1. General introduction

This chapter provides an overview of the thesis' background and a short discussion pertaining to Australia's beef feedlot industry problem. It will be followed by presentation of the thesis' purpose and outline. The strategic importance of the project will also be discussed as well as the purpose of the study.

The Australian beef feedlot industry is inefficient in the way it sources livestock and allocates them to market endpoints resulting in out of specification costs for the carcass traits, carcass weight, external fat depth, marble score and quality grade resulting in more than a quarter of all Australian cattle failing to meet market specification (McKiernen *et al.* 2007; Hobson 2009). These inefficiencies arise because no account is taken of the individual variation in an animal's initial conditions (i.e. at feedlot induction) or its potential to grow and deposit muscle, fat and bone throughout the feeding period. If initial composition and potential changes over the feeding period can be predicted with sufficient accuracy it would be possible to use sorting strategies to optimize the allocation of animals into groups to improve production efficiency and product consistency. Slaughtering groups of cattle with a common endpoint increases carcass uniformity (Tatum 1996; Trenkle 2001) and if managed correctly will increase the proportion of carcasses that meet market specifications at slaughter.

Supply chain alliances can help resolve some of the inefficiencies of the traditional fragmented beef production systems and increase competitive performance by using information feedback systems and moving from a product and sales philosophy to a marketing philosophy (Kotler and Keller 2006). Supply chain alliances ultimately create and increase value along a supply network by identification of weaknesses and strengths within the system;

and by generating increased value through identification and targeting of key performance indicators. Correctly integrating information from producers through to retail helps increase the efficiency of livestock allocation and helps to increase the number of carcasses meeting specification where this information is used properly. Information sharing and coordination between producers and retailers was shown by Tronstad and Unterschultz (2005) to help meet consumer preferences by an increase in carcasses meeting specification with greater consistency whilst maintaining high production efficiency. In the United States the Ralph's-Sunland Beef alliance analysed by Tronstad and Unterschultz (2005) showed production opportunities could be identified and implemented to meet consumer requirements through value based pricing along the supply chain alliance. Through a process of supply chain alignment, supply chain alliances become an integrated structure that removes open market transaction based trades and clarifies and defines production strategies that result in mutual benefits for supply chain partners (Handfield and Nichols 2002). Benefits to businesses that participate in supply chain management are increased production efficiency and improved cost competitiveness through collaboration and coordination (Tsung-Hui and Jen-Ming 2005; Cachon and Lariviere 2005); improved product quality and integrity; better initiation of new product development and business opportunities; broader market access and reduced marketing risk; advanced quality assurance; streamlined information transfer and increased long-term viability (MLA 2006).

Efficient supply chain operations in the Australian beef feedlot industry have become increasingly important due to global competition (Ondersteijn *et al*. 2006), increasing costs of production and risk management and lack of carcass compliance. Griffith (2000), showed differences between nominal retail prices and farm prices for beef increased by about 5 fold during the period from 1970 to 1997, (Figure 1) and commented that the marketing margins were attributable to activities involved in converting raw farm products into products demanded by consumers and compensation for risk bearing. Theses high costs suggest that there are possibilities for potential efficiency gains.

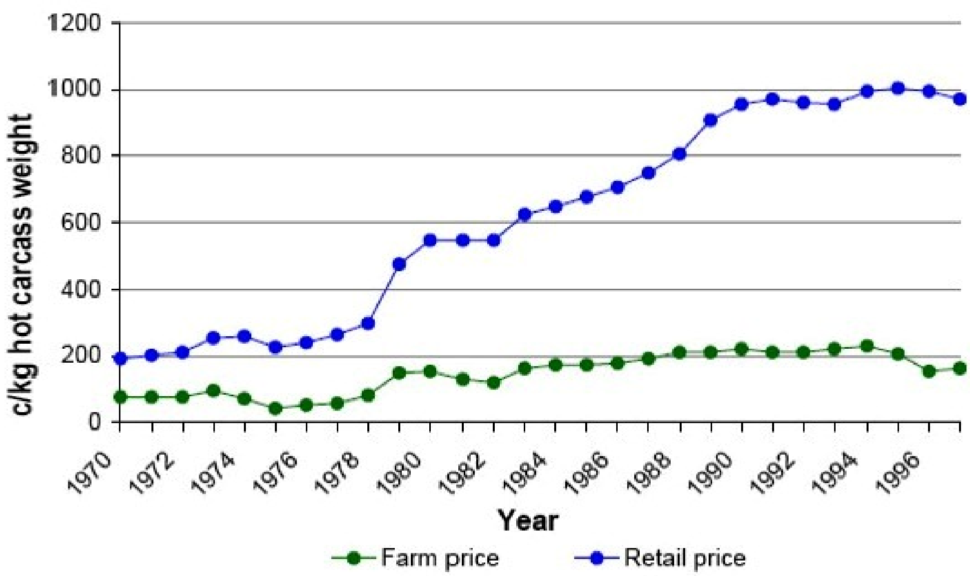

Figure 1**. The nominal retail price and farm price for beef in cents per kilogram hot carcass weight for the years including 1970 to 1997, (Griffith 2000).**

In reality beef producers are faced with many decisions, including selecting for optimal genetics, for carcass traits within breeds as well as choice of production systems and environment (McKiernen *et al*. 2007). Consistently supplying slaughter cattle with high compliance to specifications is seen by many producers as difficult, however better compliance to specification has been shown by McKiernen *et al*. (2007) to increase economic outcomes for animals through higher gross margins. Traditionally beef has been supplied with imperfect information about quality attributes of the product, carcasses or cuts, when sold to downstream customers (Carriquiry 2004). More often destination and processing are reliant on intangible quality attributes (Carriquiry 2004). Often the consumer is sold products which, if they were adequately informed, would not have been purchased (Darby and Karni 1973). The greater the discrepancy between expected and actual experience qualities, the less likely the customer is to do further business with the same firm (Darby and Karni 1973).

Better information sharing and coordination between seed stock and retail industries has the potential to achieve optimal slaughter allocation and help ensure beef palatability and consistency (Tronstad and Unterschultz 2005). There are economic benefits of being able to determine animal growth paths and therefore optimal slaughter allocation. Value-based pricing has been identified by numerous industry participants as a key strategy for improving consumer satisfaction (Tronstad and Unterschultz 2005). Using data obtained from the US National Beef Quality Audit (1991), Savell (2001) and Schroeder and Kovanda (2003) estimated that noncompliance resulted in "lost opportunity" per steer and heifer slaughtered of $US 279.82 in the year 1991. In Table 1, Savell (2001) partitioned these losses into four causes: waste (excessive fat and incorrect bone to muscle ratio), taste (insufficient marbling, age and gender including castrates and calves), management (pathology such as livers and other infections, bruises as well as dark cutters) and finally weight (animals under or over weight specifications).

Table 1. The estimated "lost opportunity" per individual steer and heifer slaughtered in the US in the year 1991 from data obtained in the US National Beef Quality Audit, 1991 (Savell 2001).

Cause	Estimated loss (US$)	Estimated loss (%)
Waste (fat and muscle to bone ratio)	219	78%
Taste (marbling and age)	29	10%
Management (bruising and dark cutters)	27	10%
Weight (too light or heavy)	5	2%
Total loss/animal	280	

Within Australian production systems variation in individual carcass value has been shown by Edmondston *et al*. (2006) to range by about \$210 (animals from the top and bottom 10% received a \$68 profit and a \$142 loss respectively). Polkinghorne (2006) estimated the variation present in carcass yield and quality resulted in \$2.50/kg of carcass weight or a net value difference of up to \$700 for individual carcasses when using both yield measurements and the Meat Standards Australia (MSA) grading model and value differences between grades of \$23/kg for ‘‘3 star’’, \$39/kg for ‘‘4 star’’ and \$50/kg for ‘‘5 star”. The MSA grading scheme used a Total Quality Management approach to predict the quality of the final product (Thompson 2002). Systems of value-based pricing introduce economic signals for supply chain participants which derive \$/kg value on an individual animal basis for each animal’s overall attributes as affected by critical control points. Value-based pricing coupled with information sharing allow supply chain participants to better meet market specification and increase profitability since their production and management becomes better aligned and customer driven.

There are opportunities for the Australian beef industry to make changes to quality and yield grades of cattle and to add value to cattle through the use of information and technology. Quality and yield grade explain much of the variation in profits when cattle are priced on a grid system (Greer and Trapp 2000). Opportunities for management systems of recording quality and yield data have arisen such as the introduction of the National Livestock Identification Scheme; further gains can be made by integrating information through advanced technology in the form of data capture, monitoring and transfer. The availability of growth and composition models and equations allow prediction of carcass endpoints and alignment of these carcasses to optimal markets. These tools allow the beef industry to increase productivity by implementing value-based marketing, or trading based on the merits of an individual carcass. It becomes possible to sort cattle at induction or prior to slaughter to meet the optimal end points, thus improving carcass uniformity (Tatum *et al*. 1996).

Carcass weight and fat content in feedlot animals can be predicted from induction traits and the energy content of feedlot rations and time on feed (Oltjen *et al*. 1986, Hoch 2004 and Robelin 1986). The biological process of skeletal muscle growth and fat deposition of cattle on feed, and the rate of change of tissue deposition for both muscle and fat dictate the optimal time an animal is fed for the market it has been allocated (Trenkle 2001). One complexity of the feedlot industry is determining at the point of feedlot entry or induction, if individuals in a pen of cattle optimally fit the market to which they are allocated. The current method of predicting tissue deposition during time on feed and matching cattle to an end point is usually done based on breed, sex and to a lesser extent a producer's historical performance. Growth and composition models such as the Oltjen model (1986a) model can be used to predict growth and composition over time on feed. As an animal matures its growth rate and composition change due to its genetic potential and nutrient intake (Joandet and Cartwright 1969). The rate of growth and development of economically valuable carcass traits on the live animal is important in the prediction of future carcass performance since the production of meat is almost entirely dependent on the growth process (Hedrick *et al.* 1994). Improvement in induction classification of feeder cattle would improve the performance of individual feeder animals and groups by the assembly of more uniform outcome groups for feeding. Such a result could increase the value of feeder animals, reduce the costs of production, or both (Butts *et al.* 1980).

Feedlot profit is a function of revenue less costs; however increasing revenue by itself does not necessarily increase an animal's net value. The net value derived from an animal or from animal replacement strategies in feedlots are driven by the gain achieved from keeping an animal for another time interval or day on feed (Perrin 1972). Given that there are induction differences such as age, frame size, sex and genetics, cattle have different endpoints which are economically optimal to feed them (Amer *et al*. 1994; Williams and Bennett 1995). In order to determine the optimal days on feed it is important to consider the fixed cost associated with obtaining feeder cattle (initial purchase, freight and induction), and the variable costs associated with time on feed. For example in a trial conducted by Brethour (2001) the optimal number of days to feed cattle varied between 120 days from when the first and last animals should have been sold. When the optimal days on feed had been achieved, carrying the animals on resulted in an average loss of about $1 per head/day for every day over the ideal slaughter weight. A supply chain which successfully predicts these critical carcass points or optimums (allocation over time on feed) can best manage them to profitably provide a product that is characteristically consistent and acceptable for the intended market.

