerjon, 2008; Kirton, et al. 1995). These methods/technologies have been used in different species to determine meat quality attributes such as; fat and muscle depth, shear force, intramuscular fat, pH, instrumental colour (L*, a*, b*, chroma, hue), eating quality attributes (tenderness, juiciness, flavour, acceptability), water holding capacity, drip loss, cooking loss, nutritional quality (fatty acids composition, protein, minerals), salt content, ash and other chemical characteristics and additionally safety characteristics.

The objective of this review is to outline the advantages and disadvantages from a scientific perspective of the more commonly examined online technologies such as; Video Image Analysis (VIA), AUS-Meat Sheep Probe (ASP), Hennessy Grading Probe

(HGP), Near Infrared Reflectance (NIR), Nuclear Magnetic Resonance (NMR), Raman, Impedance, Duel-energy X-ray Absorptiometry (DXA) and Computer Tomography (CT) that have been developed to objectively measure beef and sheep carcase yield and/or meat quality traits such as tenderness, meat colour, fat colour, intramuscular fat and water holding capacity (WHC).

1.2 Online measurement technology

1.2.1 Video Image Analysis (VIA)

VIA is one of the most widely researched online technologies. Early research was conducted in the USA into the effectiveness of VIA technology, specifically for the objective evaluation of beef carcases (Cross, et al. 1983). Since then, the technology has undergone development in several countries, notably USA, Canada, Denmark and Australia. This technology has been driven, as are many online technologies, to remove subjective assessment, as the fact remains that subjective judgement and consequently, consistency within and between assessors can often vary (Du and Sun, 2004). To define how VIA works we could simply say that VIA emulates what a trained assessor does, the human eye is replaced by a digital camera and the human brain is replaced by learning algorithms. The camera can record objective and consistent image data and the learning algorithm links the image data to the appropriate quality class or level (Jackman, et al. 2011). There are three different forms of VIA that have been developed, including; a whole beef carcase system, beef chiller assessment system and whole lamb carcase system.

1.2.1.1 Whole beef carcase system

This system is used on the slaughter floor to evaluate hot carcases by capturing images of the lateral view of carcasses or sides. From these images, colour (red, blue, green scale) and dimensional data are extracted to predict yield, conformation and EUROP fat and conformation scores (Borggaard, et al. 1996; Craigie, et al. 2013; Jones, et al. 1995; Palbiou, et al. 2011). It was reported by Craigie, et al. (2012) that there are currently five different commercially available VIA systems for beef including; VIAScan® (Cedar Creek Company, Australia), VBS 2000 (E+V GmbH, Germany), BCC-2 (Carometec A/S, Denmark), Normaclass MAC-2 (Normaclass France) and CVS, (RMS Boulder, Colorado). All these systems operate online and all use similar methods for classifying carcases or predicting various carcase traits.

The first published results on VIA technology appeared in a feasibility study conducted by Sorensen (1984) in Denmark to examine the ability of whole side VIA to objectively classify beef carcases. Data from the first commercial experiment was published by Sorensen, et al., (1988), where it was determined that carcases could be assessed objectively with a high level of repeatability for lean meat yield percentage (LMY%) and it was also able to explain a large percent of the variation in LMY%, fat and bone percentage trim. Later work by Borggaard, et al., (1996) using a modified VIA system showed that fat colour could also be predicted with a high level of accuracy based on the EUROP classification system.

During the 90's the whole beef carcase technology was installed commercially in different countries including Australia (Craige, et al. 2012; Eldridge, 1994). A number of studies have been undertaken to improve the accuracy of carcase yield predictions using a dual system combining data from both the whole body and chiller assessment VIA technology (Cannell, et al. 1999; Cannell, et al. 2002; Vote, et al. 2009). Recent studies by both Craigie et al. (2013) and Pabiou et al. (2011) investigated the ability of whole body VIA technologies to predict saleable meat yield based on wholesale cuts. Results from Craigie et al. (2013) gave a mixed response with moderately accurate predictions possible for the weight of the sirloin cut and poor predictions for the fillet and it was concluded that the results should be validated with a larger dataset with a bigger range and that further refinement would be required. Contrasting this Pabiou et al. (2011) showed that direct VIA outputs could predict saleable meat yield with a higher accuracy than the EUROP classification scores when cuts were grouped into low, medium, high and very high value cuts.

Overall based on the scientific literature it would appear the whole beef body VIA technology is a useful tool to evaluate beef carcase composition. Automation of the assessment of beef carcases with a higher level of accuracy is possible. VIA has been successfully applied to carcase classification in the Republic of Ireland on an industrial scale since 2004 using the VBS 2000 machine (Pabiou, et al., 2011). However it would seem that to increase the accuracy of predictions on a cuts basis further work is need.

1.2.1.2 Beef chiller assessment system

This system is used on quartered side. A transverse image is recorded of the rib section which is analysed to derive marbling, meat colour, fat colour, eye muscle area (EMA), total rib fat depth and additionally provide predictions of saleable meat yield. From the literature it appears that there are three commercial systems available, including VIAScan® CAS (Cedar Creek Company, Australia), Computer Vision System BeefCAM® (Hunter associates laboratory, Inc.) and VBG 2000 (developed by E+V GmbH and US Meat Animal Research Centre MARC).

There have been many studies conducted to investigate the usefulness of such systems for the prediction of yield (Cannell, et al*.,* 1999, Cannell, et al*.,* 2002; McEvers, et al. 2012; Shackelford, et al. 2003; Steiner, et al. 2003a; Steiner, et al. 2003b; Vote, et al*.* 2009). In both studies by Cannell, et al*.* (1999; 2002) it was concluded that VIAScan® predicted fabrication yields more accurately than the current online grading system used in the US and in the latter study it was also found that the ribeye (EMA) measurement replaced estimated ribeye area in the determination of USDA yield grade. Shackelford et al*.* (2003) & Steiner, et al*.* (2003b) both supported this outcome concluding that the beef industry could more accurately determine beef yield grades using VIA and this could be operated at plant speeds. Steiner, et al*.* (2003a) also showed that the technology could assess loin muscle area in both a stationary and operational scenario with a high level of accuracy and repeatability. Vote, et al*.* (2009) showed that VIA had an advantage in predicting yield over the current Uruguay National Institute of Meat (INAC) classification system and McEvers, et al*.* (2012) concluded that the prediction equations developed for VIA at the $12^{th}/13^{th}$ rib could be used to more accurately predict saleable meat yield than those currently used by the US and Canada.

In terms of meat quality traits published studies have predominately looked at VIA's ability to predict marble score and meat colour. In a review by Ferguson (2004) five out of the six studies reviewed generally showed that VIA is capable of accurately predicting visual marble scores and it was concluded that VIA is the best available technology to objectively define the spatial characteristics of marbling. In the prediction of intramuscular percentage (IMF%) Kuchida, et al. (2000) showed that the ratio of intramuscular fat area to total loin area from a VIA image was highly correlated with IMF%. However Shackelford, et al. (2003) suggested that VIA did not provide an accurate enough prediction for marble score to be used without a USDA grader. Since then however in a more recent study by Moore et al. (2010) it was shown that you could assign a marble score to carcases online using a VIA-CVS system that is now approved for this purpose.

Both, Wyle, et al. (2003) and Vote, et al. (2009) tried to use VIA technology to determine carcase palatability and Warner- Bratzler shear force respectively and it was concluded for both studies that further work was required before this could be achieved.

Based on the published literature it would appear that VIA is effective in predicting yield, loin eye muscle area and marble score (adopted by USDA). It is also apparent that there is limited published data about the effectiveness of predicting muscle and fat colour and that further work is needed in this area. A limitation with this technology is that worldwide, the quartering location for carcases varies for example Scotland is at the $10^{th}/11^{th}$ rib. Australia and the USA are normally quartered at $11^{th}/12^{th}$ rib and the current software for these systems has been developed for use at this quartering site. Therefore further development of the software (and associated algorithms) is required to obtain the required accuracy if the measurement site is changed.

1.2.1.3 Whole lamb carcase system

This system works on the same principles as the beef whole carcase system, where colour (red, blue, green scale) and dimensional data are extracted to predict yield. Although there are fewer published research results on VIA for lamb carcases, the results have been promising. Early work using a prototype by Horgan, et al. (1995) showed that VIA shape variables for cold carcases, carcase weight and sex, could predict saleable meat yield at a greater level of accuracy when compared to the subjective system used in the UK at the time.

Hopkins (1996) concluded that VIA technology could be used to predict lamb carcase muscularity. A subsequent study by Hopkins, et al. (1997) went further to say that VIAScan® (now manufactured by Cedar Creek Company, Australia) could predict yield with similar accuracy to the current grading system (based on weight and measure of fat). Similar results were found by Stanford, et al. (1998) where it was concluded that VIAScan® improved the prediction of saleable meat yield compared the Canadian system, however, it was also noted further tests would need to be conducted on a wider range of carcases (including extremely lean and fat) before final recommendations could be made.

Brady, et al. (2003) examined VIA technology called the Lamb Vision System (Research Management Systems USA, Fort Collins, Co), and showed that the Lamb Vision System + carcase weight could predict yields of wholesale cuts and concluded that it could be used as an objective means for pricing carcases in a value based marketing system. A more recent study by Hopkins, et al. (2004) concluded that VIAScan® technology offers significant potential to automatically predict meat yield. Finally in a recent study by Rius-Vilarrasa, et al. (2009) it was shown that the VSS2000 (developed by E+V Technology GmbH) was able to improve on the current MLC EUROP carcase classification scheme used in UK abattoirs.

Based on the scientific literature it is apparent that VIA of lamb is a useful tool in more accurately predicting meat yield then current classification systems used in a number of different countries (Australia, Canada, USA & UK). Based on the scientific literature it is difficult to ascertain how widely adopted this technology has been by industry and what value industry actually places on this technology. However, Hopkins, (2011) did report that within Australia two plants had adopted the VIAScan® technology, with one using a payment system based on lean meat yield. It was also reported that the adoption strategy was flawed in that there was an upfront cost and then an ongoing fee (per carcase) to have the machines installed. Anecdotally VIAScan® has been more widely adopted by New Zealand sheep processing plants. It is important to understand hurdles to adoption and this is the objective of stage 2 of this project.

1.2.2 AUS-MEAT sheep probe (ASP)

This technology was developed to classify lamb carcases and identify differences in value arising from variations in yield of saleable lean meat and market suitability Cabassi, (1990). The ASP was first evaluated by Cabassi, (1990), with further validation by Hopkins, et al. (1995) and Kirton, et al. (1995). The probe worked by displacement, such that when the probe is pushed through the tissue, once it reaches the bone the depth is recorded. The measurement was taken over the 12th rib at a position 110mm from the backbone of the carcase (Cabassi, 1990). This is the same position as the GR site (Kirton & Johnson, 1979).

Early results by Cabassi, (1990) showed that the ASP could potentially be a useful technology to replace the current more subjective assessment method. This result was supported by Hopkins, et al. (1995) where the ASP was tested in a commercial abattoir at a chain speed of 8-9 per minute and a high level of accuracy was achieved when compared to manual measures of GR. An important outcome of that study was that it was shown that operator training was necessary to achieve acceptable performance. Kirton, et al. (1995) also showed that the technology could be used as an objective measure when compared to GR and other novel probe technologies.

Hopkins, (2011) highlighted that this research paved the way for carcase description system which saw by 1995 in the order of 45% of the Australian lamb slaughter described by weight and fat level with each carcase carrying a ticket with information on it. The integration of a computer driven ticketing system with ASP meant that processors were also able to monitor buyer performance and weight and fat levels of their slaughter population (Hopkins, 2011). Despite the apparent success of this technology, the utilisation of the technology amongst Australian processors is now limited to non-existent. A major issue appears to be that the technology was bought out by another company who no longer manufacture or service the ASP. There is also a suggestion that with the genetic changes in fat distribution the usefulness of the GR measurement has diminished, but measurement at alternative sites with other probes is problematic (see below). Additionally as it stands Australian lamb processors are currently relying on subjective fat score assessments of carcases determined by palpation. This is clearly not satisfactory and it is important to establish the value they would give to say a revamped ASP.

1.2.3 Hennessy Grading Probe (HGP)

The HGP as described by Kirton, et al. (1987), was first developed for the use on pig carcases, but since then has been modified to work on both beef (Eikelenboom, Hoving-Bolink & Hulsegge, 1992; Hopkins, 1989; Kirton, et al., 1987; Phillips, Herrod; Schafer, 1987) and sheep (Garrett, Edwards, Savell & Tatum, 1992; Hopkins, Toohey, Boyce & van de Ven, 2013; Kempster, Chadwick, Cue, Grantley-Smith, 1986; Siddell, McLeod, Toohey, van de Ven & Hopkins, 2012) with outcomes from this work to be discussed in this review. The Hennessy Grading Probe uses reflectance spectroscopy and records profiles of the measurements generated from recording in fractions of millimeters, distances of penetration together with back scattered light signals. Specific optical band widths are selected to provide the optimum information obtainable between and within the various tissues of the species being objectively analysed (Hennessy Grading Systems, 2014). In general it is designed to measure fat depth in mm, provide meat yield predictions and to measure other meat quality traits.

1.2.3.1 Hennessy Grading probe - Beef

Studies by both Hopkins, (1989) and Phillips, et al. (1987) showed that the HGP was an effective technology for measuring subcutaneous fat depth in beef carcases. A study by Kirton, et al. (1987) concluded that the HGP showed promise for the use in an electronic carcase weighing and meat yield prediction system as part of a beef classification system. A major consideration was to find the correct measurement site where subcutaneous fat was not removed from some carcases during hide removal. In Australia the move the P8 site was positive for the HGP as it worked well when used at this site (Hopkins, 1989; Phillips, et al., 1987). Hennessy Grading Systems recommend that it is essential that a probe guidance system is applied to obtain optimum results. This is because human operators without objective guidance technology cannot insert and remove Hennessy probe needles in the correct carcass site at the correct angle, as well as removing the needle precisely along the same axis. This could be important as the probe measures tissue depth as it is removed from the carcase. The study by Eikelenboom, et al. (1992) appears to be the only one to publish results examining the effectiveness of HGP for predicting meat colour which was tested in veal. The results indicated that the HGP was less accurate in determining meat colour when compared to other techniques and that further work was required.

1.2.3.2 Hennessy Grading probe – Sheep

Hennessy Grading Systems developed a lamb grading probe to objectively measure carcass lean meat yield. Early work by Kirton, Woods, & Dunanzich (1984) using an early prototype version of the technology showed that the probe was satisfactory to take fat measurement immediately following slaughter and concluded additional trials were needed under commercial conditions. A subsequent study by Kempster, et al. (1986) showed that it was able to measure fat depth, but the muscle depth measurement did not enhance precision for the prediction of yield. It was unclear if this study was carried out under commercial conditions. Garrett, et al. (1992) concluded that plant operators or USDA graders equipped with a HGP could perform functions of sorting carcases into groups of varying cutability. However, in contrast in a more recent study by Siddell, et al. (2012) it was shown that HGP offered no significant improvement for the prediction of meat yield from the use of fat or muscle depths measured with the HGP. Similar results were shown by Hopkins, et al. (2013) where both the GP4 and GP7 version probes were tested. Analysis of data revealed wide variability between HGP and equivalent carcase measures (fat depth and muscle depth) and it was concluded that it would not be a viable option for the Australian sheep processing industry.

Since the development of HGP for sheep, Hennessy grading systems have claimed that the technology has been configured to accurately grade lamb carcasses for % lean meat yield along with objective meat quality traits. These claims are yet to be supported by any published literature. Overall it would seem that although there have been some promising results, it doesn't seem that HGP would be applicable in Australia.

1.2.4 Near Infrared Reflectance (NIR)

NIR spectroscopy has been used as an analytical technique for around a century (Irudayaraj, 2000). This method is becoming more attractive because of the potential for remote, online, multi-point and real time analysis. Spectroscopy is based on the principle that the chemical bonds in organic molecules absorb or emit infrared light when their vibration state changes (Damez & Clerjon, 2008).