A shift towards integrated supply chain alliances would encourage better information flow and information-sharing (Sethi *et al*. 2005) which in turn would facilitate profitable production (Flint *et al*. 1997; Buchanan and Giles 1990) with a focus on value managed relationships through customer relationship marketing. This has a type of chain focuses on the outcomes of each participant's customer and as well as the final consumer. The emergence of value-based marketing systems facilitate clear specifications for market targets for cattle (Tzokas and Saren 1999), help information transfer along the production chain (Edmondston *et al.* 2006; Cross and Savell 1994), increase the accuracy of allocation of cattle with regard to the genetics and management used by the producer, and allow sorting of individual cattle to specific target markets (rather than selling on the average), which results in value creation along the supply chain and increases the profit earned from individual animals.

1.1. Statement of research problem

Within the Australian beef industry competition occurs between individual producers, among firms and between coalitions of firms for national and international markets. A lack of information on traits such as frame score of animals and on how these traits affect performance along the 'paddock to plate' pathway has resulted in a system of traded averages. The decision to make change becomes difficult since there is no estimate or measure of the magnitude of the difference of animals within the herd or of the herd within the population. Furthermore, consumers lack the ability to purchase a product that consistently meets their expectations. The competition within the food industry necessitates industry action that makes meeting customers specifications a more easily achieved task and a task that is done more often. De Bonis *et al.* (2002) argue that the objective of a company should not be a focus on the competition but to create value for the company's chosen customer segments and to make customers more profitable through superior customer value, thereby increasing the company's profitability. Implementing a well functioning supply chain will lead to greater profitability through customer satisfaction and retention (Reichheld 2003), cost reduction as well as higher quality outputs (Buchanan and Gillies 1990; Cox *et al.* 2006).

The Australian beef industry consists of breeders pasture finishers, feedlots, abattoirs and processors who are attempting to increase profitability in the face of increasing competition both nationally and internationally and in competition with substitute products. Furthermore the meat processing industry is experiencing low profitability (Rolfe and Reynolds 1999).

These issues have contributed to a decrease in consumption (Idstein and Griffith 1999) or as stated by Lea and Worsley (2000) "the number of people who avoid meat is increasing". Consumers' concerns have increased in terms of meats' nutritional value (Schroeder and Kovanda 2003; Cox *et al*. 2006), consistency (Tronstad and Unterschultz 2005; Cox and Cunial 2006), effect on and implications of industry practices to the environment (Le Page *et al.* 2005), and food safety (Fearne *et al.* 2001). To revitalize beef demand, the industry needs to focus on those previously ignored demand factors: producing a healthy, nutritious, and safe product that appeals to consumers' evolving tastes and preferences; this focus must be combined with an emphasis on producing beef at a price that is competitive with other protein sources (Schroeder and Kovanda 2003).

Consumer concerns over food safety and quality together with retailer demands for large volumes of consistent and reliable product are driving the need for closer supply chain integration (Nicholas 2001). There are a number of technologies and processes that helps more precise food production from the farm to the dinner plate (Drabenstott 2000), one example in the beef industry being the Meat Standards Australia grading scheme. Suppliers in the beef industry however still lack some of the information required to make informed decisions and changes to their herds' breeding and/or management to better meet market specifications. Supply chain case studies by Thompson (2001) have shown that markets became more efficient in both a "technical sense" as well as a "customer sense" since the level of value adding increases to match the requirements of customers. Amaldoss *et al.* (1984) describe an increase in the firms' ability to "collaborate to compete" by the use of strategic alliances to control resource commitment for collaboration. Supply chain management helps businesses within a supply chain to act as a unified entity which includes activities such as product design and development, sourcing, manufacturing, distribution, and post delivery customer support (Tan 2001). In an “integrated” supply chain, the final consumers pull the inventory through the value chain instead of the manufacturer pushing the items to the end users (Tan 2001) which creates value (Chan *et al.* 1997, Anand and Khanna 2000).

The research problem is summarised in Figure 2, page 11. Under the current transaction system livestock and their products move from producer to consumer through a supply push. This system is characteristically transacted by opportunity marketing which results in retail discounts and product substitution. Supply push inefficiencies arise due to non-coordinated, production oriented deliveries, an alternative is the demand pull created by a system that incorporates value based marketing and supplies products with the consumer in mind Figure 2, page 11. Carcass attributes are more efficiently managed to meet their optimal endpoint which helps to satisfy market specifications. Value is created through the process of resource management and better customer relationships. Supply chain management tools exist that can minimise losses in carcass value. The objective of this thesis is to demonstrate this using actual industry data.

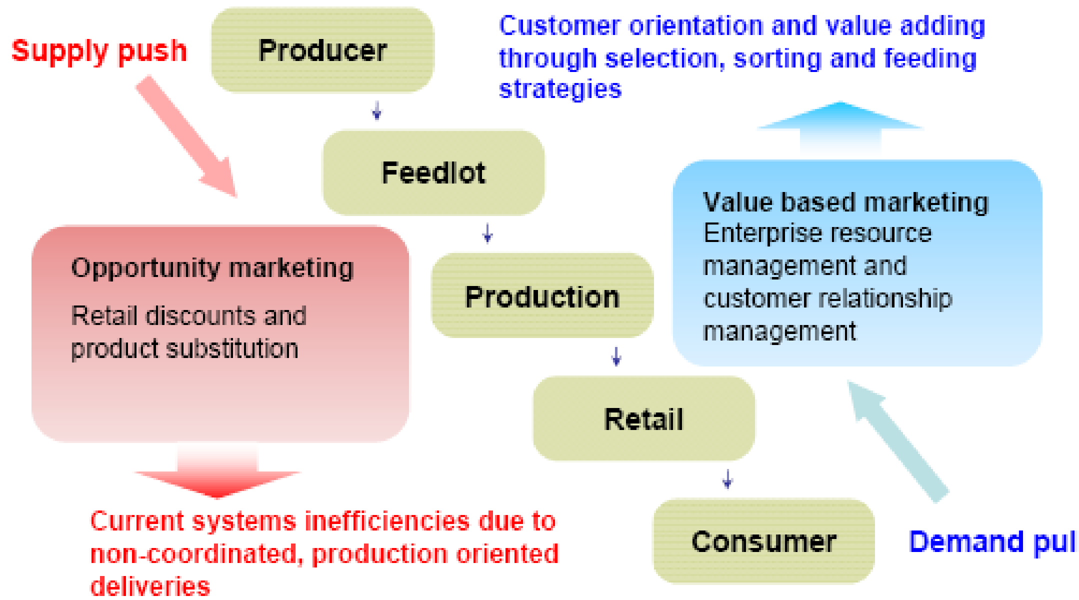

Figure 2. Overview of the research problem.

1.2. Statements of Hypotheses

1) Carcass specifications and grid prices can be used to determine out-of-specification costs for beef carcasses in the Australian beef industry.

2) An analysis of the dependent variable out-of-specification cost (for individual animals) against induction traits and time on feed can be used to determine wether the factors that contribute to out-of-specification costs are pre-feedlot, during time on feed or both.

3) Total quality management systems such as Meat Standards Australia allow information sharing within the Australian beef industry which over time increases the industry's ability to offer greater customer relationship management by better management of resources.

4) The component value of induction traits and time on feed to carcass traits hot carcass weight, marble score and external fat depth can be quantified by an analysis of carcass traits using induction traits and time on feed as independent variables.

5) The component value of induction traits can be used to increase the efficiency of sourcing and management of animals at feedlot induction to slaughter endpoints resulting in a greater percentage of carcasses meeting market specifications.

6) An analysis of the economic value of carcasses allows a more efficient purchase price schedule by quantifying the economic component value of induction traits and time on feed.

7) An increase in individual animal profitability over traditional transaction cost payments systems could be achieved by incorporating accurate growth and composition models in the Australian beef feedlot industry.

1.3. Outline of the thesis chapters

Chapter 2 reviews agricultural and non-agricultural supply chains ability to produce to specification. Furthermore it establishes the supply chain principles and the definitions that will be used subsequently within the review. The principles of customer relationship management, customer satisfaction and marketing management require the integration of these supply chain principles in order to create value, promote better information sharing and therefore better resource allocation.

Chapter 3 reviews the current costs to the Australian beef feedlot industry from carcasses not meeting market specification. In addition the factors contributing to non compliance are analysed to determine the degree to which these factors occur pre-feedlot versus within the feedlot stage of production.

Chapter 4 examines advantages for the Australian beef feedlot industry and value creation through supply chain management tools such as the Meat Standards Australia (MSA) grading scheme. MSA is a total product total quality management system that has the ability to increase the quality and consistency of Australian beef. Furthermore it helps to facilitate information sharing in the Australian beef industry via carcass reporting and consumer eating quality testing.

Chapter 5 discusses factors that affect carcass endpoints in terms of growth, development and composition of slaughter cattle. Quantifying the effect of induction traits on carcass traits makes it possible to better understand how an animal changes in growth and composition over time in terms of skeletal muscle and fat deposition. These analyses aimed to identify and quantify the sources of variation in growth and composition using induction traits and events during an animals' time on feed in order to manage the carcass trait variation.

Chapter 6 discusses the economic component value of an individual animal's induction traits and sorting strategies. Component valuing can be used by feedlots in the procurement of animals through a pricing structure (premiums and discounts) that either rewards or penalises animals based on a true value grid as determined by an analysis of value. Furthermore, sorting animals at induction allows individuals to be allocated to a slaughter group. These groups are based on the similarity of carcasses allocated to a common endpoint. A reduction in variation from market specifications occurs less within groups managed to a common endpoint.

1.4. Contribution of this work

This research reviews the principles of supply chain alliances in the Australian beef industry that could be used to optimise profits and market specifications on a per animal basis and shows these results are able to be applied resulting in an increase in industry profitability.

It is important for the red meat industry to ensure maximum value is generated from every slaughter animal both in terms of monetary value or profit and carcass quality attributes. While it is argued by Faulkner (2003) that customer-driven organisations do not necessarily need to compete on price, it remains that suppliers have to determine what their production objectives should be and how to meet them (Drucker 1976). Supplier's decision-making has critical stages including "defining the situation", however, Drucker (1955) argues that managers commonly focus on problem solving which assumes that the problem is already defined. More often this is not the case. Suppliers who lack a clear understanding of their consumer's requirements have poorly defined production objectives and as such are guided only by good intentions (Drucker 1976) and have no way to calculate the true value or cost of their customer relationships (Niven 2002). Customer-driven organisations look at their customers as part of the overall business process and ensure that they maintain customer satisfaction (Faulkner 2003; Bosworth and Holland 2004). Providing solutions for "customers needs" helps focus on long-term relationship building (Niven 2002). The initial task of suppliers should therefore identify through their customer requirements what their production objectives should be (Drucker 1976).

Drucker (1976) commented that simple goals often require a choice between very different strategies; the production goals of suppliers require clear objectives and a means to obtain their objectives. Supply chain alliances enhance information flow as well as provide price stability and reliable demand (Nicholas 2001). Supply chains would help focus production objectives by determining what characteristics are required by sequential users through to the consumer of live animals and carcass.