The literature shows that NIR spectroscopy has been a well-researched area in both beef and sheep in terms of technical meat quality traits including; pH, L*, a*, b* colour values, water holding capacity, shear force (Leroy, et al. 2003; Lomiwes, et al. 2010; Prieto, et al. 2009b; Reis & Rosenvold, 2014), sensory attributes such as marbling, odour, flavour, juiciness and tenderness (Andrẻs, et al. 2007; Venel, et al. 2001), classification of carcases (Rust, et al. 2008; Shackelford, et al. 2012; Shackelford, et al. 2005) and chemical composition such as; crude protein, intramuscular fat, dry matter, ash, myoglobin and collagen (Andrẻs, et al. 2007; Prieto, et al. 2006).

Despite the fact that NIR spectroscopy is a well-researched topic it is challenging to compare results between studies to determine how effective the technology is and the suitability for commercial application given the many different types of NIR equipment that can used (Rosenvold, et al. 2009). A recent comprehensive review by Prieto, et al. (2009a) showed that NIR had a high potential to accurately predict chemical meat properties and categorize meat into quality classes, but had limited ability to comprehensively estimate technical and sensory attributes. It was concluded that this was most likely due to the heterogeneity of meat samples and their preparation (fresh v frozen); low precision of the reference methods and subjectivity of assessors in taste panels and thus it was suggested further work is required in this area. Rosenvold, et al. (2009) did conclude that the earlier NIR measurement is recorded post mortem, the less accurately the measurement will be able to predict the future tenderness as there are many subsequent factors influencing tenderness, such as ageing temperature and time. However, in general it can be concluded that NIR has considerable potential to predict simultaneously numerous meat quality attributes (De Marchi, 2013) after further refinement of the technology.

Thus far the only real commercial application of this technology in terms of carcase traits has stemmed from the work in the USA by Shackelford, et al. (2005; 2012) and similarly Rust et al. (2008) where the technology has been found robust under commercial conditions and useful for classifying beef carcases based on their predicted sliced shear force allowing sorting of carcases into different tenderness groups. Additionally a similar concept has also been proposed for lamb carcases (Kamruzzaman, et al. 2013) where they could be sorted into tender and tough with reasonable accuracy. However with refinement of more recent techniques where VIS-NIR spectroscopy measurements have been taken on the surface of carcases (De Marchi, 2013; McDonagh, 2014, Unpublished data) the technology could be even more applicable and attractive for industry. Clearly more work on this technology to move it from concept to application is required.

1.2.5 Nuclear Magnetic Resonance (NMR)

NMR is based on the absorption and emission of energy in the radiofrequency range of the electromagnetic spectrum. All nuclei that contain odd numbers of protons or neutrons have intrinsic magnetic moment and angular momentum. The most widely explored NRM in meat science is proton relaxometry. The use of relaxometry has been highly successful due to its ability to characterise water and structural features in heterogeneous systems like meat (Damez & Clerjon, 2008).

Despite many studies reporting the ability for NMR predict important meat quality traits such as pH, sarcomere length, WHC, tenderness and juiciness there are only limited results determined for red meat with predominantly most research outcomes relating to pork as shown in recent reviews by Damez & Clerjon, (2008); Damez & Clerjon, (2013); Pearce, et al. (2011). Results in beef by Tornberg, et al. (2000) demonstrated a close relationship between NMR and pH. Additionally Pearce, et al. (2008) were able to demonstrate a moderate relationship between shear force and NMR in sheep carcases.

Based on the literature it would appear that a further research into the effects of NRM for sheep and beef would be required before we could accurately determine the effectiveness of this technology for the red meat industry. Given the high costs involved with NMR (Damez & Clerjon, 2008; Laurent, et al. 2000) it would seem that this technology is far from a commercial reality and previous Sheep CRC research with a portable NMR machine supports this Pearce, et al. (2008).

1.2.6 Raman Spectroscopy

Raman Spectroscopy is a vibrational spectroscopy technique that relies on inelastic scattering of monochromatic light, usually from a laser in the visible, IR, or near-UV spectra (Damez & Clerjon, 2008). This technology has great potential for biochemical tissue analysis at both the macroscopic and microscopic scale. Until the 1990's Raman spectroscopy was ignored due to low efficiency, complex and expensive instrumentation, however, low-cost high-performance bench top instruments are reportedly widely available (Beattie, et al. 2008).

The potential of Raman spectroscopy as a rapid non-destructive technique for prediction of tenderness and juiciness has been shown for beef in the spectral measurement and meat quality assessment in cooked beef meat that had been aged for 21 days (Beattie, et al. 2004). A separate study in sheep investigated a prototype hand held Raman system which was used as a rapid non-invasive optical device to estimate tenderness and cooking loss on *longissimus thoracis et lumborum* aged for 5 days and then frozen. Results from this study showed robust correlations could be made for both shear force and cooking loss. Conclusions were that there is potential to use Raman spectra during meat processing (Schmidt, et al. 2013). In a recent study by Fowler, et al. (2014) using the same prototype hand held Raman system as Schmidt, et al. (2013) it was determined that higher R^2 values (although still low) when compared to traditional predictors, sarcomere length, cooking loss, particle size and/or pHu were predicted for 5 day shear force in lamb *m. semimembranosus* using Raman and it was concluded that further work is warranted.

It can be considered that this is an emerging technology in meat science and this is reflected in the limited published data especially in terms of sheep and beef. Although hand held devices have been developed they do not have commercial capabilities and will require further development. Further research into the effects of Raman Spectra for sheep and beef would be required before we could accurately determine the effectiveness of this technology for the commercial use in the red meat industry.

1.2.7 Impedance Measurement

Damez & Clerjon, (2008) reported that impedance measurements were first recorded on meat in the 1930's. The measurement principle of bioelectrical impedance is reliant on the difference in electrical conductivity between muscle and fat tissue (Slanger & Marchello, 1994). In schematic terms, biological tissues are composed of cells that are surrounded by an extracellular liquid. The cell membrane acts as an insulator at low frequencies, behaving like a capacitor (Damez & Clerjon, 2008). Biological tissue, particularly meat has an anisotropic impedance i.e. impedance varies according to whether the current runs parallel or perpendicular to muscle fibre (Damez, et al. 2007). Impedance of meat decreases quickly with rigor and continues to slowly decrease during storage (Damez & Clerjon, 2008).

The published literature shows that impedance has been used to determine a number of different meat traits in both sheep and beef including pH, fat content, tenderness, and ageing. Additionally reports have also shown how this technology can be used on live animals (Berg, et al. 1996) however the current review will not discuss those outcomes.

1.2.7.1 Impedance – Beef

Early work in beef by Marchello & Slanger, (1994) and Slanger & Marchello (1994) showed bioelectrical impedance was a useful tool in predicting total skeletal muscle and fat free muscle in beef carcases and primal cuts respectively. A study by Byrne, et al. (2000) investigated the accuracy of impedance for predicting meat quality traits and pH. It was concluded from this study that electrical properties relate some way to rate of glycolysis, but it was not suitable for early predictions of meat quality traits. The measurements that were taken over the ageing period for meat quality were moderately to highly correlated. In a review by Ferguson, (2004) it was reported that the Danish Meat Research Institute developed a hand held bioelectrical impedance system specifically for the purpose of on-line prediction of IMF% in beef carcases which had been reported to achieve a high level of accuracy.

Additional work in beef looked at the prospect of being able to predict rate of ageing given that this can vary dramatically between animals. Lepetit and Hamel, (1998) determined it was possible to select meats which age rapidly if the state of ageing is known at 48 hours *post mortem*. This would have benefits to industry as a means to reduce storage costs of meat that has rapidly aged, but this would be challenging to apply practically.

1.2.7.2 Impedance – Sheep

Berg & Marchello (1994) demonstrated that bioelectrical impedance was a useful tool in predicting fat free muscle in lamb carcases. Contrasting results were found in a study by Hopkins & Hegarty, (1995) that investigated the accuracy of multi-frequency bioimpedance analysis as a predictor for carcase composition in lambs, it was concluded that impedance offered no significant improvement over standard carcase measures for estimating dissectible muscle mass and suggested that a refinement in the methodology may be required. A more recent preliminary study by Hopkins & Wang (2012) investigating the application of impedance technology to predict lamb meat tenderness showed that differences in tenderness between samples are reflected by changes in impedance. Hence it was concluded that the technology could be used to screen meat into “tough” and “tender” categories at 1 day post mortem, but the ability to predict 5 day shear force from 1 day impedance was not totally consistent.

Based on the literature this technology has been demonstrated to accurately predict key yield and meat quality traits (tenderness and IMF %) and additionally determine ageing status at 48 hours. Despite the development of a hand held device it does not appear that this technology has been significantly tested under commercial conditions or been adopted in any significant way. Electrode placement in relation to fibre orientation will be a major issue for any future practical application.

1.2.8 Duel-energy X-ray absorptiometry (DXA)

Duel-energy X-ray absorptiometry (DXA), evolved from a similar technique, Duel-energy photon absorptiometry (DPA), and was originally developed to measure bone density in humans (Clarke, et al. 1999). The principle of DXA is to couple two absorption measurements, one at the low X-ray energies (e.g., 62 keV) dependent on both fat content and sample density, the other at higher energies (e.g., 120 keV) mainly dependent on density. Coupling and subtracting one from the other gives the fat content with great accuracy (Damez & Clerjon, 2013). DXA has been shown to analyse bone, lean and fat tissues as a measure of body composition (Clarke, et al., 1999). This technology has predominately been used in pigs, with increasing research in lamb and limited examination of the measurement of beef cuts.

1.2.8.1 DXA – Sheep

It was determined by Clarke, et al. (1999) that DXA could be used as a reliable method for measuring lamb carcase composition and distribution. This was based on outcomes where high correlations were shown for chemical analysis for % fat, fat mass and chemical lean. Also high correlations between estimates of lean, fat and weight of the leg region when compared to manual dissection were reported. This outcome was supported by the results of Mercier, et al. (2006) where it was concluded that DXA is an effective technology for predicting total weight and amount of lean and fat in lamb carcases and their primal cuts (shoulder, leg, loin, flank). Dunshea, et al. (2007) also demonstrated the efficacy of DXA as a non-destructive method for determining the composition of sheep half carcases, based on the high accuracies made for total tissue mass, lean tissue mass, fat tissue mass and bone mineral content. Pearce, et al. (2009) showed similar results and concluded that DXA was not only an effective research tool, but also has the potential for online lamb carcase grading.

1.2.8.2 DXA – Beef

A study was undertaken to examine the composition of 9th, 10th and 11th rib section from beef, by scanning each section twice and comparing scanning position to manual dissection (Mitchell, et al. 1997). It was concluded that high correlations between DXA and dissection indicate that DXA could be used as a non-destructive method for evaluating composition of cuts of beef; however attention does need to be given to the orientation of cut during scanning.

Based on the literature it can be concluded that DXA is an effective technology for determining composition of meat for both sheep carcases and beef primal cuts with a high level of accuracy. Commercial applications have been developed to measure fat content at line speed and determine foreign bodies (Damez & Clerjon, 2013). A limiting factor for DXA in the past has been its speed however Damez & Clerjon, (2013) stated that widespread online utilisation is not far off, as data acquisition with DXA apparatus is becoming increasingly rapid. This poses the question how much value do processors place on the knowledge of body composition and how would they use the resultant data and recover costs.

1.2.9 Computer Tomography (CT)

CT has been used for diagnostics in humans since the 1970's and during the 80's it was applied to predict animal carcase tissues initially in pigs and recent work has paved the way for commercial use in the pork industry (Jensen, et al. 2011). Work has also occurred in sheep (Kongsro, et al. 2008) and now more recently beef primal cuts (Navajas, et al. 2010). In vivo use of CT is also applicable to small stock like sheep and pigs (Standford, et al*.,* 1998), but results from this method will not be discussed in this review. CT is based on the variable absorption of X-rays by different tissues, it provides a different form of imaging known as cross-sectional imaging. The origin of the word "tomography" is from the Greek word "tomos" meaning "slice" or "section" and "graphe" meaning "drawing." The CT imaging system produces cross-sectional images or "slices" of anatomy, like the slices in a loaf of bread. Navajas, et al*.* (2010) reported that there are two main CT scanning methods. The first to be developed was sequential scanning, in which individual cross-sectional images are collected. This method has commonly been used in breeding programmes (Macfarlane, et al. 2006). The second and more recent is the spiral CT scanning, where the X-ray tube rotates continually in one direction while the object is mechanically moved through the X-ray beam. The transmitted radiation takes on the form of a helix. This technology is able to capture very detailed information and has allowed new assessments of relevant compositional traits to be explored (Navajas, et al*.* 2010).

1.2.9.1 CT – Sheep

A recent study by Kongsro, et al. (2008) designed to evaluate the ability of CT to virtually dissect lamb carcases to determine muscle, fat and bone tissue compared to manual dissection showed that CT was more precise and reliable than manual dissection. A later study by Kongsro, et al. (2009) which aimed at predicting the fat, muscle and value of lamb carcases showed that CT achieved the best prediction models when compared to Vis-NIR, carcase shape and length measurements and EUROP classification. But it was concluded that due to the high cost and low operating speeds of CT that Vis-NIR combined with a CT dissection reference may be the next best alternative.

1.2.9.2 CT – Beef

In terms of beef obviously there are limitations in the application of CT technology for scanning whole carcases, but recent research has investigated the ability to assess whole primal cuts. Navajas, et al. (2010) showed that CT was highly accurate in predicting muscle, fat and bone tissue in beef primal cuts and additionally whole carcase tissue. It was concluded from this study that CT scanning may deliver very accurate information on beef carcase composition faster and with lower cost than physical dissection and without damaging or depreciating the primal cuts. These outcomes were supported in a study by Prieto, et al. (2010) in terms of CT's ability to predict fat, muscle and bone. This study also examined CT ability to predict technical (colour, shear force), sensory traits, IMF and fatty acid composition. Although accurate predictions could be achieved for fatty acid composition and IMF, low accuracies were shown for technical and sensory parameters.

1.3 Summary table

Table 1. Summary of various online measures technology capabilities in terms of species (beef, sheep, both), traits, benefits, limitations and whether or not the technology is commercial.

Technology	Species	Traits measured *	Benefits	Limitations	Commercial
VIA	Beef / Sheep	Yield predictions (LMY%, SMY% wholesale cuts) Fat colour	Fast Automatic Non-destructive Non-invasive Reasonable level of accuracy depending on algorithm.	Algorithms often need to be tailored to product type, which can be time consuming	Yes
VIA Chiller Assessment	Beef	Marbling Meat colour Fat colour Eye muscle area Rib fat depth SMY LMY IMF%	Fast Non-destructive Non-invasive Simple to use	Needs operator Algorithms often need to be tailored to product type, which can be time consuming	Yes
AUS-MEAT sheep probe (ASP)	Sheep	Fat depth	Fast Accurate Simple to use Non-destructive	No longer serviced or manufactured Invasive	Has been
Hennessy Grading Probe (HGP)	Beef /Sheep	Fat depth Yield prediction Meat colour[b] Muscle depth[s]	Fast, non-destructive	Limited published information to support ability to measure traits, invasive	Yes, mostly in pork industry, but has been used in beef.