The value of animals can be increased when production objectives are clearly defined within a supply chain alliance and further increased with the use of animal growth and composition models. Growth and composition models predict and quantify traits of importance. At any given point over time on feed, an estimate of an animal's composition can be generated for comparison between preferred slaughter points in conjunction with a set of market specifications. This has been shown in an experiment by Baker and Ketchen (2000) who used a growth and composition model to estimate the required final weights at which animals were expected to qualify for grading. This resulted in an average net value (average net dollar value head) for the highest, middle and lowest third of \$162, \$116 and \$41 and occurred for reasons including heavier carcass weights, higher dressing percentages and a higher percentage reaching Choice quality grade. This enables animals to be forward valued and helps supply chain participants to predict and determine the net value of an animal at any one point in time during its passage through the supply chain.

A review of supply chain literature, factors affecting growth and optimising the endpoint allocation of animals helps understand how the Australian beef industry will be able to allocate individual animals to groups or within groups that are similar i.e. days on feed in the feedlot or carcass traits at slaughter. This will ensure the best net value per animal is achieved for supply chain participants which in turn increases the profitability for each participant. This would result in an improved economic efficiency in the allocation and management of beef production, increased information flow, promote greater information sharing and provide far greater capacity to market animals both live and carcass.

2. Literature review

This literature review provides a general overview of the supply chain literature to understand the contribution of supply chain components to value within beef supply chains.

Grid pricing in the U.S. has been shown to determine the values of individual carcasses by applying discounts and premiums to a base price according to quality grade, yield grade and dressed weight (Greer and Trapp 2000). In a grid payments system, producers that market a carcass that achieves specifications receive a premium, while producers who market carcasses that fail to meet specifications incur discounts (McDonald and Schroeder 1999; Greer and Trapp 2000). As discussed by Greer and Trapp (2000) grid pricing however, only provides incentives to alter management practices, therefore the premiums and discounts associated with grid pricing improve the “likelihood” that processors (packers) will receive uniform carcasses. Beef processor partnering in a long-term commitment such as a supply chain alliance helps achieve specific business objectives through maximising the effectiveness of each participant's resources (Cox and Thompson 1997). The requirements of processors are more often met through a dedication to common goals and an understanding of each participant’s expectations and values (Cox and Thompson 1997).

2.1. Supply chain alliances

Supply chains, demand chains and value chains are extended enterprises with integrated business processes that enable the flow of products in one direction, and value as demand in the other (Bowersox *et al.* 2002). Chain management involves the collaboration of participants in order to provide a strategic advantage (Bowersox *et al.* 2002) and improve operating efficiency. For each participant involved in the chain the relationship reflects strategic choice to participate in a channel arrangement extending an operation from a single business unit or a company to the whole chain (Heikkila 2002).

Supply chains are a complex sequence of activities and material flows involved in producing and distributing a firm's outputs and consuming vast amounts of capital - in the form of plant, equipment and inventories (Hugos 2003; Pokharel 2007). It is commonly agreed that meeting customer demand is the primary goal of a supply chain (Sethi *et al.* 2005) and that information about customer demand should be the basis for decision making by supply chain managers (Sethi *et al.* 2005). Supply chains create significant value and ultimately determine a firm's ability to satisfy the demands of its customers. This has led to the realisation that business communities which join together to form a supply chain alliance are more competitive than a single company (Gong 2008).

Companies attempting to develop their supply chain efficiency in fast-growing industries face a variety of new customers, new situations and needs. Heikkila (2002) have argued that supply chain improvement should start from the customer end therefore supply chain management should be changed to demand chain management. In demand chain management goods and services are customised for each customer segment and individual customer partner (Vollmann *et al.* 2000). Heikkila (2002) has argued that this places greater emphasis on the needs of the marketplace rather than starting with suppliers and manufacturers, thereby satisfying customers needs. Vollmann *et al.* (2000) stated the chain focus should be on the final customer as well as ways to optimise benefits, remove unneeded transactions, and improve the goods and services provided to all chain members. A value chain is a framework that requires strategic thinking about the activities involved within a business and assessing the relative cost and role in differentiation (Porter 1985). The value chain provides a method to understand the sources of buyer value that realise price premiums and why products substitute (Porter 1985). Value chains disaggregate firms into their activities in order to understand costs and the potential sources of differentiation (Porter 1985).

One problem of assigning a strict definition to an integrated alliance system or transaction philosophy arises due the *decoupling point* (de Treville *et al.* 2004) or *order penetration point*. A component of the chain may be operating under supply push conditions and another part under demand pull conditions (Viswanadham and Srinivasa Raghavan 2000). Within these alliance systems the point at which orders are received determines how a product is categorised such as *make to order* or *make to stock* (Olhager 2003). The order penetration point therefore determines the point at which a product is linked to a specific customer order or not (Olhager 2003); and therefore wether it is more relative to supply, demand or value chains. This thesis has used the term supply chain and integrates components of the demand and value chain to incorporate both the pre and post coupling stage of the beef feedlot production system.

Traditional livestock marketing has been in the form of a “Supply Push”, illustrated in Figure 3, which trades on spot prices that are characterised by both poor information and poor feedback regarding customer requirements and customer satisfaction (Salin 2000). Typical sales methods have been auctions and are considered to be highly variable (Todd and Cowell 1981). There are a number of significant implications from an integrated supply chain, of particular importance to supply managers is an increased knowledge of consumer requirements and therefore the factors that determine price variation within live animals and carcasses. “Demand Pull” as shown in Figure 3, helps supply chain participants gain an understanding of the carcass attributes that are valued by their customers, moreover it allows supply chain participants to develop strategies that helps meet their customer's specifications.

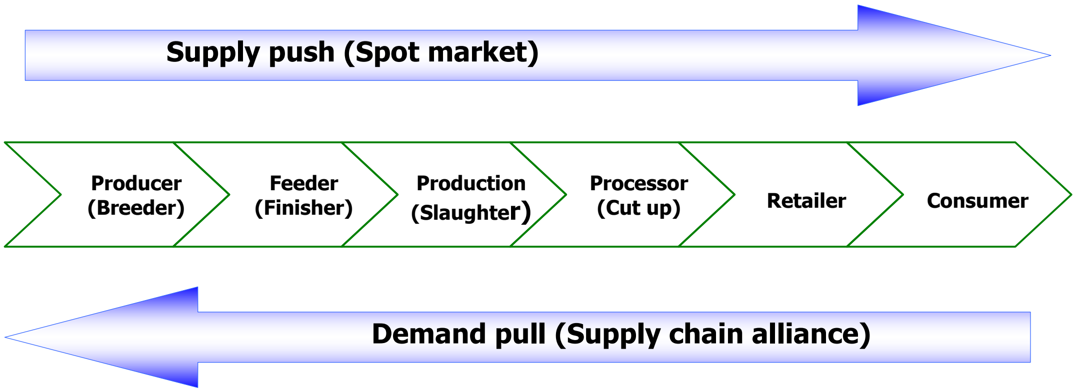

Figure 3. Flow structure for the spot market and supply chain alliance for beef livestock and carcass transactions, adapted from Salin (2000).

2.1.1. Structure and concepts

A supply chain alliance considers a set of processes, driven by customer demand that delivers products from suppliers through manufacturers and distributors to the supply chains final customers (Tsung-Hui and Jen-Ming 2005). One important mechanism for coordination in a supply chain is the information flows among members of the supply chain (Lee *et al.* 1997). Problems arise due to information distortion, whereby the upstream orders have a higher level of variability than those at the customer end (Lee 2006). Channel coordination through effective interaction, collaboration, information sharing and decision making, greatly enhances the flow of products through supply chain partners.

Effective supply chain management requires strong collaboration of participating partners and implementation of strategies to optimise the total profitability of the chain. An example of the practical need for supply chain coordination is the operational problems handled by British Airway Catering (BAC), delivering ca.44 million meals per year. Effective supply chain management is required to achieve effective supply chain integration, collaboration and coordination among channel partners that share business information in order to simplify the supply processes, streamline cross company operations and reduce consequent channel-wide costs (Tsung-Hui and Jen-Ming 2005).

Once customer requirements are determined the supply chain alliance partners attempt to integrate and manage information by a process of enterprise resource planning (Chorafas 2001, see Figure 4). Channel coordination provides the supply chain with the mechanism for information-sharing (Sethi *et al.* 2005) via cost/payoff structures, inventory replenishment policies, and demand information for suppliers (Sethi *et al.* 2005; Burkink 2002). Information transfer by suppliers may include data transfer to a feedlot including live animal characteristics, pedigree and management information. The integrated information helps to then "enterprise resource plan" or determine how an animal is managed successively along the supply chain (i.e. genetics and its induction traits may indicate that on arrival at the feedlot the animal be allocated to a short or long fed program). Moreover the information contributes to the supply chain alliances' objectives, either single or multiple objectives. Multiple objectives within a supply chain alliance may encompass factors such as minimising costs and at the same time maintaining product quality, consistency and production capacity (Pokharel 2007). As seen in Figure 4, the overall measure of the chain alliances successful allocation of resources and meeting production objectives is indicated by the "key performance indicators". These indicators are a measure of attainment for both financial and non-financial objectives relating to production outcomes (including production efficiency, financial performance usually relating to profitability, liquidity and solvency) (Wilson *et al.* 2004). Moreover these indicators can be used in a beef supply chain alliance to benchmark and quantify whole chain customer performance (i.e. quality traits, profitability measures at levels including producer to consumer).

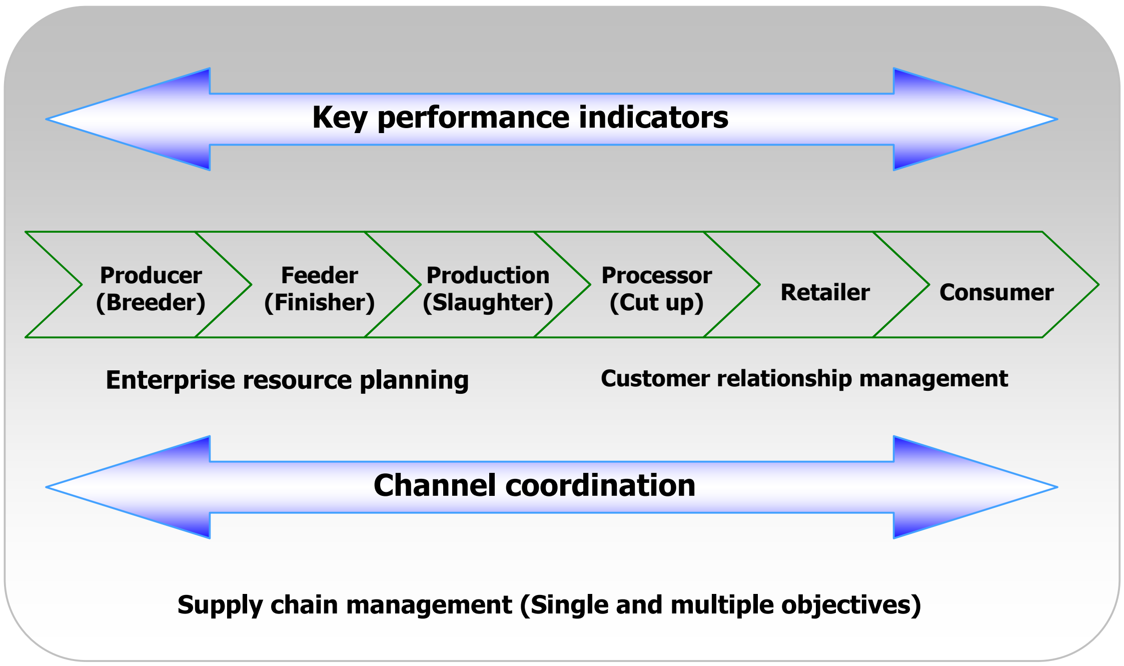

Figure 4. Factors affecting beef supply chain alliance product and information flow, adapted from Salin (2000).