Technology	Species	Traits measured *	Benefits	Limitations	Commercial
VIS/NIR	Beef / Sheep	Chemical components Shear force WHC[b] pH Colour Sensory Age[s] Marbling	Fast, Non-destructive, Non-invasive, Cost effective, Potential to measure multiple traits	Need complex data analysis, Need to standardize reference methods.	Potentially for classification of beef carcases
NRM	Beef/Sheep	Tenderness pH	Non-destructive, Non-invasive Highly correlated with Lipid, water, and protein content	Expensive, Requires special shielding, Slow, Limited research results for sheep and beef.	No, experimental
Raman Spectroscopy	Beef/Sheep	Tenderness Juiciness Cooking loss Fatty acids Purge pH	Non-destructive, Non-invasive	Slow, Prototype phase	No, experimental
Bioelectrical Impedance	Beef – carcase/primal Sheep	pH Fat content Ageing Tenderness Muscle mass	Non-destructive, Inexpensive	Invasive	No, experimental

Technology	Species	Traits measured *	Benefits	Limitations	Commercial
DXA	Sheep/ Beef primal	Fat Muscle Bone	Highly accurate body carcase composition and primal cuts Non-destructive Non-invasive	Requires special shielding, Slow, No work on beef carcase	Under development with JBS and Sheep CRC
Computer Tomography (CT)	Sheep/ Beef primal	Fat Muscle Bone IMF	Highly correlated with IMF and body carcase composition, Non-destructive, Non-invasive	Not suitable for whole beef sides as no suitable equipment Expensive Calibration, slow	Not currently used online at abattoirs, Used in breeding programmes

* As shown in the published literature

1.4 Conclusions

As part of the need to meet the consumer demands and increase the consumption of red meat, it has been identified in the literature over the past 20-30 years that there needs to be a change from subjective to objective evaluation of carcass yield and quality traits, hence there has been extensive research in this area. From the literature, it is clear that there are several measurement technologies that have the capacity to accurately measure carcass yield and/or meat quality traits, however, there are very few that have been proven to function online in challenging abattoir environments (i.e. moisture, sound, space, safety). Often the progression from a proof of concept prototype to an effective commercial technology is challenging and is seldom successful. It does appear that despite the significant amount of research in this area there is limited work on the commercial application. A greater understanding of Australian processor views is a paramount step into understanding how research can have a strategic approach to the adoption of old and development of new technologies for the red meat industry.

2 Projective Objective

1. To gain an overview of previous success and failings of the use of online measures in the red meat industry.

2. Identify any barriers to the successful adoption of current online carcase measures available.

3. Identify any barriers to the successful adoption of future online carcase measures available.

4. Develop a strategic guide based on information collected to increase the adoption rate of online measures.

3 Methodology

3.1 Development of Survey

3.1.1 Survey objectives

- Is to get a greater understanding of processor views into the value of online measurement technology.

- Understand which carcase yield and meat quality traits they place greater importance on based on their business model.

- Understand previous adoption of commercial online measurement technologies.

- Understand previous benefits or barriers to adoption of these current commercial online measurement technologies.

3.1.2 Target population

The target population of the survey was to get a significant cross section of industry including small, medium and large processors across multispecies with a focus on cattle, sheep and goats.

3.1.3 Data collection

The surveys were conducted over a 6 month period. Questions were strategically worded to ensure data is not skewed by factors such as seasonal variation for example 'Over the previous 12 months what percentage of livestock was purchased through the following methods….'.

The survey was developed using an online method called google forms, however, all surveys have been conducted in person with any follow up calls if necessary. The survey is attached see Appendix 1.

3.1.4 Statistical analysis

To analyse the ranks assigned to each trait a simple linear regression analysis, was used allowing the rank assigned to a trait by an abattoir to depend linearly on a trait effect, with the trait effects allowed to differ across states x size (of abattoir). So the model was as below:

Rank = baseline + Trait + State:Trait + Size:Trait + State:Size:Trait + error

Where, abattoir size was determined by number of employees (small, <100 staff, medium, 100<500 staff, large, 500+staff).

Other traits were analysed using a REML procedure in Genstat (Genstat 2014), which Contained fixed effects for quality or yield and plant size. Other analysis of data was used using general summary of statistics.

3.2 Consultation process

Initial contact with individual processors was made via the telephone. Once the initial contact was made an introductory letter was sent immediately via email. The introductory letter was developed to provide processors with further information regarding the project. This letter was aimed to aid the processor to determine the most suitable contacts within the company.

Please see Appendix 2 attached.

4 Results

4.1 Descriptive overview of surveyed abattoirs

In total, data was collected in face to face interviews with personnel from 65 abattoirs across Australia, with 19 from NSW, 18 from QLD, 11 from VIC, 5 from SA, 9 from WA and 3 from TAS. Abattoirs were strategically engaged to ensure a good cross section of the industry was represented on factors such as plant size (small =<100 staff, medium = 100<500 staff, large =500+staff), species (cattle, sheep and goat), hot bone / cold bone and state. A basic summary of statistics of abattoirs surveyed is shown in Table 2.

Table 2. Summary statistics of abattoirs surveyed.

	Max	Min	Average
Number of employees	2,100	4	433.7
Number of cattle killed per day	3,450	9	732.6
Chain speed per hour (cattle)	215	4	79.3
Number of sheep killed per day	11,000	20	3476.9
Chain speed per min (sheep)	13.2	0.25	6.6
Number of goats killed per day	3200	1	468.9
Chain speed per min (goat)	10	0.25	4.5

Significant differences ($P < 0.001$) were found between plant size for chain speed in beef and sheep, such that, large beef processors had significantly faster chain speeds when compared to medium processors and medium processors had significantly faster chain speeds than small processors. In sheep there was no significant difference between large and medium processors for chain speed, but they were both significantly faster than small processors.

Of the abattoirs surveyed 57% processed sheep, 73% processed cattle, 34% processed goat and 14% processed other species (including; deer, pigs, water buffalo, and camels) as illustrated Fig 1.

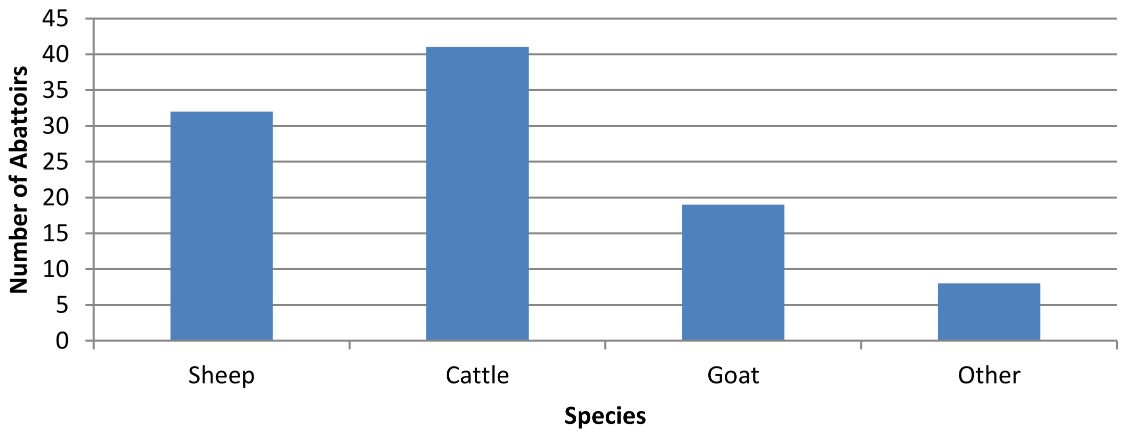

Fig 1. Number of abattoirs that process each species

4.2 Cattle

Cattle processors were asked to record which carcase yield and meat quality traits they currently measure and record (Fig. 2). This question was asked in the context that if they measure and record or use information on a regular basis, hence it does not have to be on every carcase. For example some processors will only measure certain traits for their MSA graded cattle.

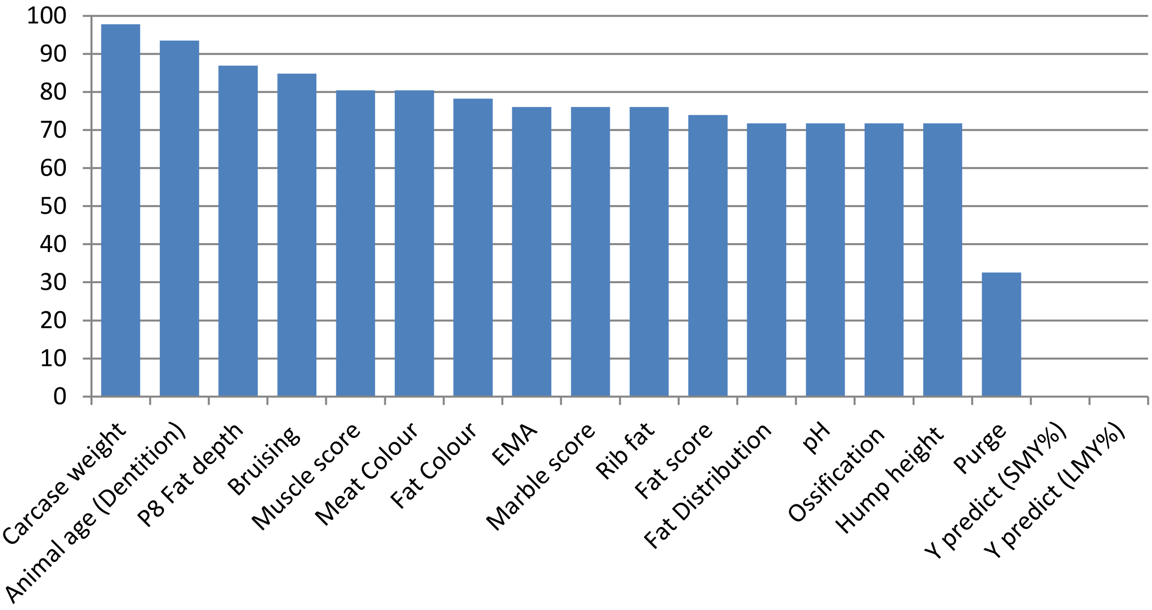

Fig 2. Percentage of beef abattoirs that currently measure and record traits.

From Fig 2 it is evident that none of the processors surveyed measure and record either yield prediction traits such as Saleable Meat Yield (SMY%) or Lean Meat Yield (LMY%). Nearly 100% of abattoirs surveyed measure carcase weight and P8 fat. In a follow on question, beef processors were asked how these traits are measured (subjective, objective or not applicable). On average across all traits where measurements were recorded 66% were conducted using subjective assessment. Hence 34% of measurements are conducted using objective measurements and are represented by the following traits; carcase weight, P8 fat, rib fat, pH, hump height and purge (Fig 3).

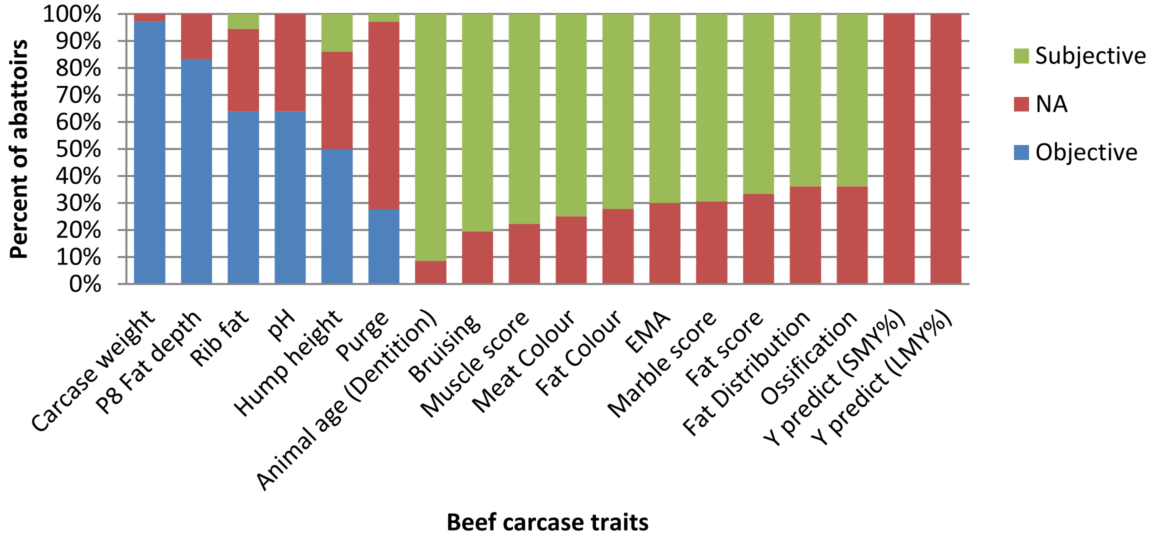

Fig 3. Percentage of abattoir that measure carcase traits either objectively or subjectively

Processors were asked to rank carcase yield and carcase quality traits in order of importance to their business in terms of online measurement technology, where 1 was the most important and 14 the least important. These traits included; P8 fat depth, meat colour, fat colour, tenderness, Eye Muscle Area (EMA), rib fat, marble score, intramuscular fat (IMF %), yield predict Saleable Meat Yield (SMY%) and Lean Meat Yield (LMY%), butt score, purge, pH and animal age. Based on these results it was shown that meat colour and tenderness are significantly ($P < 0.001$) the two most important traits and purge (described as an indicator of water holding capacity) the least important trait to the beef abattoirs surveyed (Table 3).

Table 3. Predicted value, standard errors and least significant difference (LSD) rank for ranked beef carcase quality and yield traits.

Trait	Predicted value	Standard error	LSD Rank
Meat Colour	3.26	0.55	a
Tenderness	4.76	0.55	ab
P8 Fat depth	5.93	0.55	bc
Marble score	6.35	0.55	c
Fat Colour	6.57	0.55	c
Y predict (SMY%)	7.04	0.55	cd
Animal age	7.08	0.55	cd
pH	7.18	0.55	cd
Y predict (LMY%)	7.22	0.55	cd
Rib fat	8.36	0.55	de
IMF%	9.31	0.55	e
EMA	9.82	0.55	e
Butt score	9.88	0.55	e
Purge	12.24	0.55	f

Fig 4. shows what percentage of processors that would use an online measurement tool in their business if it could measure the various carcase traits with a high level of accuracy. This data shows that over 70% of beef processors surveyed would use online measurement technology if it had a high level of accuracy for most traits except purge, rib fat, EMA, hump height and animal age. Based on these results, it further indicates that having an online measurement technology that can measure purge is of little value.

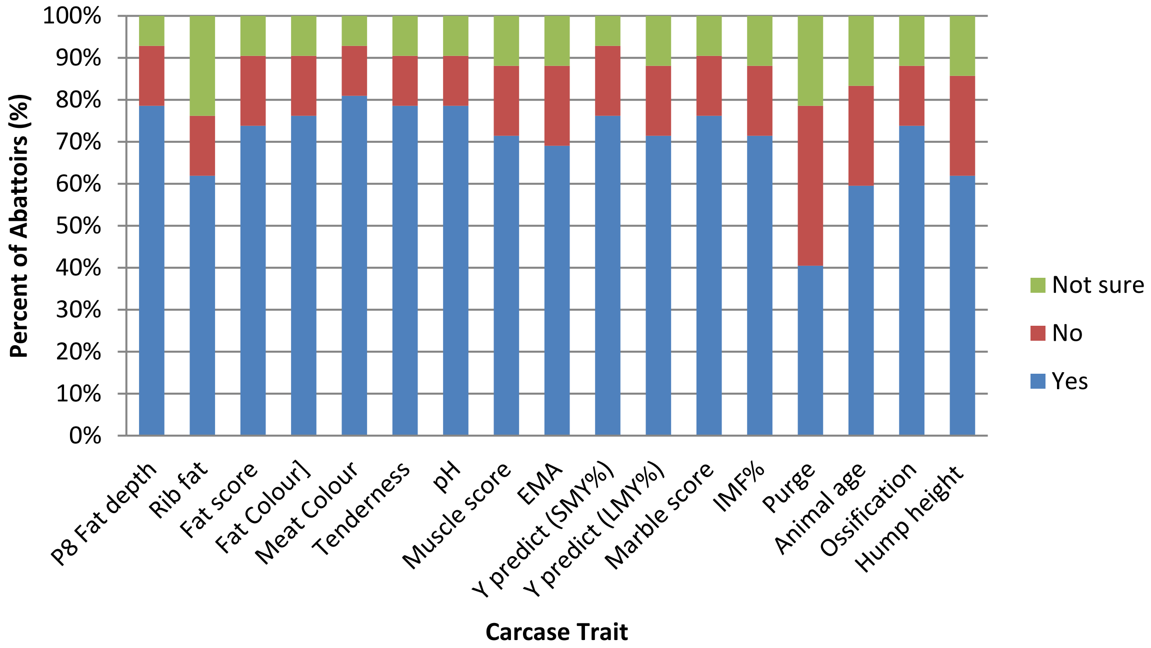

Fig 4. Percentage of beef abattoirs that would use an online measurement tool in their business if it could measure the various traits with a high level of accuracy.