From the above discussion it can be seen how the various processes begin to combine and provide the underpinning structure for a supply chain alliance. Supply side business unit managers have a mechanism which can be used to formulate strategic plans for customer oriented production within a beef industry supply chain. Importantly this structure places suppliers and their customers in a single efficient business process allowing customer requirement information to be used to underpin total product quality management. This process creates higher customer demands, more consistent delivery of a quality product, higher reliability and reduces costs (Schnetzler *et al.* 2007).

2.1.2. Enhancing the supplier to customer relationship

Traditionally livestock are transacted in an environment of poor quality information flow with regards to customer's demand; this leads to distorted customer demand signals up stream (Van Eenoo 2006) commonly known as the "bullwhip effect" (Lee *et al.* 1997) and results in inefficient and costly inventory utilisation (Van Eenoo 2006). This effect is decreased by the adoption of a supply chain alliance since these require managers who service consumers to reassess their business relationships with their suppliers and buyers (Dunne 2001). Customer relationship management assists in the process of customer serviceability and resource efficiency along the supply chain by increasing compliancy rates from producer to retail as well as improved quality (i.e. eating quality and consistency, nutritional and food safety). It has been shown by Katz and Boland (2000) and Yu *et al.* (2002) that increasing efficiency resulted in reduced cost of production (through risk shifting and risk reduction) when information was integrated along a supply chain. Furthermore supply chain participants were willing to accept the increased risk of price discounts in exchange for information that allowed quality-based price premiums (Katz and Boland 2000). Producers through to retail have both the desire to make change to their product and management, and, it has been shown that increasingly there are information pathways to facilitate these production and management changes. A pilot survey of New South Wales beef producers (n=10), cited by Hayes *et al.* (1998) indicated valuable information included 1) individual animal feedback correlated with carcass body, 2) prices associated with buyer's specifications, 3) benchmarking against other producers and industry, 4) ability to predict sales price and 5) alliance opportunities for beef products and contact points. Furthermore supply chain participants have greater capacity to increase their ability to use this information since the establishment of Australia's NLIS database and the propensity for Australian producers to use better information sharing tools such as computers and the internet (Rolfe *et al.* 2003).

2.1.3. Consumer requirements

Minimising losses from products out of specification is achievable by a process of "supply chain metrics" (a measure of the value that identifies the minimum threshold of performance Melnyk *et al.* 2005). One of the central functions of customer marketing is to create a relationship between consumers and a product (Walker and Olson 1991) and retain customers (Eriksson and Vaghult 2000). This is increasingly important since beef consumption by Australians has changed significantly in recent years resulting in the per capita consumption of red meat falling steadily (Storer *et al.* 1998). Figure 5 shows that between the years 1979 to 2007 there has been a decrease in Australian beef consumption of ca. 20% or 10kg per capita; during this period there has been a significant rise in poultry meat consumption which has resulted in consumption levels that now exceed beef.

Customer retention is problematic and requires information from customers concerning 1) what they value, 2) their satisfaction with suppliers' abilities to deliver that value, and 3) how their perceptions of value are changing (Eriksson and Vaghult 2000). Changes in factors such as demographics, incomes and social awareness have been shown (Dunne 1999) to influence consumer demand. Consumers are developing an awareness of health (nutrition, contamination and HACCP), welfare (stock handling and transport), and environmental issues (Cox *et al*. 2006; Desmarchelier *et al.* 2007; Dunne 1999). The cost of quality noncompliance is costly (Allerton 1999); food service industry trials conducted by (Cox *et al.* 2006) showed 42% of product did not meet specification despite the provision of product specifications;

however, quality partnerships were able to reduce customer complaints by 96% and improve customer satisfaction by 34%.

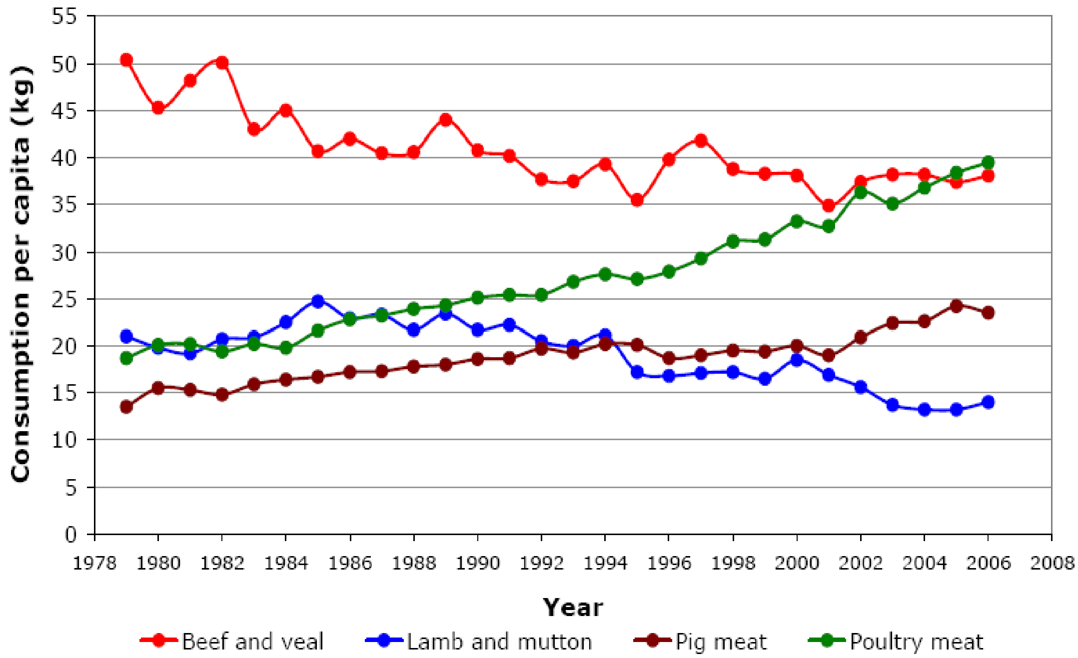

Figure 5. Australia's domestic consumption of Beef and veal, lamb and mutton, pig meat and poultry meat per capita in kilograms for the years 1979 to 2007 inclusive (ABARE 2007).

Supply chain alliances are derived from the requirement to increase quality consistency, reliability of supply and ensure safety (Hayes *et al.* 1998). The Australian beef industry has developed Meat Standards Australia (MSA) as a "cuts based" grading tool for palatability assurance to maintain eating quality (Polkinghorne 2006). The inception of MSA in 1999/2000 as a total quality management system has led to an increasing number of graded carcasses being required to satisfy consumer demand (Figure 6) of ca. 80,000 carcasses annually. Moreover MSA graded beef attracts premiums (increasing in magnitude annually, Figure 6) from consumers above non-graded beef. Price premiums were ca. \$0.39 kg at retail across all cuts (carcass equivalent), Figure 7, for the year 2004/2005 (Rodgers *et al.* 2007). This average retail margin for MSA beef increased in 2006/2007 to $1.52 kg retail across all cuts (carcass equivalent) (MSA 2007).

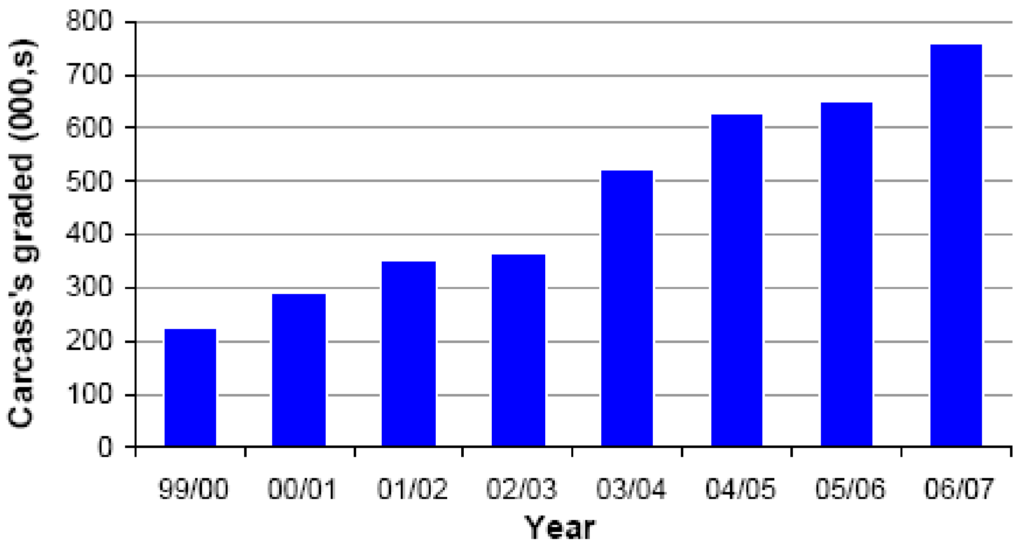

Figure 6. Australian cattle numbers graded in the Meat Standards Australia grading system, the numbers graded were based on MSA (2006).

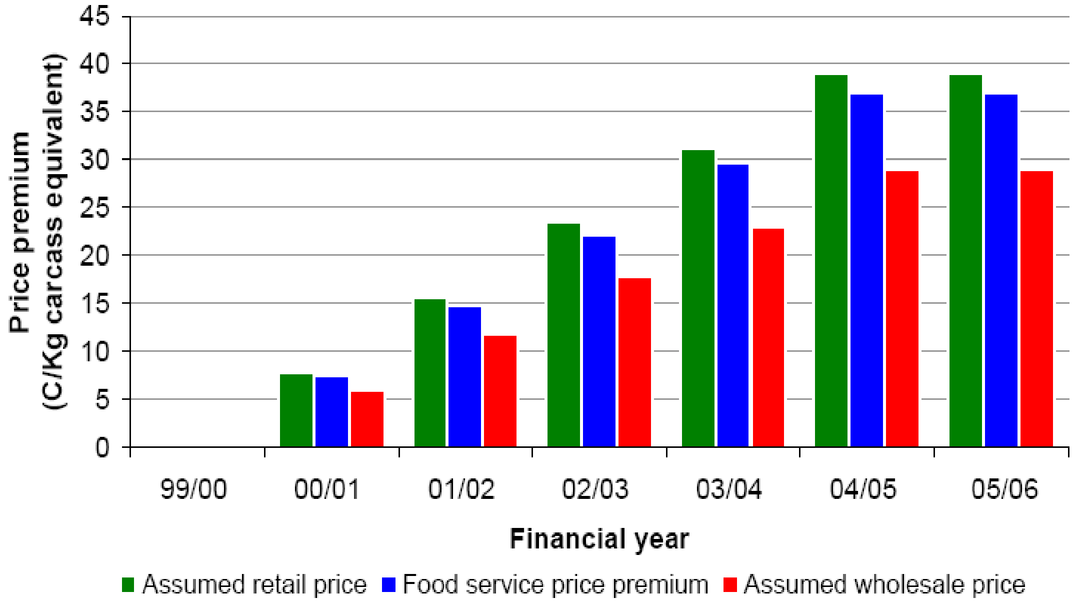

Figure 7. The price premiums (c/kg) across all cuts (carcass equivalent) under the Meat Standards Australia grading system from inception (1999/2000) to 2004/2005, including a projection for the year 2005/2006 (Rodgers *et al.* 2007).

2.1.4. Processor requirements

Quality grade, yield grade, and other performance factors explain much of the variation in profit under grid pricing (Greer and Trapp 2000). Despite the ability to reward carcasses according to their individual merit many cattle are sold through auction systems and other "average based" trading systems. The use of pricing grids independent of an integrated delivery system however does not guarantee future delivery of desirable carcass traits, only how these carcasses might be valued. It is argued by McKiernen *et al.* (2007) that consistently supplying slaughter cattle with high compliance to targeted specifications for both the domestic and export beef trade is still seen by many producers as difficult since beef producers are presented with genetic values for carcase traits within breeds and a large selection of breeds with various carcase attributes. These, combined with genetic differences in growth, makes selection of sires to suit their production system and environment a difficult task for most producers (McKiernen *et al.* 2007). Cox and Thompson (1997) have stated that a “contractual relationship” model which integrates four interlinked factors namely relationships, responsibilities, risks and reimbursement help produce a product that is fit for purpose. These models increase information flow and financial reimbursement to producers and increased value received by consumers through increased efficiency. Furthermore value-based pricing of cattle can be introduced which improves economic signals to producers (Greer and Trapp 2000). Of importance are the responsibilities and risks incurred by producers (Just 1974) and the rewards by grid pricing systems that derive a value for each carcass based on its overall quality (McDonald and Schroeder 1999).

It is argued by Walters (2006) that it is essential for businesses to understand their customer’s demands prior to making supply chain structure decision; as managers lose sight of their markets and customers, customers switch their loyalties (Walters 2006). This is important when considering the requirements of producers of both the live animal characteristics at feedlot induction and at slaughter. Cox and Thompson (1997) have stated that while no optimum buyer-supplier relationship exists, “contractual relations” interlink the elements that allow a strategic alignment between producer and consumer.

2.1.5. Benefits and disadvantages of supply chain alliances

Supply chain alliances help meet the shifting patterns of consumer demand (Reid 2003) allowing suppliers to obtain clear reliable market signals. Supply chain alliances can reduce the numbers of deliveries outside of market specifications through a structure that is more adaptive and flexible (Day and Montgomery 1999). The benefits that can be realised from an integrated supply chain include improved customer relations (Dunne and O'Keefe 2003), cost reductions, and increased competitive advantage. Despite the potential benefits, there are many factors that lead to failed integrated supply chain implementation. The major factors leading to failure are not due to technological reasons but rather the failure of the project team to recognise the complexities of the implementing an integrated supply chains (Van Eenoo 2006). Supply chain alliance structures are not costless (Hayes *et al.* 1998), loss of business control means that mechanisms are required to ensure benefits of the alliance are distributed to all of its participants in an equitable manner.

2.1.6. Benefits from an integrated supply chain

2.1.6.1. Participant benefits

Participants benefit from supply chain alliances through improved competitiveness (Hayes *et al.* 1998), increased quality through customer awareness (Dunne and O'Keefe 2003), greater risk management, increased information flow and profitability (Wincel 2004). Alliances are likely to focus on marketing with a focus on the customer (Hayes *et al.* 1998). Participants of a supply chain alliance would more likely be aware of customer requirements (therefore more often meet specifications and reduce downgrades) (Chorafas *et al.* 2001) and variability of production (Sethi *et al.* 2005). This can result in minimising production uncertainty (minimises the uncertainty over of management action) with the expectation that benefits will be derived from the exchange and use information within the alliance (Batten and Savage 2006).

There is a greater likelihood of ongoing business with compatible suppliers and current suppliers. An interoperable system encourages others within the system conduct business within the alliance (Batten and Savage 2006). If appropriate channel coordination is in place, a supplier more easily can become a supplier to new customers; more so where the new customers are channel coordinated and within the supply alliance network. There is a reduced likelihood of similar changes again in the future now that the members of the supply chain have committed to a standard system.

2.1.6.2. Risk and quality management

Supply chain alliances have the potential to reduce risks by providing participants with more secure forward prices (Chauhan and Proth 2005) and specifications (Cox and Thompson 1997), and, securing levels of supply at a forward price therefore allowing greater product management (Huang *et al.* 2003). Cattle management is therefore made easier given that each participant can manage according to specifications from their customer. This has the potential to increase carcass value and reduce costs resulting in an increased likelihood of increased profits (May and Lawrence 2002) from production to retail and greater consumer satisfaction. Furthermore the supply chain alliance reduces risk from exposure to price fluctuations (Ravaland and Gronroos 1996) in the open market.

2.1.6.3. Information flow and coordination

Supply chain alliances can improve coordination of products, flow of information and more accurate information on consumers' demands from retailers and other end users to processors. This has the potential to reduce downgrading and results in a greater likelihood of price premiums for superior products and customer satisfaction. Traditional supply channels push product and firms at each level are isolated decision making units holding speculative inventory based on their sales forecasts (Bello *et al.* 2004) with each participant holding inventory to buffer their own internal operations from uncertainties of upstream supply and downstream demand. The supply chain alliance conveys more accurate economic signals regarding the quality of its products. The value of investments can be difficult to measure and verify, particularly when they are associated with areas like eating quality, nutritional value and adherence to environmental friendliness (Bello *et al.* 2004). Under this scenario it is difficult to pass costs along to a customer since the specific benefits to a particular customer cannot easily be demonstrated and verified (Bello *et al.* 2004).

2.1.7. Disadvantages from an integrated supply chain

2.1.7.1. Loss of control

Having committed to this new system, the supplier may well find itself more dependent than before on one or very few customers (Batten and Savage 2006), which means that if it loses those customers' business; it has fewer alternatives than before integration into the alliance to turn to. If one of its customers withdraws, the supply chain participant is limited to its remaining customers or must try to convince other potential customers to convert to a new system. The ability to change production is a difficult task furthermore the red meat industry is by nature fragmented and an integrated system is difficult to achieve in all operations (Desmarchelier *et al.* 2007). Producers have minimal ability to alter the rates of development of their animals once production is underway (Allen 1994) and the production cycle (measured in months and years) incurs seasonal impacts and high costs for adjustment of production (Allen 1994)

2.1.7.2. Effects of concentration

Business's that integrate into a supply chain have the potential to lose non-incorporating customers (Batten and Savage 2006). The adoption of a new system of transacting may lead to the loss of business. This could happen when existing suppliers and/or customers are not in a position to interoperate with the supplier's new system. Therefore, this question must form part of the supplier's cost-benefit analysis undertaken before the decision is made to adopt a new system. The supplier may be faced with alternatives: choose a new system and lose old business (Dunne and O'Keefe 2003), or maintain the old system in order to maintain old business but risk losing new business. Furthermore the alliance may suffer incompatibility, although systems may be classified as meeting certain national or international standards, it is not uncommon for them to fail to interoperate (Batten and Savage 2006). Finally business relationships tend to continually change, existing customers and suppliers are not obligated to continue working with any particular supplier indefinitely (Batten and Savage 2006).

2.1.7.3. Mutual trust, investment and equity transfer

Supply chain alliances must deliver a return to their participants particularly where a significant investment has been made to accommodate the alliance. A major challenge in the management of these alliances is how to control the resource commitment of partners to the collaboration (Amaldoss *et al.* 1984). Profit-sharing arrangement matters in such alliances partners commit more resources when profits are shared proportionally rather than equally (Amaldoss *et al.* 1984), but presupposes that the resources committed by participants can be monitored. Mutual trust plays a role in a firm's success based on the willingness of its partners to invest their resources to the venture and management of resources becomes a challenge when attempting to minimise the risk of under committed partners (Kogut 1998).

The literature reviewed in this section has provided evidence that supply chains alliances can enhance supplier customer relationships through greater understanding what consumers and processors require in order to maintain quality and reduce product variation. This understanding is enhanced by a level of information sharing that can result in participant benefits within the supply chain. Given the importance of product quality and consistency to consumers and processors it is likely that supply chain alliances would benefit the beef feedlot industry.

2.2. Customer relationships

It has been argued by Fournier *et al.* (1998) that the relationships companies ask consumers to maintain are unreasonable, which then results in marketing initiatives that are inefficient and ineffective instead of being unique and valuable. Both customer satisfaction and retention can be improved through a value managed relationship (Buchanan and Gilles 1990), a collaborative and communicative partnership between suppliers and their customers reduces system costs (Buchanan and Gilles 1990). Research by Cigliano *et al.* (2000) found that due to the costs associated with customer programs (i.e. loyalty programs), many of them were unsuccessful in maintaining customer relationships given that transaction margins are small and don't afford significant transaction rebates. While businesses seek long term committed partnerships with consumers, Fournier *et al.* (1998) believes that customer relationships and customer loyalty are struggling. Customer loyalty ('sticking with a supplier') drives growth and business profit by eliminating customer exits (Reichheld 2003), and increases loyal customers who become ‘promoters’ (recommend their supplier). Customer relationship management and value management shifts the business’s focus from attracting customers, to having the customer and taking care of them (Ravaland and Gronroos 1996). Suppliers are more equipped to sustain customer relationships through delivery of superior value over time and are also in a position to find new ways to sustain their relationships (Anderson and Narus 1999), moreover this helps suppliers to integrate knowledge of their customers perceived value into their marketing efforts (Anderson and Narus 1999).

2.2.1. Customer relationship management (CRM)

The purpose of a business is to create and keep customers; and to grow a relationship with them (Eriksson and Vaghult 2000; Anderson and Kerr 2002). It has been shown by Berry and Linoff (2004) that across a range of industries customers are central to their business and that customer information is one of their key assets. Relationship management is a process of making and maintaining value relationships with customers (Ching *et al.* 2004). The core of relationship marketing is the maintenance of long term relationships with the customers. Customer relationship management helps businesses create, maintain and expand their customer base (Anderson and Kerr 2002), and adds value to customer transactions by identifying related items with their customers. Customer’s requirements are changing for red meat products by demanding more processed food as a result of dual careers and time inefficiencies. This has led to suppliers to moving away from undifferentiated commodities to specialised products and caused a reduction in open market transactions (Hennessy 1996). Suppliers who use Customer relationship management create stronger business relationships with customers and more efficiently and effectively negate problems; as well as better meet their consumer’s requirements (Anderson and Kerr 2002).