4.3 Sheep

Sheep processors were asked to record which carcase yield and meat quality traits they currently measure and record (Fig. 5). This question was asked in the context that if they measure and record or use information on a regular basis, hence it does not have to be on every carcass. For example some processors will only measure GR for over the hook carcases.

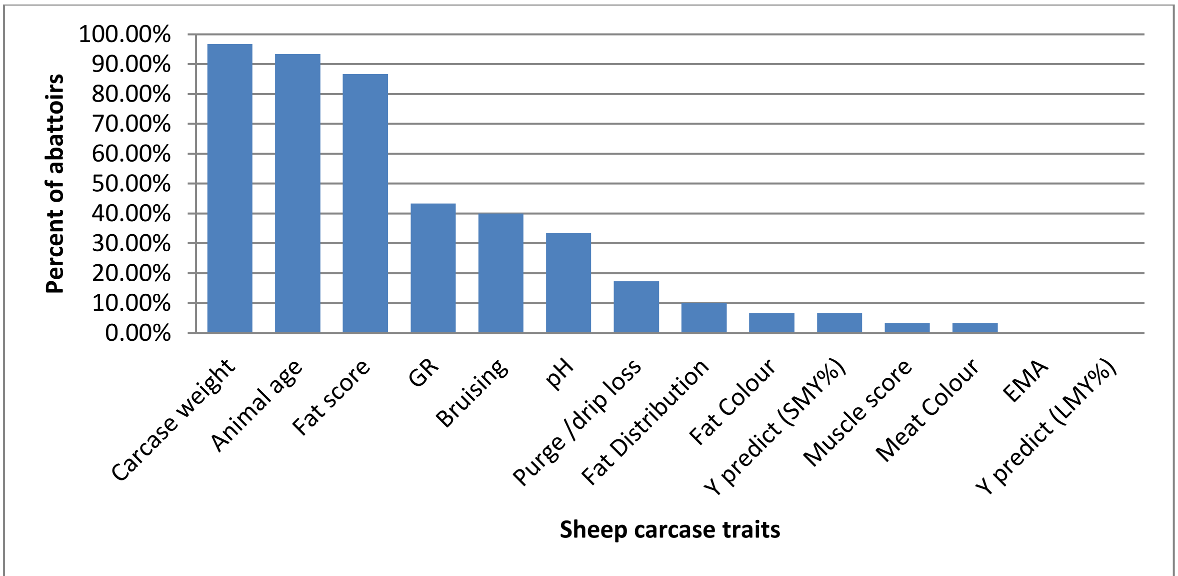

Fig 5. Percentage of sheep abattoirs that currently measure and record traits.

The majority of processors measure and record carcase weight, animal age and fat score (via physical palpation), this outcome is not surprising given these are the key factors which sheep and lamb carcases are traded on.

In a follow on question, sheep processors were asked how these traits are measured (subjective, objective or not applicable). On average across all traits where measurements were recorded 89% were conducted using subjective assessment. Hence only 11% of all measurements are conducted using objective measurements and are represented by the following traits; carcase weight, GR, pH, purge and yield predict saleable meat yield (SMY%).

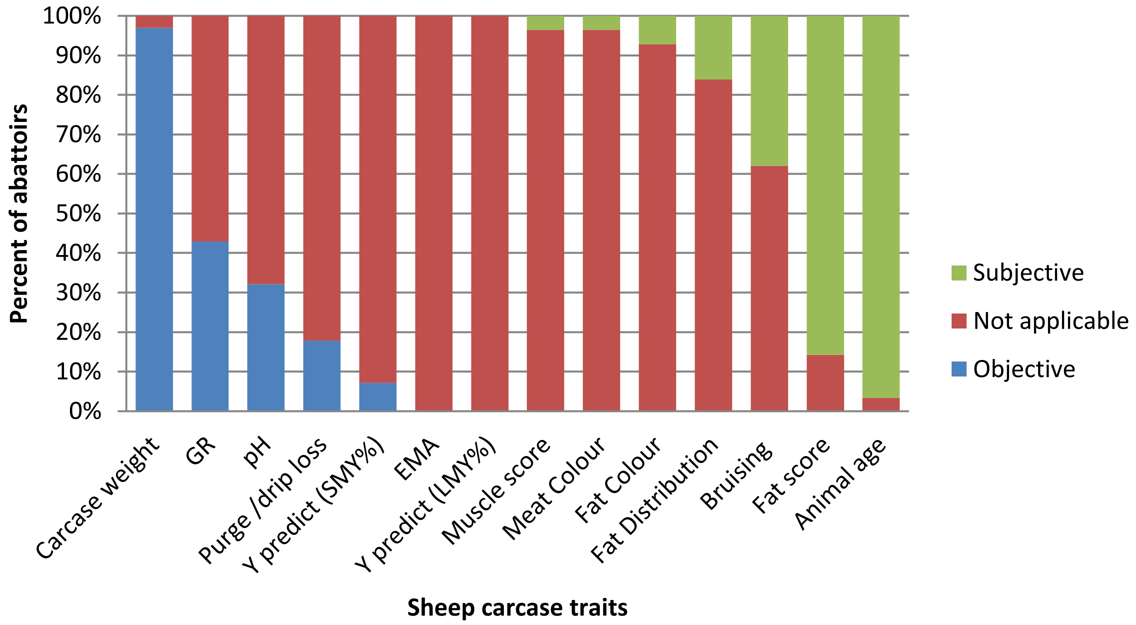

Fig 6. Percentage of abattoir that measure sheep carcase traits either objectively or subjectively.

Processors were asked to rank sheep carcase yield and carcase quality traits in order of importance to their business to have an online measurement technology, where 1 was the most important and 13 the least important. These traits included; GR, meat colour, fat colour, tenderness, EMA, marble score, IMF %, yield predict SMY% and LMY, purge, pH and animal age. Based on these results it was shown (Table 4) that tenderness was ranked as the most important, but was not significantly different ($P < 0.001$) to; pH, animal age, meat colour, GR or SMY%. Purge (described as an indicator of water holding capacity) and marble score were ranked least important respectively to sheep processors, but were not significantly different ($P < 0.001$) to; IMF%, muscle score or EMA.

Table 4. Predicted value, standard errors and least significant difference (LSD) rank for ranked sheep carcase quality and yield traits.

Trait	Predicted Value	Standard Error	LSD.Rank
Tenderness	4.41	0.64	a
pH	4.96	0.64	a
Animal age	5.36	0.64	a
Meat Colour	5.45	0.64	a
GR	6.11	0.64	ab
Y predict (SMY%)	6.11	0.64	ab
Y predict (LMY%)	7.46	0.64	bc
Fat Colour	7.5	0.64	bc
IMF%	8.09	0.64	cd
Muscle score	8.23	0.64	cd
EMA	8.64	0.64	cd
Purge	9.32	0.64	d
Marble score	9.36	0.64	d

Fig.7 shows what percentage of processors that would use an online measurement tool in their business if it could measure the various traits with a high level of accuracy. This preliminary data shows that around 70% of processors currently surveyed would use online measurement technology if it had a high level of accuracy for GR, tenderness and pH.

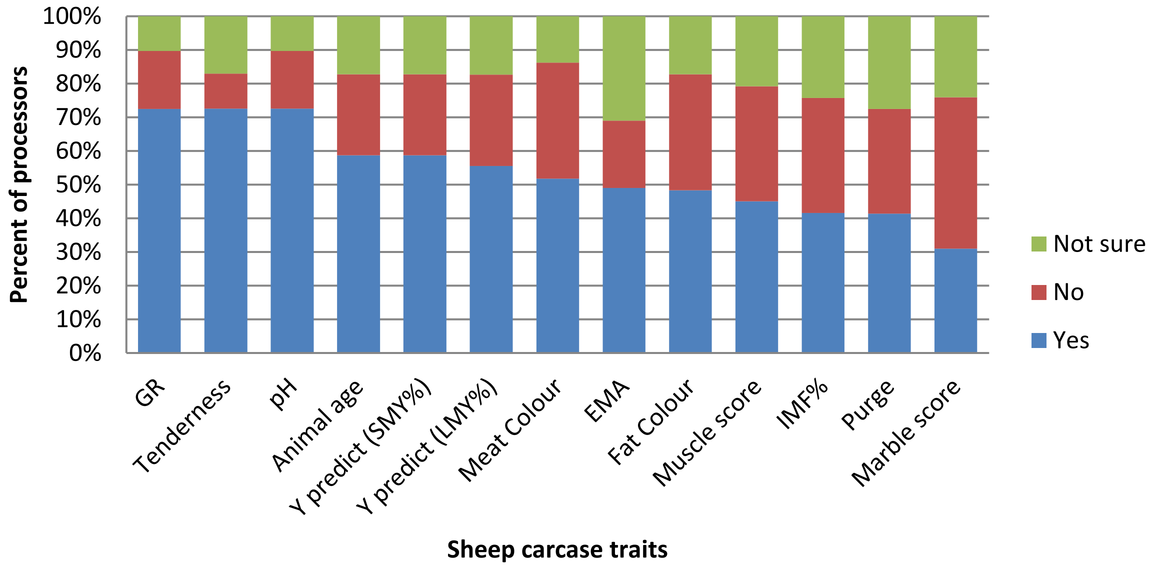

Fig.7 Percentage of sheep processors that would use an online measurement tool in their business if it could measure the various traits with a high level of accuracy.

4.4 Goat

When goat processors were asked what goat carcase traits do you currently measure and record? 75% of processors responded with carcase weight, 6.3% of processors responded with carcase weight and sex, 6.3% of processors responded with carcase weight and dentition and 12.5% of processors responded with nothing.

In a follow on open ended question which asked goat processors which yield and meat quality traits were most important to them the ranking was 47% carcase weight, 20% yield, 13% fat, 13% carcase conformation and 7% meat colour (Fig. 8).

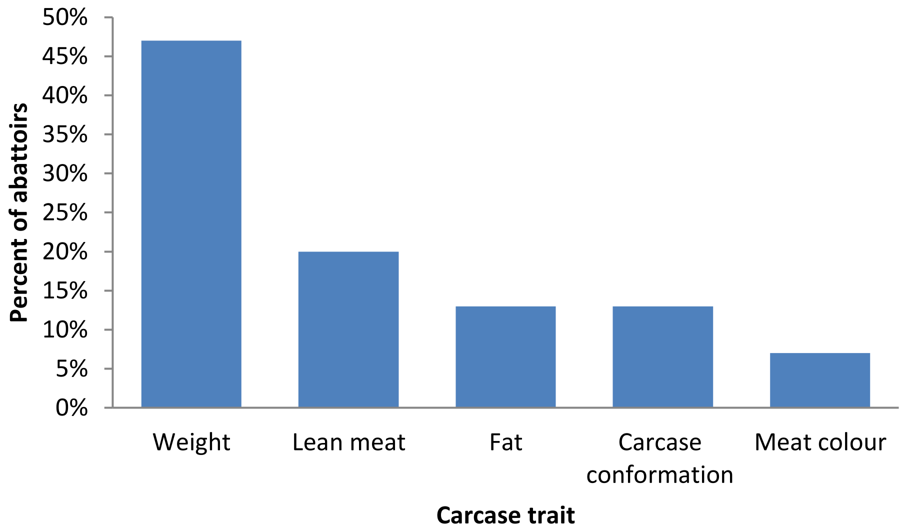

Fig 8. Most important carcase traits to goat abattoirs.

4.5 Current commercial technologies within Australia

4.5.1 VIAScan® Beef Carcase system

Of the beef processors surveyed, 86% of respondents said “yes” that they had heard of the VIAScan® beef carcase system before and 47% of respondents said “yes” their company had used or been involved with the VIAScan® beef carcase system. Of the 47% beef processors surveyed, 28% had trialled the technology and 19% had commercially used the technology. The majority of the 19% had used the technology at the request of the “customer” a major supply chain and 17% of beef processors surveyed went on to commercially adopt VIAScan® beef carcase system. This former reason can be a powerful motivation for adoption and change if facilitated well.

For the 17% of processors that adopted the technology, they were asked in an open ended style question “what were the benefits of the VIAScan® beef carcase system?” Few processors reported on any benefits, 18% said that the company was “happy with the technology, but not the business model” and 18% said that it ‘met the customer needs’ where 64% did not believe there was any benefit to the system. When 83% of beef processors who didn’t adopt the technology were asked in an open style question what "barriers to using the VIAScan® beef carcase system?" a major issue was the ongoing fee per carcase. Other responses have been grouped and listed in Table 5.

Table 5. Barriers to using the VIAScan® beef carcase system?

	Barriers
1	Have to pay on a per carcase
2	Business model from the supplying company
3	Was not seen as effective
4	Cost and confidence in the technology
5	Failed to meet business performance targets
6	It was hard to determine the cost benefit analysis as was a new area
7	Flexibility
8	Speed
9	Size
10	Not doing enough animals, didn't see the return from investment

Of the 17% of beef processors who originally adopted the VIAScan® beef carcase system 0% were still using the technology, some had removed the technology as recent as 2 years ago. The reasons for lack of use of the VIAScan® beef carcase system are listed in Table 6.

Table 6. Why VIAScan® beef carcase system is no longer used

	Why VIAScan® beef carcase system not used
1	No longer required by the customer
2	Over complicated
3	Slowed chain down
4	They went to MSA grading
5	Did not want to pay on a per carcase system
6	Poor business model

4.5.2 VIAScan® beef chiller system

Of the beef processors surveyed, 79% of respondents said "yes" that they had heard of the VIAScan® beef chiller system before and 42% of respondents said "yes" their company had used or been involved with the VIAScan® beef chiller system. Of the beef processors surveyed that said they had been involved with VIAScan® beef chiller system, 30% had trialled the technology and 12% had commercially used the technology. The majority of the respondents that had involvement with the technology were at the request of the "customer". It was determined that 9% of beef processors surveyed went on to commercially adopt the VIAScan® beef chiller system.

For the 9% processors that adopted the technology, they were asked in an open ended style question "what were the benefits of the VIAScan® beef chiller system?" responses indicate there were no apparent benefits other than meeting the customer needs. For the 91% of processors who didn't adopt the technology they were asked in an open style question what were the "barriers to using the VIAScan® beef chiller system?" a summary of responses are listed in Table 7. The most common reported barrier surrounding the technology was the functionality of the technology. Functionality was defined as how easy the technology is to use, weight of the unit, size of the unit and speed.

Table 7. Barriers to using the VIAScan® beef chiller system?

Barrier	Percentage of responses
Application to business	6%
Low confidence in technology	34%
Functionality - **Ease to use** - **Weight of unit** - **Size of unit** - **Speed**	42%
Still requirement for graders	9%
Other*	9%

Other* in Table 7 relates to responses that placed importance on quartering site where measurements were taken from. If for example there was moisture/water on the surface it would affect results for traits such as meat colour, fat colour, marble score. There was a potential to generate inaccurate EMA results if placement was not square on the quartering site and cuts made at the quartering site needed to be straight or it would alter dimensions.

No beef processors within Australia still commercially use the VIAScan® beef chiller system when asked in an open ended question as to why this technology is no longer used? The following responses shown in Table 8 were given.

Table 8. Why VIAScan® beef chiller system is no longer used

	Why VIAScan® beef chiller system not used
1	No longer required by the customer
2	Over complicated
3	Slow – found subjective grading system more efficient
4	If it broke down there was a requirement to have human back up graders on site
5	MSA grading program was adopted
6	As time went on had issues with servicing

4.5.3 VIAScan® Sheep carcase system.

Of the sheep processors surveyed, 50% of respondents said “yes” that they had heard of the VIAScan® sheep carcase system before. Of the sheep processors surveyed, two processors said they had used or been involved with the VIAScan® sheep carcase system. One was involved in the development and trialling of the technology and the other trialled and then went on to commercially use the technology.