Customer retention is central to the development of business relationships and specific to individual suppliers (Eriksson and Vaghult 2000). The implementation of CRM practices helps develop relationships which are characteristically ongoing between participants, have a commitment for future business and lead to significant mutually beneficial changes in the interfirm relationship (Eriksson and Vaghult 2000). Customer retention leads to reduced sales and marketing costs compared to selling to new customers (Eriksson and Vaghult 2000; Reichheld and Sasser 1990) argues that customer retention has a link to a firm's long term profitability. Another reason for retaining customers is the potential of becoming partners in the business development within relationships, rather than mere parties engaged in transaction. This deep state of collaboration has been found profitable because it involves a much more advanced coordination of activities (Eriksson and Vaghult 2000). The truly embedded customer firm has changed its organisation and management to fit the coordination with the supplier and their respective networks. But networks are evolving structures, where customers gain more knowledge about the supplier's context and network ties. This often leads to the customer overstepping the supplier, to do business with the supplier's suppliers or other supplementary suppliers (Eriksson and Vaghult 2000).

Customer value has been defined by Eriksson and Vaghult (2000) as the customer's perception of what they want to have happen in a transaction, for either a product or service. Suppliers add value to their transactions when customer's "expressed and implied requirements are satisfied reliably, without deviation, over the life of the relationship in a cost effective manner" (Eriksson and Vaghult 2000). Outlined in Figure 8 are the primary stages of CRM formulation, 1) identification and idea development to fulfill the customers needs, 2) product development to substantiate the idea and 3) the product's market introduction, communicating the fulfillment of the need (Costa *et al.* 2004). Customers want to do business with organisations that understand what they want and need, and CRM helps businesses manage their customer relationships more effectively which drives down costs and at the same time increases suppliers viability with regards to product offerings (Anderson and Kerr 2002).

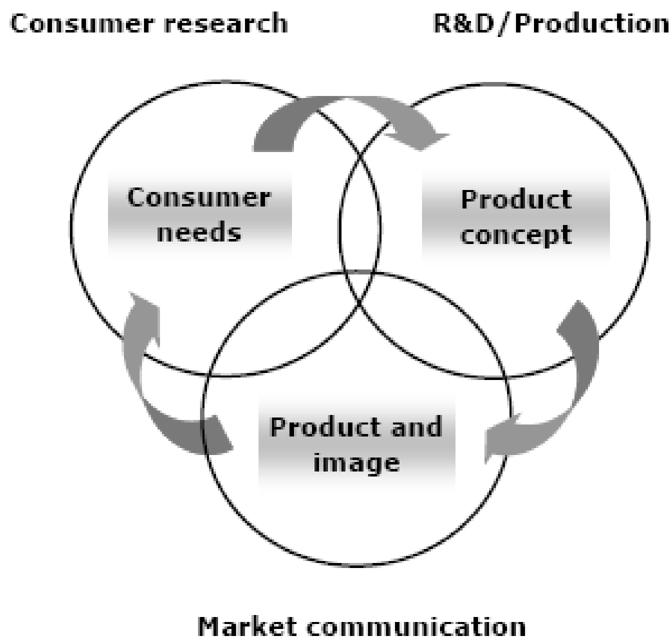

Figure 8. The consumer oriented new product design concept (Costa *et al.* 2004)

Non-price factors have contributed to the decline in beef demand since 1980 including health/nutrition concerns, food safety, changes in consumer lifestyles, product quality, and product convenience problems (Schroeder and Graff 2000). Within service industries customer defections have been shown to affect profits more than scale, market share, unit costs and competitive advantage (Reichheld and Sasser 1990), moreover the opposite is also true, as a customer relationship strengthens over time the profits customers generate for their suppliers increases. There are opportunities in beef supply chains to enhance customer relationships (i.e. product design to meet consumer requirements) which focuses on consumers' current and future needs (Costa *et al.* 2004), as well as innovative and/or improved food products with added value. Suppliers who engender strong relationships with their customers will long term relationships where customers remain with suppliers despite their opportunity to trade elsewhere (Eriksson and Vaghult 2000).

2.2.2. Customer acquisition and profitability

It is argued by Niven (2002) that historical indicators of a businesses success (financial measures only to compare trading periods) are poor indicators of customer relationships, quality or further opportunities and, provides no ongoing predictive power of business performance. Customer-supplier relationships provide value which contributes to a reduction in costs (initially attracting customers) and an increase in profit (increased spending and premiums on their expenditure) (Faulkner 2003). Work published by Reichheld (1990) states that there is a cost of $500 a year for every customer lost to the food chain "Domino's", furthermore Niven (2002) has shown that an increase in customer retention/loyalty of 1.5% per year equates to an increase in profit of ca. $200 million in the year 1997 for the retail chain "Sears". Basch (2002) believes efficient customer relationships are defined in four ways; physical needs (having a task performed or physical accomplishment), informational needs (meeting the customers requirement for information and feedback), emotional needs (a belief or trust in what had been transacted) and spiritual needs (as part of a greater purpose). It is argued by Arussy (2005) that efficient relationships are a "paradox", illustrated in Figure 9, whereby the duration of the relationship is an antagonism between the customer and supplier. The traditional post sales environment is characterised by suppliers viewing the post-sales relationship as a cost against the initial sale as opposed to an opportunity for the next customer purchase, and that the customer is treated as "a destination that, once reached, is safe territory" (Arussy 2005).

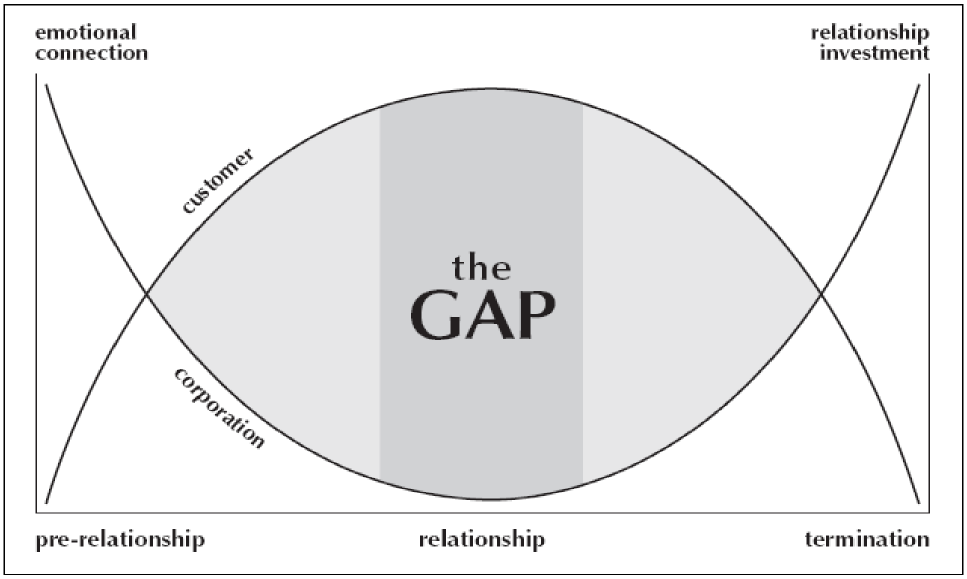

Figure 9. The efficient relationship paradox (Arussy 2005)

Work by Reichheld and Sasser (1990) has shown that most customers cost money in their initial year, then become profitable from their second year as shown in Figure 10. Initially, new customers are an economic cost (expenditure on advertising and marketing) (Reichheld and Sasser 1990), customer preferences and education, and the best means to do business (Anderson and Kerr 2002). “Customer relationship management (CRM) can be the single strongest weapon you have as a manager to ensure that customers become and remain loyal” (Anderson and Kerr 2002). Trends for industrial distributors show an increase in sales per account up to the nineteenth year of the relationship (Reichheld and Sasser 1990), as purchases rise supplier operating costs decline. Company profits increase above the base profit due to increased purchases, profits from reduced operating costs and increased referrals, and increased premiums.

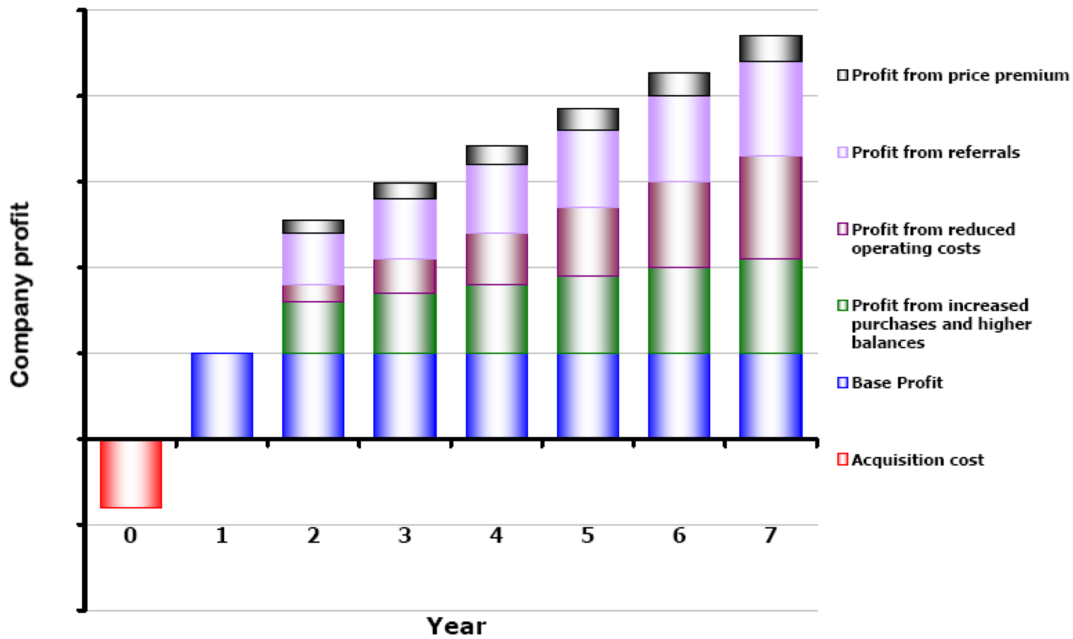

Figure 10. Profitability of customers over time (Reichheld and Sasser 1990).

The central idea of customer relationship management data mining as shown by Berry and Linoff (2004) is that data from the past contains information that will be useful in the future. Customer behaviour is not random and reflects the differing needs, preferences, propensities, and treatments of customers (Berry and Linoff 2004). Figure 11 shows that the rate of acquiring new customers increases as the target market becomes saturated (a decrease in percentage response equates to an increase in the cost of successive responses). In addition to increased profit levels due to long term customer relationships there is an added advantage. The value customer relationship management provides to customers becomes economically profitable where customers actively promote their supplier (Reichheld 2003).

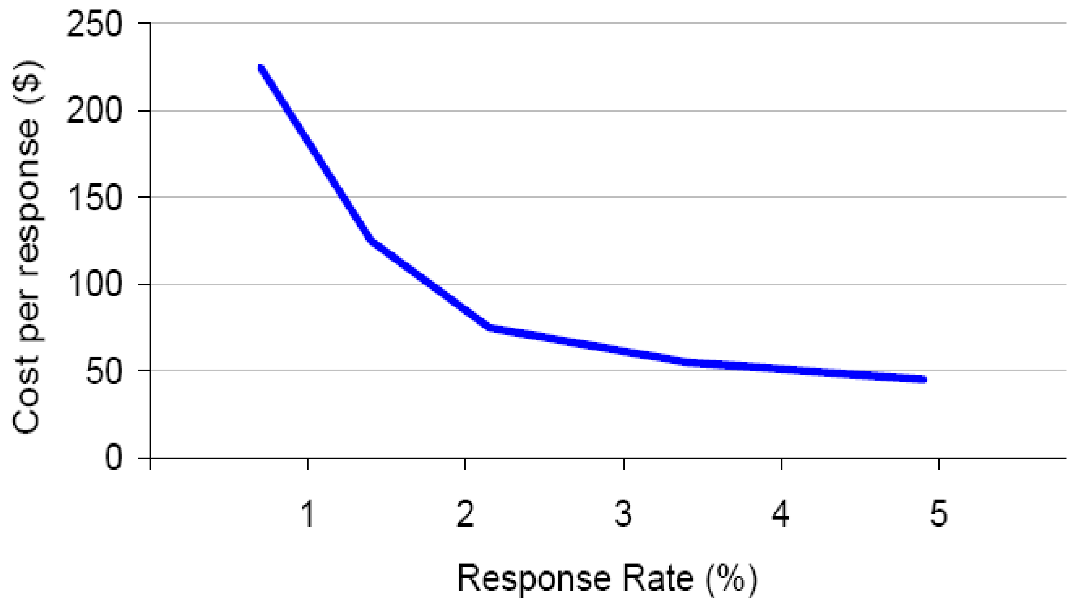

Figure 11. The response rate to acquisition campaigns and cost per customer acquired (Berry and Linoff 2004)

2.2.3. The means-end chain

The means-end chain model helps to determine as well as understand consumer's decision-making processes. In addition it defines how product characteristics are perceived and the consequences a products consumption. Means-end chain theory links attributes that exist in products, the consequences to the consumers provided by the attributes, and the personal values that the consequences of the product (Chao-Min 2005), furthermore it attempts to explain how a product influences a desired outcome. Means-end chain models comprises of elements that make up consumer processes that link values to behaviour (Gutman 1982). Central to the means-end model is that consumers' choices are a cluster of actions that produce desired consequences while minimising undesired consequences (Gutman 1982), and that the consumption of products is ultimately a means to achieving important values to the domain of goal-oriented consumer behaviour (Pieters *et al.* 1995).

In means-end chain theory products are seen as means through which consumers obtain valued ends. According to this theory consumers choose products because they believe that the specific attributes of the product can help them to achieve desired values through the consequences or benefits of product-use (Hofstede *et al.* 1998). Product attributes are the specific characteristics of the product and influences what a product provides consumers at the point of consumption (Hofstede *et al.* 1998). It is argued by De Costa *et al.* (2007) that in agribusiness there have only been a small number of studies that encompass issues pertaining to motivations for choice of meal solutions, however is of importance when individuals select, purchase, prepare and consume foods. Consumers eating experience is influenced by cooking methods (Thompson 2002; Brunsø *et al.* 2004) (including the time, efficiency, social activity and labour to prepare), importance of quality aspects (attributes of products such as health, natural, fresh, sustainability issues and organoleptic qualities) and consumption situations (distribution of meals throughout a day or eating "out"). Further work by Brunsø *et al.* 2004 includes purchasing motives (what expectations exist and the importance of the consumer expectations such as tradition or pleasure).

Means-end chain theory links products to consumers by postulating hierarchical relations between attributes of the product, consequences of product use and values of consumers (Hofstede *et al.* 1998). Convenience, together with price, sensory appeal and health-related concerns, is believed to be an important determinant of food choice (De Costa *et al.* 2007). While factors such as healthiness, sensory information, and convenience are ambiguous to the supplier, they form a broad concept which not only incorporates to qualities of "food" but also those of the consumer. It is further argued by (De Costa *et al.* 2007) that the consumers need for convenience impacts on many food-related behaviour such as shopping, storage, meal composition, meal preparation and eating patterns.

What motivates consumers to purchase a particular product or separate component differences has been shown by (Brunsø *et al.* 2004) as the quality aspects (the evaluation of the products attributes) and the procurement, cooking methods, and consumption situations (to discriminate individuals product differences). Means-end chain theory encompasses these concepts showing that consumers do not buy products for the product's sake but for what the product can do for them, and that there are links between attributes of the product, consequences of product use and values of consumers (Hofstede *et al.* 1998).

2.2.4. Value concepts in the supply chain

The essential function of relationship marketing is relationships, and the maintenance of relationships between suppliers and consumers (Ravaland and Gronroos 1996). Alliances create customer loyalty and a stable, profitable long-term relationship with the potential to provide a competitive advantage (Ireland *et al.* 2002). Participating members can more effectively overcome uncertainty and actively reposition in competitive markets since alliances increases the probability of maintaining competitive advantages (Ireland *et al.* 2002). Creating value is considered an important strategy in relationship marketing and the ability of a company to provide superior value to its customers is regarded as a competitive strategy (Ravaland and Gronroos 1996). Cattle transactions have traditionally been based on averages, where both high and low quality cattle receive the same price (Schroeder *et al.* 1998), and differences in live weight transaction prices reflected approximately 25% of the sale value differences (Schroeder *et al.* 1998).

2.2.4.1. Value adding

Customer satisfaction depends on value (Kotler and Levy 1969; Ravaland and Gronroos 1996), a ratio of perceived benefits relative to perceived sacrifice. Whether the buyer is satisfied after purchase depends on the offer's performance in relation to the buyer's expectations (Kotler and Keller 2006). The perceived sacrifice includes all the costs the buyer faces when making a purchase (i.e. price, acquisition costs and risk of failure or poor performance) and the perceived benefits (i.e. a combination of physical attributes, purchase price and other quality indicators, Ravaland and Gronroos 1996). Customer satisfaction depends on value (Harmsen and Jensen 2004) and as well as the total costs or sacrifice (Ravaland and Gronroos 1996), however it is argued by Simmons and Taylor (2006) that while every supply chain exists to serve their final customer, often chain members don't have an understanding of the issues that are important to their consumers. Value innovation has been suggested to be the key variable underpinning the creation of competitive advantage by creating a new "market space" enabling companies "out-competencing" rather than "out-performing" their competitors (Matthyssens *et al.* 2006). Furthermore Matthyssens *et al.* (2006) argue that value innovation implies the willingness and ability to remove obsolete activities and items in an organisation.

Price incentives must be present for producers and processors to meet consumer's needs when making production and marketing decisions (Schroeder *et al.* 1998). The ability to accurately measure beef quality and price cattle to reflect the individuals' value is a required for a supply chain within the beef industry and has been argued by Schroeder *et al.* (1998) that improved beef quality without the elimination of average pricing would result in little, if any, improvement in coordination of the beef marketing system. A value based pricing system provides the appropriate signals required for the payment of beef quality attributes (Schroeder *et al.* 1998).

Customer purchasing decisions may be influenced by the customer-supplier relationship and "despite an offering not exactly the one sought, the parties involved try to come to an agreement where the objectives of both parties can be met" (Ravaland and Gronroos 1996). It is argued by Ravaland and Gronroos (1996) that in this situation the issue is not what is being offered but the ability of a supplier to maintain its customer relationship and presents as the total episode value, equation 1; in addition a poor episode value can be balanced by a positive perception of the relationship.

Equation 1. Total episode value (Ravaland and Gronroos 1996).

$$Total\ episode\ value = \frac{Episode\ benefits + relationship\ benefits}{Episode\ sacrifice + relationship\ sacrifice}$$

Ravaland and Gronroos (1996) further argue that when examining the customer-perceived value in a relationship it is difficult to assess the value received from a traded product without including the effect of a maintained relationship. In long-term relationship with the supplier the value concept differs in that it encompasses factors such as safety, credibility and continuity that encourage customer loyalty (Ravaland and Gronroos 1996), illustrated in Figure 12. In addition the importance of "total episode value" is that it combines the costs and benefits associated with a customer-supplier relationship which determines the overall value perceived by the customer (Tzokas and Saren 1997).

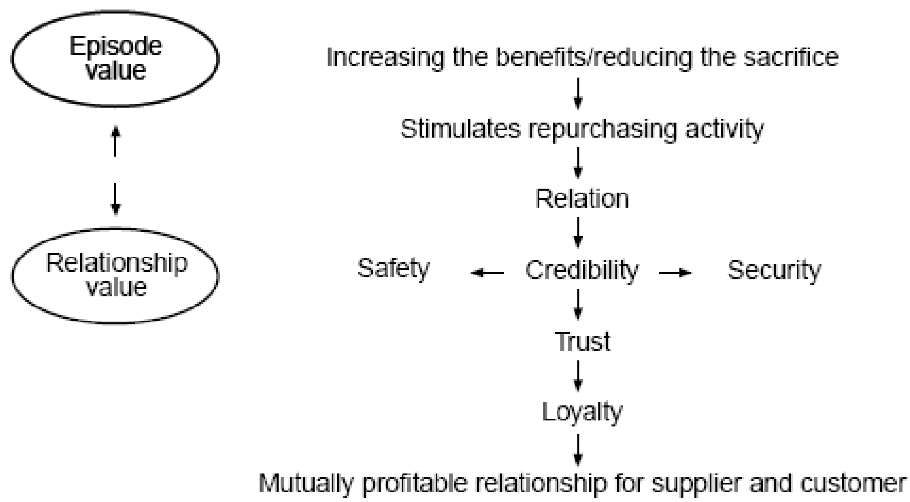

Figure 12. The effect of value adding strategies in a long term relationship (Ravaland and Gronroos 1996).

The value creation process has primarily been driven by customers (Tzokas & Saren, 1999), not suppliers. Value-based marketing is one way to remedy the lack of clear economic signals between different levels of supply chains (White *et al.* 2007). One industry strategy has been grid pricing whereby cattle are valued on either a live or dressed basis (White *et al.* 2007). Value improvement could be further achieved from the use of consumer eating quality and yield data (Polkinghorne 2006), which could foster a shift in performance in conjunction with information systems that act in conjunction with consumer value payments to each supply chain segment (producer to retail). Using a combination of yield and eating quality data it has been shown by Polkinghorne (2006) that in groups of similar cattle carcasses (280kg) can range in retail value up to $700. Value-based marketing and pricing therefore have the ability to conceptually link price and value, and more accurately communicate consumer demands to producers (Schroeder *et al.* 1998).

2.2.5. Marketing

The objectives of marketing are satisfying customer needs (Kotler *et al.* 1999) by building profitable customer relationships and communicating value to customers (Anderson and Narus 1999) by serving as a link between the customer and various processes within the firm (Moorman and Rust 1999). This can be approached by managing the customer demands from both new customers and repeat customers (Slater and Olson 2001). While traditional marketing theory and practice have focused on attracting new customers and making the sale (Kotler *et al.* 1999), the emerging emphases is shifting towards retaining current customers and building lasting customer relationships (Anderson and Narus 1999; Kotler *et al.* 1999). Ultimately, marketing is the art of attracting and keeping profitable customers (Slater and Olson 2001; Kotler and Keller 2006).