For the processor that adopted the technology, when asked in an open ended style question “what were the benefits of the VIAScan® sheep carcase system?” it was reported that technology gave them;

1. “Marketing edge on feedback”
2. “Perception with customer was positive and a leading edge system”

3. “Producers getting genetic benefits”

When the sheep processors who didn’t adopt VIAScan® sheep carcase system were asked in an open style question what were the “barriers to using the VIAScan® sheep carcase system?” responses have been grouped and listed in Table 9.

Table 9. Barriers to using the VIAScan® sheep carcase system?

Barrier	Percentage of responses
Cost	8%
Wasn’t required / never considered	13%
Speed	3%
Waited to see if it was successful	8%
No response	68%

No sheep processor is currently commercially using the VIAScan® sheep carcase system. Reasons for this are listed below;

- Supplier company had changes in management frequently
- Technical support was poor as unable to reach when needed
- Premiums offered for producers but then it actually scared some off as they thought that there was a discount.
- Was a real cost to business with supplier Annual fee + per animal Fee
- Was not financially applicable
- Accuracy was an issue
- Too many impediments to the system, too technical to fix and maintain, required equipment the plant could not access easily
- If there was a customer that would pay a premium for the use of VIAScan® the processor would use it.

4.5.4 AUS-MEAT sheep probe

Of the sheep processors surveyed, 71% of respondents said “yes” that they had heard of the AUS-MEAT sheep probe before and 30% of respondents said “yes” their company had used or been involved with the AUS-MEAT sheep probe. Of the 30% Sheep processors surveyed that said they had been involved with AUS-MEAT sheep probe, 3% trialled the technology and 27% commercially used the technology.

For the 27% of processors that adopted the technology, they were asked in an open ended style question “what were the benefits of the AUS-MEAT sheep probe?” these responses are given in Table 10.

Table 10. Benefits to AUS-MEAT sheep probe

Benefits	Percentage of responses
Gave online measure	12.5%
Objective	12.5%
Accurate at low speeds	50.0%
1 person job	12.5%
Would still use if not broken	12.5%

For the 73% of processors who didn't adopt the technology they were asked in an open style question what were the "barriers to using the AUS-MEAT sheep probe?" The most common reported barriers were, it was not accurate enough at faster chain speeds and was considered a waste of a person for little perceived benefit over fat score.

No sheep processors within Australia still commercially use the AUS-MEAT sheep probe when asked in an open ended question as to why this technology is no longer used? The following responses shown in Table 11 were given.

Table 11. Why AUS-MEAT sheep probe is no longer used

	Why AUS-MEAT sheep probe not used
1	No longer manufactured and sold
2	Can no longer get fixed or source spare parts
3	Line speed was too slow
4	No real customer demand

4.5.5 Hennessey Grading Probe

Of the processors surveyed, 75% of respondents said "yes" that they had heard of the Hennessey Grading Probe before and 36% of respondents said "yes" their company had used or been involved with the Hennessey Grading Probe. Of the 36% processors surveyed that said they had been involved with Hennessey Grading Probe, 4% trialled the technology and 32% commercially used the technology.

For the 32% of processors that adopted the technology, they were asked in an open ended style question "what were the benefits of the VIAScan® beef carcase system?" these responses are given in Table 12.

Table 12. Benefits to Hennessey Grading Probe

Benefits to Hennessey Grading Probe	Percentage of responses
Speed	39%
Accuracy	27%
Easy to train staff	30%
Less data input	4%

For the 68% of processors who didn't adopt the technology they were asked in an open style question what were the "barriers to using the Hennessey Grading Probe?" these responses are listed below;

- Advice was not up to accuracy at time
- Extra cost no perceived benefit
- Had concerns over accuracy
- Wasn't considered applicable to business but would consider now
- Only considered for beef
- Was not accurate for sheep
- Was never really pushed

All processors who adopted the technology (32%) continue to use the technology, so there appears to be a place for this technology in the beef industry.

4.6 Objective online grading

4.6.1 Information usage

Irrespective of species all processors were asked a series of questions to further understand how objective online measurement technologies could be further used in their business. When processors were asked "how would they use the information collected from potential online measurement technologies?", 77% of processors said they would make real time decisions on market suitability, 52% said they would market product differently, 58% said they would provide feedback to suppliers, 52% said they would derive a payment based system for suppliers and 20% said other.

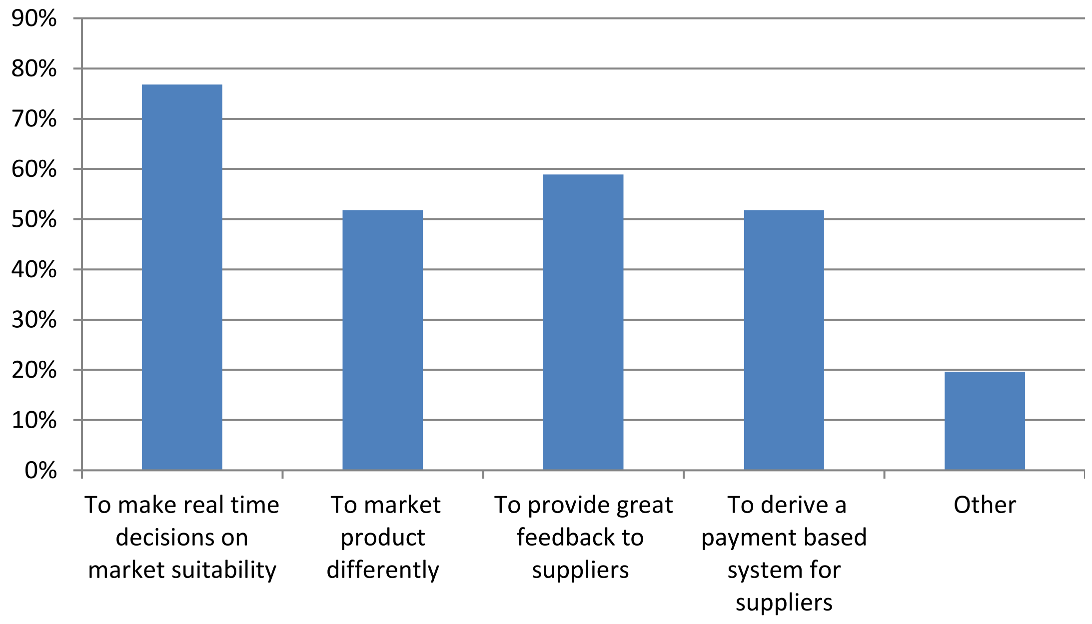

Fig 9. Percentage of abattoirs that would use information collected from online measurement technologies.

The "other" category responses were summarised and shown in Table 13.

Table 13. "Other" response summary of how information might be used from online measurement technology.

Response
Change Supply
Creditability
Grading feedback to suppliers
Means to be able to improve/benchmark the business product relates to producer relates to price
Performance based trend analysis
Try and predict shelf life
Would have to be adopted by all if payment system
Maybe in the future
Not applicable to business

4.6.2 Where technology should be implemented

Of the processors surveyed, 48% of processors would prefer to see any new online objective measurement technology to be implemented solely *pre rigor* on the slaughter floor and 14% said they would prefer any new technology to be installed solely *Post rigor* near chiller. However 38% of respondents would install technology either pre or post *rigor.*

4.6.3 Payback period for technology

Processors were asked what they consider a "reasonable payback period in terms of technology costs". They were asked to select from the following options < 12 months, 1-2 years, 3-5 years or 6-10 years. Of the processors surveyed 66% considered 1-2 years as the most reasonable payback period for new technology (Fig. 13). Statistical analysis also indicated that plant size had no significant effect ($P > 0.05$) on payback period.

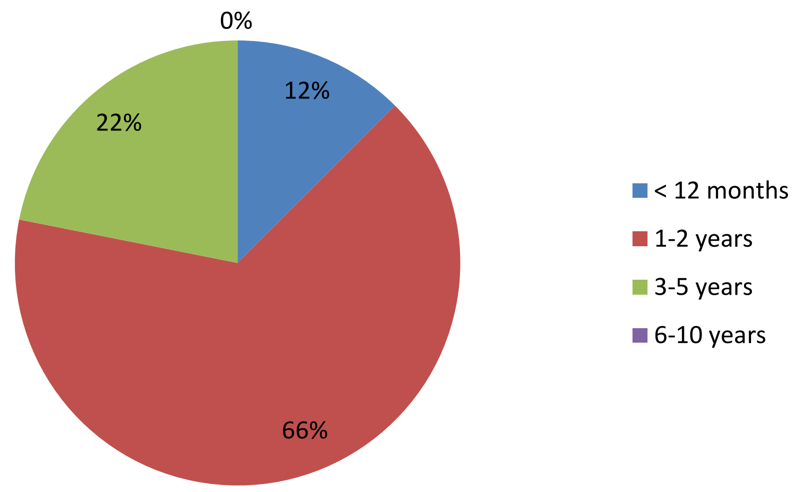

Fig 10. Percentage of processors that thought <12 months, 1-2 years, 3-5 years or 6-10 years was a reasonable payback for online measurement technology costs.

4.6.4 Level of technology accuracy

Based on results shown in Fig 11, 32% of processors surveyed considered that the level of accuracy needs to be greater than 95%.

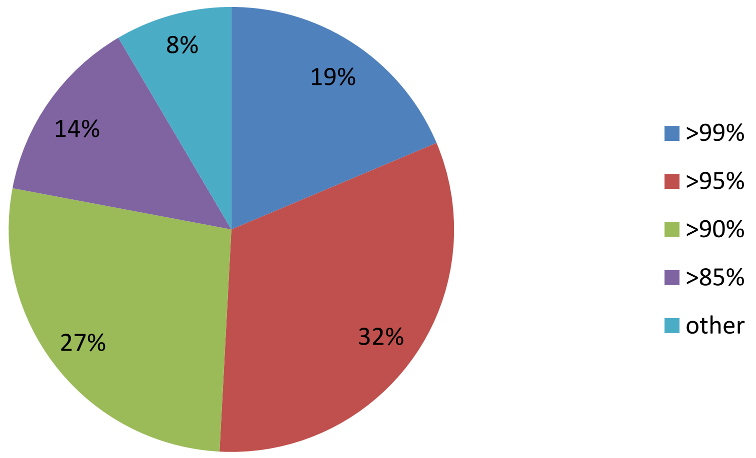

Fig 11. Level of accuracy considered acceptable for objective online measurement technology.

4.6.5 Importance of trait segregation

Processors were asked to rank on a scale of 1 to 5 (where 1 = not important and 5 = highly important) how important it was to their business to be able to segregate on both meat quality and meat yield traits now and in the future (Table 14). Results show that abattoir size had a significant ($P < 0.001$) effect on how important it is to processors to be able to segregate on both meat quality and meat yield traits now and in the future. Smaller abattoirs found it less important than medium ones and for medium ones it was less important than large (except there was no significant difference in level of importance between medium and large abattoirs for segregation of quality traits in the future). Irrespective of abattoir size all abattoirs thought that it will be more important to be able to segregate on meat quality and meat traits in the future compared till now (except there was no significant difference between now and the future on meat quality traits for large processors).

Table 14. Interaction between abattoir size (Small; medium; large) and how important it is to segregate (now or future) for meat quality or meat yield traits.

	Quality		Yield	
	Now	Future	Now	Future
Small	1.87ax	3.50ay	2.12ax	3.37ay
Medium	3.69bx	4.22by	3.37bx	4.56by
Large	4.20cx	4.70bx	3.60cx	4.80cy
Average s.e.d.	*0.44*		*0.41*	

Values followed by the same letter within a column (a, b) or row (x, y) are not significantly different at *P*=0.05

4.6.6 Importance of online grading systems to Australian processing sector

Eighty percent of the processors surveyed believe that online grading systems have a role in the Australian meat processing sector now, and 88% believe that they will play a role in the future Fig 12a, 12b.

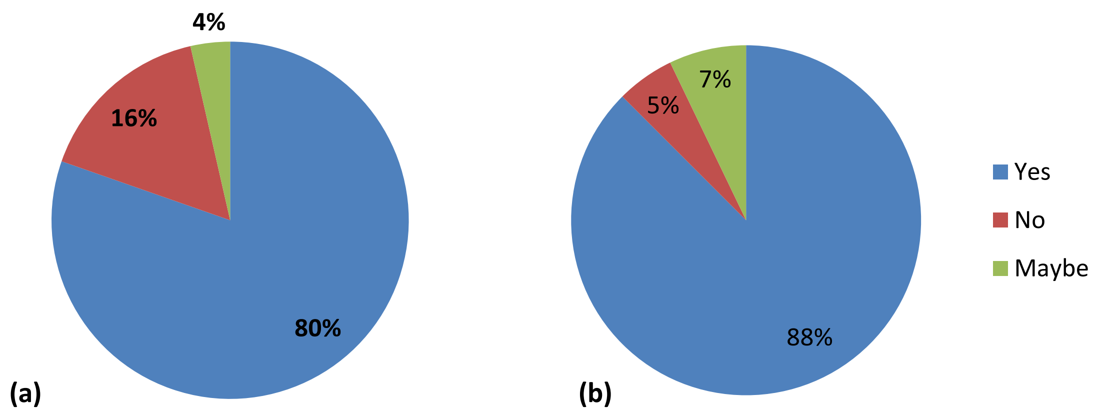

Fig 12. Percentage of processors that think online grading systems have a role now (a) and in the future (b) in the Australian processing sector.

When processors were asked if they like to see a new technology tried and proven before they adopt 64% of processors surveyed said yes (Fig.13).

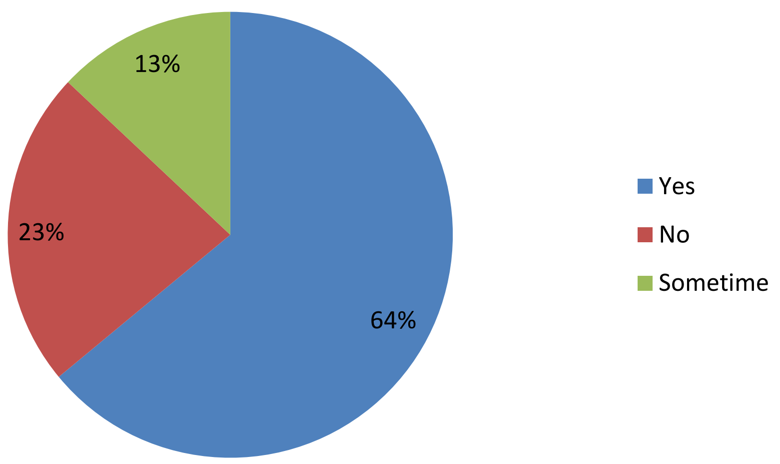

Fig 13. Percentage of processors that like to see technology proven.

4.6.7 Supplier faith in current measurement techniques

All processors were asked in an open ended style question if they had “concerns over supplier faith in measurements and accuracy?” 70% of processors surveyed said that they did have concerns while 20% did not express any concerns. Of the processors surveyed many responded with a simple “yes” or “no”, however some processors provided longer answers, Table 15, summarises longer responses for “yes” and “no”.

Table 15. Summary of responses for those abattoirs that answered "yes" or "no" to having concerns over supplier faith in measurements and accuracy.

Yes	No
Has to be accurate	Price is pre set
More detailed education	Solid suppliers
More of an issue for sheep	Open door policy to producers and good line of communication
Integrity is needed and important to business	Have flat grid
Hence would be good to have objective measurement	Close relationship with feedlotters
Comes down to market and what it accepts	Hold education days
Cattle traits - Dentition - P8 - Sex - Marble score - Meat colour - Butt score These traits can be big cost to producer if out of spec.	
Need confidence in accuracy of measurements	
Doesn't always think there is consistency between plants on economic important traits	
Consistency in grading between abattoirs	
If technology was in place it would decrease customer concerns by reducing the human error.	
Sheep traits - GR (fat depth at 12^{th} rib) - Dentition	

Additionally, 10% of processors did not specify if they did or didn't have concerns over supplier faith in measurements and accuracy mostly because it was "not applicable" to their business model as either they were not recording anything or they never purchased or owned the livestock. Another response inferred that they did not have concerns over supplier faith in the measurement and accuracy in terms of grading, but issues were more related to "external factors such as seasonal conditions" like sudden changes in temperature results in increased "dark cutting" or first 2 weeks of spring flush of feed and "increased yellow fat".

4.6.8 What can technology do meet the consumer demand for consistent quality?

Processors were asked in an open ended style question “Given consumer demand over consistent quality what do you think is required from technology to achieve this goal?” when answers were categorised (Fig 13) the most frequent responses were, accuracy (22%) and consistency/repeatability (25%). 11% of processors responded “nothing” and this response was in the context that either they do not see the need for online objective technology or that it would not be applicable to their business model. Other more frequent responses included; technology needs better source or determine individual cut quality (8%), be developed within a national standard like MSA or AUS-MEAT (5%), cost effective (4%), easy and simple to use (3%).

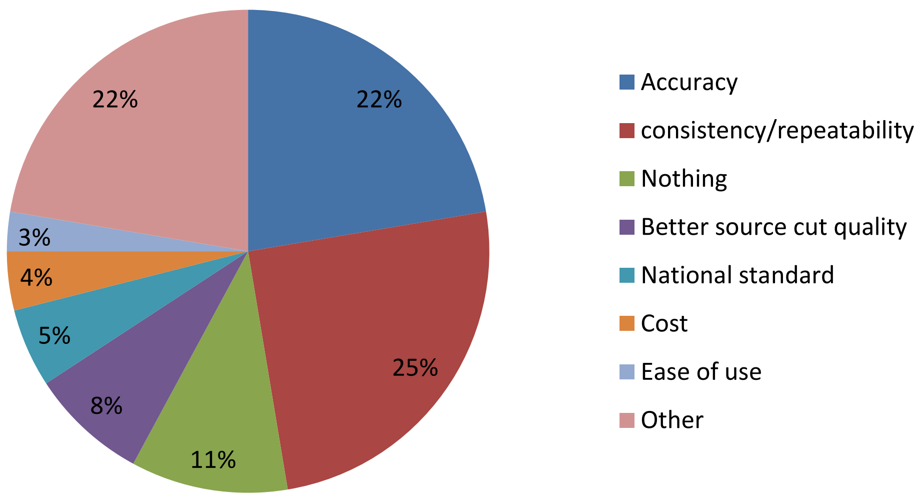

Fig 13. Processors responses to what they think is required from technology to meet consumer demand over consistent quality (%).

From Fig 13 it is shown that 22% of processors surveyed responded with responses which could not categorised in the above groups and has been termed as “other”. A summary of these responses are shown in Table 16.

Table 16. Responses categorised as "other" for what processors think is required from technology to meet consumer demand over consistent quality.

Responses categorised as "other"
Precision
Prove that technology can be done smarter and better than humans
In the last 3 years more people have been taking notice of what they are eating. Consumers want traceability of each product. Technology needs to bring this up to speed.
Deliver
To have a technology available to be able to find a way to validate, measure and manage; eating quality, food safety, nutritional value
Improved genetics greatest importance
Validate what we are grading
Speed up the process
Scientific backing
System that can be used and is affordable by all
Making more efficient to get quality
Replace subjectivity
A standard to operate by which is acceptable by the consumer
Define Eating Quality
Producer education and training

4.6.9 Hypothesised issues with new technology and barriers to technology adoption

In two open ended style questions processors were asked firstly "if a technology was developed for measuring a specific trait that meets all accuracy targets, what other issues need to be addressed before adoption were to occur?" and secondly "what are the common barriers to adoption of new technology?" the responses to these questions have been summarised together (Table 17). When the tally of summarised responses was examined, cost was the single most important factor reported, followed by size/space. Given these were open ended questions, processors were not prompted in their response and were able to provide unlimited responses for either question.

Table 17. Summarised barriers to adoption and issues around new technology.

Factor	Tally
Cost	50
Space/size	23
Chain speed/time	16
Ease of use	15
Access to Maintenance/technical support	11
Market acceptance	11
Supplier acceptance	11
Attitudes to change	9
Availability	9
Education and Training (staff, producers, customers)	9
Ability to use objective measures in small plant	8
Business model	8
Labour	7
Trust and transparency	6
Information Technology (IT)	5
National Standard	5
Accuracy	4
Consistency	3
Going first	3

A list of “other factors” reported by respondents is shown in Table 18. Both Table 17 and 18 highlight the diverse range in views from the 64 abattoirs surveyed.

Table 18. List of "other" responses not categorised for technology issues and common barriers to adoption for processors.

What other technology issues would need to be met before adoption to occur?	Other common barriers to the adoption of new technology?
• Future proofed, was the last processor trying to use sheep technology somewhat frustrated with the lack of longevity of servicing and support • Premium discount around measurement • Operate in industrial environment • Education for farmers/shareholders/board investigate other like companies • Robust validation plan • Calibration • It has to be able to enhance or not impact on eating quality, safe quality (micro, chemical, foreign object) and nutritional quality. • Has to have a well formatted/powerful report engine to summarise data deliveries in real time, show bench marking history. • Data needs to have a value proposition to the business. • Need to determine where the benefits really are – in-house, consumer, producer? • Where is commercial benefit • Non-critical breakdowns / can't afford to stop chain • Has to be fail safe • Suitability for business	• Trying new technology that are not commercially ready • Integrity • Commercial barriers • Industrial barriers • Political regulation • Technologies aren't up to delivering accurate assessments • Does what it is supposed to do • Adaptability to environment • Cost of up keep • Comparison to current systems • Research & Development • Access to information • In house development • Application

5 Discussion

From the survey data it is clear how diverse the Australian red meat processing industry is in terms of size (range in the number of employees 4-2100), scale of operations (per day through put range; cattle 9 to 3450; sheep 20 to 11,000; goat 1 to 3200) and differing business models (highly specialised species specific v's multispecies, animal type, method of purchase, end users and conventionally chilled operations vs hot boning). The results from this study strategically captured this diversity, in order to understand whole industry needs, given all models play an important role to the overall success of industry.

5.1 Previous and current commercialised online carcase measurement technologies within Australia

Gaining an insight in to how processors have viewed previous online future technologies is important for industry especially for the development of new online measurement technologies for the Australian red meat industry. This section discusses the five commercialised objective online carcase measurement technologies within Australia, as identified in the review of literature (section 1.1). Each technology is discussed in the context of how Australian processors have viewed the technology by outlining; initial adoption rates, benefits, barriers, current adoption rates and why there might be a change if any. Hence this section identifies any barriers to the successful adoption of previous/current/future online carcase measurement technologies available (Project objectives 2 & 3).

5.1.1 VIAScan® beef carcase system

VIAScan® (Cedar Creek Company) is one of five commercial companies worldwide who manufactures and services, Video Image Analysis technology for assessing whole beef carcases (Craigie, et al*.,* 2012), and the only company reported to supply the Australian red meat industry. Results from the current study showed that 86% of beef processors had heard of the technology, 47% had firsthand experience with the technology, and of that, 17% of processors surveyed commercially adopted the technology.

In the current study, processors were asked what the perceived benefits of the VIAScan® beef carcase system were. From the results it showed that 18% said that they were "happy with the technology, but not the business model" and 18% said that it "met customer needs" and 64% didn't respond. Based on these responses and other general discussions with processors there appeared to be a top down adoption strategy and there were few processors that felt they had any ownership of the technology, essentially it was more customer driven.

Processors that didn't adopt the technology were asked "what the barriers to adoption were?" These responses were summarised in Table 5, with most barriers associated with cost, but not necessarily regarding the outlay cost, but more importantly the "business model of the suppling company" and having to "pay per carcase assessed" hence there was an ongoing cost for the life of the technology. It was also said that it was hard to "determine the cost benefit analysis as this was a new area" in terms of the potential to incorporate value based trading and what the real payoffs would be. Other barriers listed were associated with the functionality of the technology including (speed, flexibility, size, effectiveness, confidence in the technology and ability to meet performance targets). These views might have been formed during the development or initial commercialisation phase of the technology especially given 39% of industry that had firsthand experience didn't adopt.

During the consultation process it was apparent that a major issue that has occurred with technology development and commercialisation of any new technology within Australian meat industry is that it has been marketed and sold before been 100% ready. These outcomes were also supported by Coleman (2013). The pressure for industry to try and get a return on investment via rapid adoption rates has potentially resulted in long term negative effects for the technology. Further, it is always hard to change perceptions around a technology, especially if "they" or someone they "know" has had firsthand negative experience. Hence future strategies need to be implemented to ensure that excessive exposure to a technology doesn't occur until it is commercial ready. It is fully understood that the step taken from development to commercialisation of any technology is big, and industry exposure is needed to achieve this, especially to fully test the robustness under commercial conditions, however expectations and roles of industry (processors) need to managed.

Despite Australian processors showing relatively early commercial adoption of this technology (during the 1990's) in comparison to other international processors (Craigie, et al*.,* 2012), alarmingly results from the current study show that no processors surveyed continue to commercially use this system. This technology had been removed as little as two years ago in some cases. In contrast to Australia, from the literature it appears that overseas, VIA beef carcase technology adoption rates have increased in recent times, and this is partly due to the fact that since 2004 it has been used as part of the EUROP Classification system (Pabiou et al., 2011). The utilisation of VIA for the EUROP classification system was driven predominantly by suppliers having little faith in subjective carcase assessment (Allen, 2006).

In order to avoid future failure in terms of adoption of this or any new technology it is critical to understand why? Results showed that the reasons for the discontinued use were functionality (slowed chain down and over complicated), but discontinued use was largely driven by the fact that the "customer no longer required it", "the poor business model of having to pay per carcase" and due the greater adoption of "MSA grading". It terms of functionality, progressions have been made with VIA technology to probably negate some issues (Craigie, et al., 2013; Pabiou, et al, 2011; Vote, et al., 2009). Improved strategies could be implemented to ensure continued adoption of technologies such as;

- Ensure that the technology is 100% commercial ready for use, so customer faith is not lost in the technology.
- Improved business models by the technology manufacturer, so that only a one off fee is required for the purchase of the technology.
- It would be advisable that any new online measurement technology should be incorporated and/or accredited by our national grading systems (AUS-MEAT and /or MSA), like in Europe and USA.

5.1.2 VIAScan® Beef chiller assessment system

VIAScan® (Cedar Creek Company) is one of three commercial companies worldwide who manufactures and services, Video Image Analysis technology for assessing beef meat quality and yield traits on a quartered side and the only company reported to supply the Australian red meat industry. Results from the current study showed that 79% of beef processors had heard of the technology, 42% had firsthand experience with the technology, and of that, 9% of processors surveyed commercially adopted the technology. When those that did adopt the technology where asked about the benefits and it was reported that it "met the requirements of the customer". During the interview process it was indicated that there was little choice in the adoption if they wanted to maintain their customer (as was the case with VIAScan® beef carcase system). This approach gives little ownership to the processor or desire to utilise, understand or reach full benefits of such a technology as it can be seen more of a regulation and tick the box requirement.

The perceived barriers for those that didn't adopt were that, 42% of respondents said it was due to functionality (ease to use, size, weight and speed of unit). Early versions of the technology were quiet heavy (5kgs) and were manually carried around the chiller and due to their size they were not easy to move around. The current system has a portable handpiece attached to a fixed computer (cedarcc.co.nz). Thirty four percent said they had "low confidence in the technology". Based on the literature it was shown that VIA was effective in predicting yield, EMA and Marble score (all adopted by USDA). It was reported in the current study that only 6% of processors believed that this type of technology had no "application to business" and when the responses were considered it was determined that these responses came from processors that were classified as small. From the responses it did not appear that there was any real solutions to breakdowns and hence 9% of respondents still reported that there was a "requirement for graders" that were qualified. Other logistical issues were also reported with regard to the importance of the measuring site needing to be cut square and free from moisture to avoid adverse effects on results generated. Although these later logistical issues are valid, good protocols, education and extension of these protocols would reduce these considered barriers in the future.

Current results show that no processors surveyed continue to commercially use this system. From the literature it appears that VIA carcase assessment systems are far better supported internationally. In order to avoid future failure in terms of adoption of this or any new technology it is critical to understand why Australian processors have not continued to support or increase adoption rates of a technology that is scientifically valid for measuring certain traits. Similar responses to the initial barriers to adoption and the discontinued use of the whole beef carcase system are sighted. The fact that it was "no longer required by the customer" and the lack of efficiencies gained in terms of "grading time" and "skilled labour" it was "not considered viable". Other issues were "lack of support for servicing and maintenance" and "lost value when MSA grading program was adopted".

Again, it is concluded here that high early exposure to a developing technology may have created a pre-set of negative connotations around the technology. The same improved strategies could be implemented to ensure continued adoption of technologies such as;

1. Ensure that the technology is 100% commercial ready for use, so customer faith is not lost in the technology.
2. Improved business models by the technology manufacturer, so that only a one off fee is required for the purchase of the technology.
3. It would be advisable that any new online measurement technology should be incorporated and/or accredited by our national grading systems (MSA), like what has occurred in Europe and USA.

5.1.3 VIAScan® Sheep carcase system

VIAScan® (Cedar Creek Company) is one of three commercial companies worldwide who manufactures and services, Video Image Analysis technology for assessing whole sheep carcases and the only company reported to supply the Australian red meat industry. Only 50% of the sheep processors surveyed had heard of this technology and of that only 2 processors trialled it and then only one processor commercially adopted the system. The benefits of this system indicated by the company included "marketing edge on feedback", "perceptions with customer was positive and a leading edge system" and "producer benefit of genetic gain". These outcomes support findings by Davidson & Pethick (2005) presented in a summary review of the benefits of the sheep VIAScan® system.

The main barriers reported by Australian processors in the current study were; cost, speed, wasn't required/never considered and others were waiting to see if it was successful. The technology is still installed at the company that adopted it however they no longer commercially use the system. The system is only used to determine the supplier (producer) of the month.

The processor was asked why they have discontinued use to fully understand the logic for this development, especially considering the technology has scientifically been proven to be successful under commercial conditions (Hopkins et al., 2004). The majority of reasons supplied were related to the dissatisfaction with the supplier company, including; "continued changes in management", "technical support not always available", "cost – with supplier annual fee + per animal fee". These results support the conclusion by Hopkins (2011) that the adoption strategy was flawed. Practical issues were also reported such as; the plant not been able to service or fix themselves, accuracy was not always maintained and the fact that the premiums offered to producers were not always seen as that. Some producers thought if they weren't going to meet specifications they were better off sending to alternative processors. These practical issues are major problem with technology adoption, having the skills to fix, service and or maintain in house are seen as very important to the majority of processors (Coleman, 2013). Hence, it is critical to have strategies in place to alleviate these concerns in the future. For example, have a preventative service and maintenance plan (like a motor vehicle) and scientifically determine optimal calibration periods. These should be included in future business models and cost benefit analysis. Ultimately it was deemed by the processor as not "financially applicable" but it was stated that they would use the technology if there was a "customer that would pay a premium for its use".

It is understood that VIAScan® sheep carcase system, has had greater success in adoption in New Zealand plants with one major company adopting (Jay, et al. 2014). This company holds a significant market share and processes 30% of New Zealand sheep. The business models of the plants that have adopted this technology are different to the majority of the Australian sheep processors. It appears that the companies that have adopted the technology are cooperative groups which are wholly and solely owned and supplied by their own farmers. Hence, the technology would be highly valued by these companies due to the whole supply chain benefit. Such a technology has the potential to provide (on farm benefits in genetic and nutritional management strategies based on feedback, and off farm benefits by better meeting customer specifications with increased product knowledge). With the greater adoption rates in New Zealand it could also be speculated that there is greater servicing and support for those processors.

5.1.4 AUS-MEAT Sheep probe

The AUS-MEAT sheep probe (ASP) was developed to objectively measure GR (fat depth over the 12th rib at a position 110mm from the backbone) in sheep carcases. 71% of sheep processors surveyed had heard of the technology, 30% said they had been involved with the technology and 27% had adopted the technology. Of the processors the adopted the technology they reported the benefits to be that; “it could be done online”, “objective”, “accurate at low chain speeds”, “1 person job”. These processor perceived benefits are support by the literature (Hopkins, 2011). Importantly, 12.5% of sheep processors that adopted the technology reported that they “would still use the technology if the technology was not broken”. One point that was not fully captured in the reported survey data was how simplistic the ASP was in terms of been able to fix and in house service. Two processors had actively sourced old second hand units for parts so they could continue using the system up until recently.

It was viewed by those processors who did not adopt the technology that the main barrier to adoption was accuracy rates at faster chain speeds. This is an important barrier for consideration of new technology. There is a need to future proof any new technology within Australia. From the descriptive results in the current study, it was reported that the fastest sheep chain speed was 13.2 per minute, while average was only 6.6. Aims, for any future technology would need to target above the current fastest chain (although not necessarily representative) to ensure long term currency given the continued aim of processing efficiency. The second most common barrier was waste of a labour unit for little perceived benefit over fat score. This response would be indicative of the company’s business model, in that having accurate measure of fat is not important (near enough is good enough) or their in house grading system is what sets them apart from the competition. Many small to medium size abattoirs pride themselves on the animal type they purchase and have many years of experience in subjective carcase grading and are able to deliver accurately what the customer wants. This way of thinking becomes invalid when the skill set is unavailable often in larger processing plants.

Despite 27% of processors adopting the technology, none currently use the technology, as eluded to previously. This is mainly because the technology is no longer manufactured and sold, and the technology can no longer be fixed or spare parts sourced. Additional reasons show that line speed was too slow and there was no real customer demand. It has been hypothesised by some, that the sheep industry did not really support this technology and that is why it didn’t work. However, considering the general rate of adoption of any new technology in this sector is slow, perhaps there was not enough lag time before processors were able realise / understand the benefits given the ASP was only scientifically proven in the early 1990’s and was no longer manufactured from the 2000’s. The patent on this probe has now lapsed and there is potential for it to be manufactured by another technology company, but service back up would be essential for any new development. Since Hennessy Grading Systems Pty Ltd appears to have a business model for the HGP, maybe they could manufacture a “new” ASP?

5.1.5 Hennessey Grading Probe

Hennessey Grading Systems Pty Ltd is a New Zealand based company that manufactures the Hennessey Grading Probe (HGP). Despite originally been developed in the late 1980’s for the pig industry and then later adapted for the beef industry and more recently being marketed to the sheep industry, 75% of processors had heard of the technology (some because of its reputation in the pork industry) and 32% of processors (all beef) have commercially adopted the technology.

From the industry consultation, adoption of the HGP was predominately amongst larger beef processors because of the speed, accuracy, ease of training and reduction of data input. Based on the results as to the barriers to adoption of this technology there is potential scope to increase adoption rates through further education and awareness. Many of the perceived barriers seem to be more about lack of current knowledge. Given the technology has been adopted by large beef processors, the logistical proof of principle has been demonstrated in terms of been able to train staff and achieve satisfactory accuracy levels (for beef) at increased production speeds. Some processors had indicated that their business models have changed and hadn't thought about the technology in recent times, others knew about it, but felt it was never really pushed. Based on the validations of the Australian sheep industry (Hopkins, et al., 2013; Siddell, 2012) it would not be recommended for the sheep industry unless the technology was enhanced. Thirty two percent of beef processors continue to use this technology commercially.

5.2 Understanding processor views on various traits

This section will discuss what measurements are currently recorded, what traits processors see as important to objectively measure online and if processors would use an online measurement technology to assess various traits if such a technology existed. This section will identify future barriers to adoption of online measurement technologies and strategies for adoption of future technologies by having a greater understanding of areas of greatest importance with regard to online objective technology.

5.2.1 Cattle

A large proportion of carcase traits are measured subjectively, with all meat quality traits been subjective, except pH. Not surprisingly nearly 100% of cattle processors surveyed, measure carcase weight, animal age (dentition) and P8 fat depth as these are the most simplistic and common language terms used to categorise and trade beef carcases (Anon, 2005).

No beef processors surveyed use an online technology to measure SMY% or LMY% despite the science supporting the capabilities of VIA to achieve this. Further to this over 70% of processors said they would use an online measurement to measure SMY% and LMY% if it had a high level of accuracy. These outcomes further support the need to ensure recommended strategies in section 5.1.1 and 5.1.2 are implemented especially if another technology is developed with similar capabilities.

Strategically beef processors were asked to rank in order of importance to their business the benefit of having an online measurement technology. This question was often the most challenging question for processors to answer given their knowledge of how different traits can interact with each other. As a result meat colour and tenderness were the most important traits, tenderness was not significantly different to P8 and purge was the least important. These results could be used for future strategic plans in terms of setting priority areas for online technology development. In the case of P8 fat where there is a current robust technology that is commercially available (HGP), there is scope to create new awareness of the technology with no need to develop a new technology in this space unless it could measure multiple traits.

5.2.2 Sheep

Similar to the beef results nearly 100% of sheep processors surveyed measure carcase weight, animal age (dentition) and fat score (physical palpation) as these are the most simplistic and common language terms used to categorise and trade sheep carcases (Anon, 2005). Compared to beef across all traits, sheep processors put a lower importance on the ability to have online objective carcase measurements. This result is most likely indicative that currently there are less sheep traits measured especially in the case of meat quality indicators such as meat colour and IMF%. The only three traits to be supported by over 70% of industry were tenderness, GR and pH, which are also supported in their ranked order of importance along with animal age, meat colour and SMY%.

In terms of future direction these outcomes raise questions for industry. In terms of GR, is it valuable to revisit and enhance ASP? One of the main practical barriers to this technology was chain speed. Hence, is it feasible to modify existing technology given software advances to meet and exceed chain speed requirements, perhaps it is feasible to have a manual and robotic version of the same technology to meet the needs of whole industry not just portions of the sector.

At the other end of the scale less than 40% of sheep processors saw value in adopting online measurement technology for marble score, purge, EMA, muscle score and IMF% and this too was supported in the way processors ranked the order of importance of these traits. These responses are most likely reflective of how businesses are currently run (product marketed) and hence a significant shift in processor mindsets may be needed in order to achieve adoption of these types of technologies in current times.

5.2.3 Goats

Australia is a relatively small producer of goat meat, but is the world's largest exporter of goat meat (Anon, 2013). Although there are fewer goat processors within the Australian red meat industry, this in an important and growing market for Australia, for example the Australian goat slaughter has increased from 1.63 million in 2011-2012 to 1.99 million in 2112-2113 (ABS). Goat meat is a significant protein source around the world particularly in developing countries (Biswas, Das, Banjerjee & Sharma, 2007). The fact that goats have the ability to survive and reproduce under adverse environmental conditions (SchÖnfeldt, Naudé, Bok, van Heerden, Smit & Boschoff, 1993) makes goat production extremely attractive to Australian farmers who operate grazing enterprises in rangeland areas.

In terms of the current study for goat processors the single most important trait was carcase weight which can already be captured objectively. Other traits of importance include LMY%, fat, carcase conformation and meat colour. During the consultation it was highlighted the importance of goat carcase conformation given this is a common method used to trade goats on the export market. Weight is not always a good indicator of conformation and hence having an objective tool to assess goat carcase conformation could assist in better meeting market specifications.

5.3 The potential roles of objective online grading and the value processors place on these.

(This section addresses project objectives 3 and 4)

Of the processors surveyed 80% agreed that online objective grading systems have a role in the Australian meat processing sector now and 88% see it for the future. This is a positive outcome in terms of the mindset of industry. As the literature suggests online objective grading tools have been developed and evaluated for over the past 20-30 years, hence industry has had enough exposure over this time to experience the short comings, but also the benefits of these technologies.

For the development of anything new, it is important to see how results might be used. Processors were asked “how they would use any information collected from online objective measurement technologies”. The fact that 77% of processors said they would use “to make real time decisions on market suitability, and just of half the processors survey said they would “market product differently”, “provide feedback to suppliers” and “derive and payment system” show that processors can see value and purpose. The challenge for the industry is to link these outcomes to be mutually beneficial for whole industry. Initiatives, like livestock data link in theory will help bridge some gaps.

In order to increase adoption rates of future technologies it was identified that pre-rigor on the slaughter chain was the most common response (48%) for where on the production line technologies should be implemented. Most responded that way to ensure they could get maximum benefit of the technology for real-time decision making. However 38% of processors where happy to put new technology either pre-rigor/pre-chiller or post rigor chiller, and most outcomes were set on the pretence that it would depend on the technology and what was the best fit, but often barriers are space and the cost to retro fit (Coleman, 2013). There was 14 % that said they would prefer technology to be based post rigor in the chiller and this was generally due to a space concern. Based on the outcome of this question if a technology was developed to measure traits pre rigor there is a greater proportion of industry that support this approach.

In order to capture the majority of industry, payback of online measurement technology costs needs to be 2 years or less. The current study indicates that if this occurs 78% of processors are more likely to adopt. This result is slightly contrasted to Coleman (2013) where only 55% reported 2 years or less as a reasonable payback, however the Coleman (2013) report was in the context of all technology for the meat processing industry. Hence this might suggest that processors want less risk for online measurement technology and would be less likely to spend as much money compared to other areas like waste water management.

The majority of processors wanted either >90% or > 95% level of accuracy. This was especially enforced if there was going to be a payment based system around the measurements. It will be a challenge to achieve these levels of accuracy. However from the literature (Cross & Belk, 1994), it has been proven that technology like VIA are able in significantly improve accuracy in measurements when compared to a subjective grader.

Thus strategies around increased education of industry, to highlight the use of technologies would be a step forward when compared to the current systems.

There were 70% of processors surveyed that indicated they had concerns over supplier faith and accuracy in current measurements. These concerns are why VIA technology was incorporated in the EUROP classification system, to essentially remove the subjectively and keep suppliers happy (Allen, 2006). There were concerns by industry that there is a lack of consistency in grading between plants especially with regard to economically important traits. This concern could be alleviated by a blanket approach across industry if there were suitable/viable technologies available. Irrespective of species animal age is one important economic trait that has the ability to significantly affect the price paid back to producers. Despite animal age not been ranked in the top three important traits to be measured objectively online, when processors were asked about concerns regarding supplier faith, animal age (dentition) was sighted the most contested trait by suppliers. Many processors indicated that it would be good to "show proof of dentition to suppliers if questioned, especially given the significant prices differences associated with dentition. Those processors who indicated that they didn't have issues with supplier confidence, indicated it was because of methods such as "open door policy", "education days", "flat grid or set price" or "long term relationship with suppliers".

Results from the current study indicate that irrespective of plant size there was a general trend that processors think being able to segregate on meat quality and meat yield traits will become more important to them in future compared to now, with exception of large plants where there is already a high level of importance for the future for quality traits. This also indicates that processors will find it more important to have the tools to do this in the future such as online measurement technologies.

The majority of processors surveyed prefer technology tried and proven before they adopt. This is largely about mitigating risk around being the "Guinea Pig" and hence the continued financial support from industry such as Plant Initiated Projects and Meat Donor Company projects are critical to the development of any new technology.

Accuracy and consistency were the two main factors processors indicated were needed from technology to deliver a consistent quality to consumer. Given the industry has worked hard to develop national standard such as MSA it is important new technology can work in with such grading systems.

In the current study "cost" was the most frequented response to what processors saw as the main barriers to adoption. This response and many others such as space and size, ease of use, access to maintenance and support, market and supplier acceptance, education and training, and labour are all consistent with the findings of Coleman, (2013). However, the current study also documented other unique responses that carry a consistent theme in terms of what has happened with previous technologies. For example, a response indicated that the technology need to be "future proofed" as they were "frustrated with the lack of longevity of servicing and support". Improved strategies during the development of the technology need to be factored in. An example of this would be to include maintenance protocols and formal training packages to better equip processors that have the staff skill and capability to in house service and maintenance to a level to ensure continued production can occur until external support can get there if needed.

6 Conclusions

Based on the processor consultation key important traits for online measurement technologies were identified for each species (cattle – meat colour, tenderness; sheep – tenderness, pH, age, meat colour, GR and SMY%; goat – lean meat, fat, carcase conformation and meat colour). The responses would indicate that overall there is support for online measurement technologies and it appears that this support will increase in the future, with the increased desire to be able to segregate on meat quality and meat yield traits. It could be concluded that if you were going to develop a new technology tomorrow to maximise adoption it is recommended implementing pre-rigor pre chiller, target chain speeds of 200-250/hr (cattle), 11-15/min (sheep) and 10-12 (goats); have a payback of 2 years or less; and have accuracy levels greater than 90-95%. While traditional barriers to adoption of technology were identified throughout this study (cost, space, ease of use, etc) more specific barriers were identified for online measurement technology. For example, of the five commercialised online measurement technologies that have been available to the Australian red meat industry, three were manufactured and serviced by the same company. Throughout the industry consultation it was apparent that the business model used to sell the technology was a major barrier even for those that had adopted the technology (outlay cost + annual fee + per animal fee). Other unique barriers for online measurement technologies is the need to be have national accreditation (AUS-MEAT and/or MSA) firstly to support the current programmes and secondly to generate customer confidence. It was also identified that there is potential to revisit some current technologies such as those to measure fat depth in both beef (Hennessey Grading Probe) to increase adoption and sheep (AUS-MEAT Sheep Probe) enhance existing concept. Strategies need to be in place for future development of online measurement technologies to ensure there is longevity, especially when you consider the lag time for adoption to occur.

The development and adoption of objective online measurement technologies is challenging and complex. Often with these technologies the benefits can easily be identified and often there are benefits identified across the whole supply chain; on-farm (e.g. improved management strategies for genetics and nutrition based on feedback), at the processor (e.g. improved accuracy, ability to make real-time decisions), and to the customer (e.g. satisfaction, improved meat quality). The complexity and challenge lies in making the pieces to the puzzle fit and been able to maximise the benefits to whole supply chain without one section been perceived to be getting a greater benefit compared to the rest. The processing industry holds key puzzle pieces to an integrated supply chain. Hence the area of processor adoption of online measurement technologies has the potential to achieve whole industry benefits and needs continued support.

7 Recommendations

1. Critical to manage expectations and roles of industry (processors) during commercial technology development “don’t oversell” till scientifically proven under commercial conditions.
2. Ensure that the technology is 100% commercial ready for use before showcased to industry, so customer faith is not lost in the technology.
3. Ensure business models of the technology manufacturer are viable.

4. It would be advisable that any new online measurement technology should be incorporated and/or accredited by our national grading systems (AUS-MEAT and MSA), like has occurred in Europe and the USA. Early engagement recommended.
5. Considerations for how equipment will be serviced and maintained (in-house or external) need to be incorporated at initial stages of the project and developed as necessary. These considerations may include;
    - Have a preventative service and maintenance plan (like a motor vehicle)
    - Scientifically determine optimal calibration periods.
    - Develop formal training packages, so knowledge is not lost with staff turnover.
    - Include these initiatives in future business models and cost benefit analysis.
6. Considerations should be made to building on existing technology concepts (ASP) and engage existing reputable manufactures to get greater critical mass to ensure; sustainability of manufacturing business, resources for technical support and quality.
7. Increase awareness of current successful technologies (eg Hennessy Grading Probe) to targeted groups (eg medium to large beef plants).
8. Use descriptive information to future proof longevity of technology (eg chain speed) and think ahead with targets.
9. Continued financial support from industry such as Plant Initiated Projects and Meat Donor Company projects are critical to the development of any new technology to mitigate risk.

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10 Appendix

10.1 Appendix 1 - Survey

The value of online measures- A processor perspective

Background Information

Company Name

[ ]

Position within company

[ ]

Company Location

[ ]

Please select State

[▾]

Other entities currently owned by Company?

- ☐ Property
- ☐ Feedlot
- ☐ Value add facilities
- ☐ Meat Retailer
- ☐ Meat distributor and or wholesaler
- ☐ Other food products
- ☐ Transport / Trucks
- ☐ Abattoirs
- ☐ Other: [ ]

Other entities previously owned by abattoir in 2004?

- ☐ Property
- ☐ Feedlot
- ☐ Value add facilities
- ☐ Meat Retailer
- ☐ Meat distributor and or wholesaler
- ☐ Other food products
- ☐ Transport / Trucks
- ☐ Abattoirs
- ☐ Other: [ ]

What species do you process at this plant?

- ☐ Cattle
- ☐ Sheep
- ☐ Goat
- ☐ Other: [ ]

How many chains do you have?

[ ]

Number of employees of the Abattoir?

[ ]

CATTLE

Cattle- General

On average how many cattle do you kill per day?

[ ]

On average what is your chain speed?

[ ]

Carcase type - please select relevant beef categories killed at your plant?

- ☐ Veal
- ☐ *YS* yearling steer - 0 permanent incisor
- ☐ *Y* yearling beef - 0 permanent incisor
- ☐ *YGS* young steer - ≤ 2 permanent incisor
- ☐ *YG* young beef - ≤ 2 permanent incisor
- ☐ *YPS* young prime steer - ≤ 4 permanent incisor
- ☐ *YP* young prime beef - ≤ 4 permanent incisor
- ☐ *PRS* prime steer - ≤ 7 permanent incisor
- ☐ *PR* prime beef - ≤ 7 permanent incisor
- ☐ *SS* steer any age
- ☐ OX *S* - female ≤ 7 permanent incisor up to 42 months/ male no SSC any age
- ☐ *C* cow with 8 permanent incisor all age
- ☐ *B* Bull

Of the categories selected above on average over the previous 12 months what percentage of the kill do they represent?

Over the previous 12 months what percentage of the kill would be hot boned?

Cattle - Suppliers and end users

Method of purchase - Which of the following methods of purchasing CATTLE has your plant used in the previous 12 months?

- ☐ Saleyard Auction
- ☐ Paddock/OTH
- ☐ Forward Contract
- ☐ Producer Alliance
- ☐ MSA
- ☐ AuctionsPlus
- ☐ Other: ____________

On average, over the previous 12 months, what is the percentage of CATTLE purchased for each of the above selected "method(s) of sale"?

Market Supply - please select the following which is relevant to your plant for CATTLE?

- ☐ Wholesaler - Service Kill
- ☐ Wholesaler
- ☐ Supermarket -Service Kill
- ☐ Supermarket
- ☐ Butcher - Service Kill
- ☐ Butcher

- ☐ Private
- ☐ Food Service - Service Kill
- ☐ Food Service
- ☐ Export
- ☐ Other: ____________

Market Supply - On average what percent of product would be processed for each of the selected "market(s) supplied" above?

Cattle- Trait Evaluation

Which of the following traits do you currently measure and record?

	Yes	No
P8 Fat depth	○	○
Rib fat	○	○
Fat score	○	○
Fat Distribution	○	○
Muscle score	○	○
Meat Colour	○	○
Fat Colour	○	○
EMA	○	○
Marble score	○	○
Y predict (SMY%)	○	○
Y predict (LMY%)	○	○
Purge	○	○
pH	○	○
Bruising	○	○
Carcase weight	○	○
Animal age (Dentition)		

	Yes	No
	○	○
Ossification	○	○
Hump height	○	○
Other	○	○

How do you measure the following traits?

	Subjective	Objective	Not applicable
P8 Fat depth	○	○	○
Rib fat	○	○	○
Fat score	○	○	○
Fat Distribution	○	○	○
Muscle score	○	○	○
Meat Colour	○	○	○
Fat Colour	○	○	○
EMA	○	○	○
Marble score	○	○	○
Y predict (SMY%)	○	○	○
Y predict (LMY%)	○	○	○
Purge	○	○	○
pH	○	○	○
Bruising	○	○	○
Carcase weight	○	○	○
Animal age (Dentition)	○	○	○
Ossification	○	○	○
Hump height	○	○	○
Other	○	○	○

Rank from 1 to 14 in the order of importance to your business the ability to have an ONLINE objective measure of following traits

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
P8 Fat depth	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Meat Colour	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Fat Colour	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Tenderness	○	○	○	○	○	○	○	○	○	○	○	○	○	○
EMA	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Rib fat	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Marble score	○	○	○	○	○	○	○	○	○	○	○	○	○	○
IMF%	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Y predict (SMY%)	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Y predict (LMY%)	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Muscle score	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Purge	○	○	○	○	○	○	○	○	○	○	○	○	○	○
pH	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Animal age	○	○	○	○	○	○	○	○	○	○	○	○	○	○

If there was a tool that could measure any of the below traits ONLINE with a high level of accuracy would use it in your business?

	Yes	Not sure	No
P8 Fat depth	○	○	○
Rib fat	○	○	○
Fat score	○	○	○
Fat Colour	○	○	○
Meat Colour	○	○	○
Tenderness	○	○	○
pH	○	○	○
Muscle score	○	○	○
EMA	○	○	○
Y predict (SMY%)	○	○	○
Y predict (LMY%)	○	○	○

	Yes	Not sure	No
Marble score	○	○	○
IMF%	○	○	○
Purge	○	○	○
Animal age	○	○	○
Ossification	○	○	○
Hump height	○	○	○
Other	○	○	○

SHEEP

Sheep - General

On average how many sheep do you kill per day?

On average what is your chain speed?

Sheep Category?

- ☐ Lamb
- ☐ Hogget
- ☐ Mutton
- ☐ Ram

Over the previous 12 months what percentage of the kill would each of the selected sheep category represent?

Over the previous 12 months what percentage of the kill would be hot boned?

Sheep - Suppliers and End users

Method of purchase - On average over the previous 12 months which methods of purchasing SHEEP have you used?

- ☐ Saleyard Auction
- ☐ Paddock/OTH
- ☐ Forward Contract
- ☐ Producer Alliance
- ☐ AuctionsPlus
- ☐ New Selling Option LMY
- ☐ Other: ________

On average, over the previous 12 months, what is the percentage of livestock purchased for each of the above selected "method(s) of sale"?

Market Supply - please select the following which is relevant to your plant for Sheep?

- ☐ Wholesaler - Service Kill
- ☐ Wholesaler
- ☐ Supermarket -Service Kill
- ☐ Supermarket
- ☐ Butcher - Service Kill
- ☐ Butcher
- ☐ Private
- ☐ Food Service - Service Kill
- ☐ Food Service
- ☐ Export
- ☐ Other: ________

Market Supply - On average what percent of product would be processed for each of the selected "market(s) supplied" above?

Sheep - Trait Evaluation

Which of the following traits do you currently measure and record?

	Yes	No
GR	○	○
Fat score	○	○
Fat Distribution	○	○
Muscle score	○	○
Meat Colour	○	○
Fat Colour	○	○
EMA	○	○
Y predict (SMY%)	○	○
Y predict (LMY%)	○	○
Purge /drip loss	○	○
pH	○	○
Bruising	○	○
Carcase weight	○	○
Animal age	○	○
Other	○	○

How do you measure the following traits?

	Subjective	Objective	Not applicable
GR	○	○	○
Fat score	○	○	○
Fat Distribution			

	Subjective	Objective	Not applicable
	◯	◯	◯
Muscle score	◯	◯	◯
Meat Colour	◯	◯	◯
Fat Colour	◯	◯	◯
EMA	◯	◯	◯
Y predict (SMY%)	◯	◯	◯
Y predict (LMY%)	◯	◯	◯
Purge /drip loss	◯	◯	◯
pH	◯	◯	◯
Bruising	◯	◯	◯
Carcase weight	◯	◯	◯
Animal age	◯	◯	◯
Other	◯	◯	◯

Rank from 1 to 13 in the order of importance to your business the ability to have an ONLINE objective measure of following traits

	1	2	3	4	5	6	7	8	9	10	11	12	13
Meat Colour	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Fat Colour	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Animal age	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Y predict (LMY%)	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Tenderness	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
IMF%	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
GR	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Muscle score	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
pH	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Purge	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
EMA	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Marble score	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Y predict (SMY%)													

If there was a tool that could measure any of the below traits ONLINE with a high level of accuracy would use it in your business?

	Yes	Not sure	No
GR	○	○	○
Meat Colour	○	○	○
Fat Colour	○	○	○
Tenderness	○	○	○
EMA	○	○	○
Marble score	○	○	○
IMF%	○	○	○
Y predict (SMY%)	○	○	○
Y predict (LMY%)	○	○	○
Muscle score	○	○	○
Purge	○	○	○
pH	○	○	○
Animal age	○	○	○
Other	○	○	○

Goat

Goat - General

On average how many goats do you kill per day?

On average what is your chain speed?

Goat Category?

- ☐ Kid - 0 Permanent incisors
- ☐ Capra - < 2 Permanent incicors
- ☐ Doe
- ☐ Goat Wether
- ☐ Buck
- ☐ Other: ____________

Over the previous 12 months what percentage of the kill would each of the selected goat category represent?

Goat - Suppliers and End users

Method of purchase - On average over the previous 12 months which methods of purchasing livestock have you used?

- ☐ Saleyard Auction
- ☐ Paddock/OTH
- ☐ Forward Contract
- ☐ Producer Alliance
- ☐ AuctionsPlus
- ☐ Other: ____________

On average, over the previous 12 months, what is the percentage of livestock purchased for each of the above selected "method(s) of sale"?

Market Supply - please select the following which is relevant to your plant for GOATS?

- ☐ Wholesaler - Service Kill
- ☐ Wholesaler
- ☐ Supermarket -Service Kill
- ☐ Supermarket
- ☐ Butcher - Service Kill

- ☐ Butcher
- ☐ Private
- ☐ Food Service - Service Kill
- ☐ Food Service
- ☐ Export
- ☐ Other:

Market Supply - On average what percent of product would be processed for each of the selected "market(s) supplied" above?

Goat - Trait Evaluation

What goat carcase traits do you currently measure and record?
Carcase weight, GR, Fat score etc

Of the carcase traits recorded for GOATS are they measured subjectively or objectively?

What carcase traits do you consider to be most valuable for GOATS?

Information usage

How would use information collected from online measurement technologies?

- ☐ To make real time decisions on market suitability
- ☐ To market product differently
- ☐ To provide great feedback to suppliers
- ☐ To derive a payment based system for suppliers
- ☐ Other: __________

What level of accuracy would you consider acceptable for a objective measurement technology?

- ☐ >99%
- ☐ >95%
- ☐ >90%
- ☐ >85%
- ☐ Other: __________

How important is it to your business to be able to segregate on meat quality traits NOW?

	1	2	3	4	5	
Not important	○	○	○	○	○	Highly important

How important is it to your business to be able to segregate on meat quality traits in the FUTURE?

	1	2	3	4	5	
Not important	○	○	○	○	○	Highly important

How important is it to your business to be able to segregate on meat yield traits NOW?

	1	2	3	4	5	
Not important	○	○	○	○	○	Highly important

How important is it to your business to be able to segregate on meat yield traits in the FUTURE?

	1	2	3	4	5	
Not important	○	○	○	○	○	Highly important

Current Technologies

VIAScan® Beef Carcass System

Have you heard of Video Image Analysis (VIAScan®) beef carcass system technology before?

Has your company ever used or been involved with VIAScan® beef carcass system before?

If so, how was your company involved with VIAScan® beef carcass system?

Was VIAScan® beef carcass system Adopted?

If so, what were the benefits VIAScan® beef carcass system?

If No, what were the barriers to the VIAScan® beef carcass system?

Do you still use VIAScan® beef carcass system?

If No, why do you no longer use VIAScan® beef carcass system?

VIAScan® Chiller Assessment System

Have you heard of Video Image Analysis (VIAScan®) chiller assessment system technology before?

Has your abattoir ever used or been involved with VIAScan® chiller assessment system before?

If so how were you involved with VIAScan® chiller assessment system?

Was VIAScan® chiller assessment system Adopted?

If so what were the benefits VIAScan® chiller assessment system?

If No, what were the barriers to the VIAScan® chiller assessment system?

Do you still use VIAScan® chiller assessment system?

If No, why do you no longer use VIAScan® chiller assessment system?

VIAScan sheep carcass system

Have you heard of Video Image Analysis (VIAScan®) sheep carcass system?

Has your abattoir ever used or been involved with VIAScan® sheep carcass system before?

If so how were you involved with VIAScan® sheep carcass system?

Was the VIAScan® sheep carcass system Adopted?

If so what were the benefits of the VIAScan® sheep carcass system?

If No, what were the barriers to the VIAScan® sheep carcass system?

Do you still use VIAScan® sheep carcass system?

If No, why do you no longer use VIAScan® sheep carcass system?

AUS-MEAT Sheep probe

Have you heard of AUS-MEAT sheep probe before?

Has your abattoir ever used or been involved with AUS-MEAT sheep probe before?

If so how were you involved with the AUS-MEAT sheep probe?

Was the AUS-MEAT sheep probe technology Adopted?

If so what were the benefits of the AUS-MEAT sheep probe?

If No, what were the barriers to the AUS-MEAT sheep probe?

Do you still use the AUS-MEAT sheep probe?

If No, why do you no longer use the AUS-MEAT sheep probe?

Hennessy Grading Probe

Have you heard of Hennessy Grading Probe before?

Has your abattoir ever used or been involved with Hennessy Grading Probe before?

If so, how were you involved with the Hennessy Grading Probe?

Was the Hennessy Grading Probe Adopted?

If so what were the benefits of the Hennessy Grading Probe?

If No, what were the barriers to the Hennessy Grading Probe?

Do you still use the Hennessy Grading Probe?

If No, why do you no longer use the Hennessy Grading Probe?

Objective Online Grading

Do you believe online grading systems have a role in the Australian processing sector NOW?

Do you believe online grading systems have a role in the Australian processing sector in the FUTURE?

Where on the processing chain would you prefer to see any new technology implemented?

- ☐ Pre-rigor on slaughter floor
- ☐ Post- rigor in chiller
- ☐ Other:

What do you consider a reasonable payback in terms of technology cost

- ☐ <12 months
- ☐ 1-2 years
- ☐ 3-5 years
- ☐ 6-10 years
- ☐ Other:

Do you have concerns over supplier faith in measurements and accuracy?

Given consumer demand over consistent quality, what do you think is required from technology to achieve this goal?

If a technology is developed for measuring a specific trait that meets accuracy targets, what other issues would need to be met before adoption to occur?

In your experience, what are common barriers to the adoption of new technology?

Do you prefer to see a technology tired and proven before you adopt?

10.2 Appendix 2. Survey letter

Dear

Re: Request for your assistance to participate in an industry study to identify the value of online measures from a processor perspective.

Both Meat and Livestock Australia (MLA) and Australian Meat Processing Corporation have jointly funded and contracted NSW Department of Primary Industries to gain an insight to processor views on the value of online measurement technology. Online measurement technology can be defined as an objective technology designed to capture carcase yield and/or meat quality traits at production speed either on kill floor or chiller.

As discussed on phone in order to achieve this we request you and other key staff such as production manger and marketing staff to participate in a short survey which will take approximately 40 minutes. Based on the outcomes of this research the aim is to achieve a more strategic direction of R & D funding to increase the profitability of the processing industry. All information collected will be confidential and will not be linked to your company or plant.

We expect to carry out this project at minimum inconvenience to your business and appreciate the opportunity for your participation in this study.

Should you have any specific questions please do not hesitate to contact me on my mobile 0447 218 040.

Yours sincerely

Edwina Toohey

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