2.2.5.1. Marketing value

It is argued that organisation's need to move beyond customer management and understand more fully what customers' value in terms of which products and services help them to achieve their goals and purposes (Payne and Holt 1999; Slater and Olson 2001). It has become more important for suppliers to determine the key elements of customer value (Siskos *et al.* 2001), since this helps to understand customer requirements (Payne and Holt 1999; Easton 2002), furthermore it allows suppliers to plan their future “value proposition” (what is required to create value) for example Aquino and Falk (2001) have shown “*Wolf-Friendly*” beef receives consumer support for a product marketed under environmental attributes and endorsed by environmental groups as being environmentally sustainable as well promoting the humane treatment of animals. Historically growing markets and expanding economies have allowed businesses to practice the "leaky bucket" approach to marketing (Kotler *et al.* 1999). Traditional marketing of red meat products has been fragmented and inefficient but these inefficiencies present opportunities to create value for customers as part of a supply chain (Todd and Cowell 1981). Changing demographics, slow economic growth, sophisticated competitors and overcapacity in industries are factors that contribute to fewer new customers (Kotler *et al.* 1999). It has been indicated by (Kotler *et al.* 1999) that the costs of attracting new customers are therefore rising (costing five times as much to attract a new customer as it does to keep a current customer satisfied).

Marketing is now accompanied by information flow and communication between buyers and sellers, Figure 13 (Kotler 2000; Guenzi and Troilo 2006). Marketers now view sellers and buyers roles as sending goods, services and communications to the market (Guenzi and Troilo 2006); and in return receiving money and information (Kotler 2000).

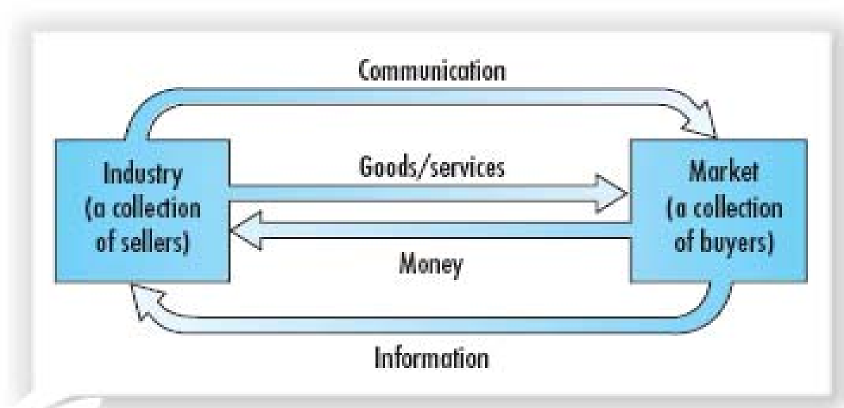

Figure 13. A simple marketing system (Kotler 2000).

Marketing is successful if it delivers value (Hunt and Arnett 2006) and satisfaction to the buyer (Kotler 2000; Guenzi and Troilo 2006), and customers choose between different products based on their perception of the most value or appeal (Paşa and Shugan 1996).

Kotler (2000) defines value as the ratio between what the customer gets and what they give, (see equation 2). Based on this equation, the marketer can increase the value of the customer offering by (1) raising benefits, (2) reducing costs, (3) raising benefits and reducing costs, (4) raising benefits by more than the raise in costs, or (5) lowering benefits by less than the reduction in costs (Kotler 2000).

Equation 2. Value equation (Kotler 2000).

$$Value = \frac{Benefits}{Costs} = \frac{Functional\, benefits + emotional\, benefits}{Monetary \cos ts + time \cos ts + energy \cos ts + psychic \cos ts}$$

2.2.5.2. Market segments

Given the diversity amongst consumers marketers can rarely satisfy all potential customers. Market segmentation groups customers who have a preference or require varying products or product composition. Market segments can be identified by examining demographic, psychographic, and behavioural differences among customers (Kotler 2000). Market segmentation outlined by Kotler (2000) is conducted by choosing target markets where suppliers develop a market offering (positioned in the minds of the target buyers as delivering a set of central benefits) and a global industry where the positions of competitors is in major geographic or national markets.

2.2.5.3. Relationship marketing and marketing channels

Day and Montgomery (1999) have outlined the changes in relationship marketing as a shift from the emphasis on discrete transactions and the acquisition of new customers to relationships and the retention of valuable customers; through an integrated effort that mutually benefits both sides, through interactive, individualized, and value added contacts (Fyall *et al.* 2003). And second, the array of relationships has been expanded from that of seller and customer to include partners up and down the value chain (e.g., suppliers, the customers of customers, channel intermediaries) (Day and Montgomery 1999).

Relationship marketing aims to build long-term relations with customers, suppliers and distributors in order to earn and retain long-term relationships (Sheth and Sisodia 2002; Srinivasan *et al.* 2005). Effective marketers accomplish this by promising and delivering high-quality products and services at fair prices to the other parties over time (Kotler 2000). Relationship marketing builds strong economic, technical, and social ties among the parties; minimises transaction costs (Sheth and Sisodia 2002) and time and in successful cases, transactions move from being negotiated each time to being a matter of routine (Kotler 2000). Ultimately relationship marketing builds a “marketing network” which consists of the company and its customers (Srinivasan *et al.* 2005). Under this structure competition is between marketing networks and profits go to the company that has the better network (Kotler 2000).

Marketing channels have existed in essentially three forms communication channels (that information to and from participants), distribution channels (that deliver product) and selling channels to establish transactions with potential buyers. Marketers clearly face a design problem in choosing the best mix of communication, distribution, and selling channels for their offerings (Kotler 2002). Supply chain alliances facilitate a longer channel stretching from raw materials to components to final products that are carried to final buyers (Kotler 2000) and customer value is created (Jüttner *et al.* 2007).

This literature reviewed in this chapter has shown that there are a number of opportunities for a beef meat supply chain to increase final customer value as well as increase the value of carcasses for each successive suppler participants of the beef production chain. Supply chain alliances can create value for their participants through a more coordinated production approach such as means-end theory to define the component value of carcasses which can increase feedlots ability to meet market specifications which has been shown to increase customer satisfaction and retention.

2.3. Sorting and resource allocation

Cattle in Australia are usually traded based on lot averages. Under average pricing the value of cattle are usually determined on a pen basis based on average weight (Johnson and Ward 2005). Under a system of value-based pricing or grid pricing the value of individual animals incorporates quality attributes such as yield and quality (Johnson and Ward 2005) which further helps remove the information gap between retailers to producer (Johnson and Ward 2005). It is argued by Fausti *et al.* (1998) that fed cattle should be valued on an individual basis as opposed to averages because traditional cash pricing becomes a barrier to the communication of consumer preferences. The implications of average pricing are that the price discovery mechanism fails because information is not provided to producers of their individual animals' market value, or, the information is distorted (Fausti *et al.* 1998).

It is considered by Fleming *et al.* (2005) that efficiency in the production of individual animals is of immediate interest to managers as well as the overall efficiency of the firm. One focus of economics is efficiency in allocation (Gowdy 2001). It was shown by Farrell (1957) that efficiency comprises two components, “technical efficiency” (the ability of a firm to maximise its outputs) and “allocative efficiency” (the ability to use inputs in optimal proportions). An improvement from allocative efficiency arises through resource selection pressure which shifts economic weights from less to more efficient pursuits (Louçã, 2001) by selecting the optimal mix of inputs (such as animals and feed), which inturn helps to increase overall economic efficiency (Coelli *et al.* 2005). Optimal allocation of animals to markets within a supply chain can be achieved through sorting procedures aided by improved information sharing. Information about an animal’s background (genetic and environmental effects) are factors that can be supplied within the supply chain to help determine potential growth and composition. This information inturn can be used to allocate animals to more uniform groups and slaughtered based on the requirements of consumers of the supply chain. Furthermore grid pricing offers increased opportunity for producers with high quality cattle to realise premiums (McDonald and Schroeder 1999). Therefore the supply chain /grid pricing structure has the potential to secure increased numbers of higher quality cattle for production and consumers.

2.3.1. Price averages and individual animal value

Average pricing determines the value of cattle on a pen basis using the average weight which provides limited information value in making management decisions (Feuz 1999). However, value-based pricing or grid pricing, determines value on an individual animal basis and incorporates quality characteristics into the valuation of a carcass-typically, yield grade and quality grade (Johnson and Ward 2005). Grid pricing offers monetary incentives and disincentives that communicate market preferences (Johnson and Ward 2005). In order to improve beefs' competitive position against other meat products and foreign imports it has been commented by Fausti *et al.* (1998) that Value Based Marketing System (VBMS) for fed cattle should be developed. To create value and successfully market beef this involves consistently producing what is required by consumers at a competitive price (Egan *et al.* 2001). The US Value Based Marketing Task Force (1990) recommended a marketing system that applies discounts and premiums to encourage the production of carcasses that better meet specifications (i.e. external fat depth) with the belief that this will reduce revenue loss and increase beef consumption (Fausti *et al.* 1998).

Because the primary mechanism to price cattle has traditionally been average pricing (Johnson and Ward 2005), average pricing has favoured producers who sell below-average pens of cattle and penalises producers of above-average pens of cattle while VBMS encourages beef production that more closely matches consumer preferences (Fausti *et al.* 1998). Despite the ability of VBMS to provide economic signals (Feuz 1999) such as premiums and discounts for cattle that fit within a desired set of specifications (MacDonald 2006), there is reluctance by producers to enter into this pricing mechanism (Fausti *et al.* 1998). Risk aversion and producer bias away from VBMS are potential long-run barriers to producer acceptance of the VBMS concept (Fausti *et al.* 1998). Due to inadequate transfer of information pertaining to price signals supply chain alliances have formed within the beef industry by those participants who want more coordinated consumer-responsive beef production (Feuz 1999).

2.3.2. Precision agriculture

The use of *precision agriculture* has the ability to increase the implementation of more intensive resource management. While precision agriculture has evolved more so in cropping industries there are increasingly moves towards greater application of precision agriculture with farm animals, the use of growth and composition modeling is one such example. In cropping enterprises the emphasis has changed from "farming the soil" to variable-rate technologies, vehicle guidance systems, product quality (McBratney *et al.* 2005) and environmental management (Bongiovanni and Lowenberg-Deboer 2004). Despite some advances in precision management the development of decision-support systems for implementing precise decisions remains a stumbling block (McBratney *et al.* 2005). Associated benefits of precision agriculture have been defined by McBratney *et al.* (2005) as "a concomitant increase in quantity and/or quality of production along with the same or decreased inputs". These benefits focus on sustainable development, taking into account profitability as well as environmental and social benefits (McBratney *et al.* 2005).

Further issues pertaining to precision agriculture outlined by (McBratney *et al.* 2005) are appropriate criteria for economic assessment (formulation of optimisation criteria), recognition of temporal variation (such as variation across a field and across years), holistic or whole-farm focus (becoming an integrated process across farm, zone and enterprise), quality assessment methods (separation of product into quality classes) which increases economic benefits and product tracking, traceability (fulfilling consumer requirements to track the products they purchase) and environmental auditing (a consequence of product-tracking is the ability to demonstrate the management of and application of treatments to products) (McBratney *et al.* 2005). A number of these issues have been addressed in livestock production by the implementation of NLIS and the use of RFID ear tags. RFID technology uses low, medium, and high frequency tags that range between passive short reading range to active beacon RFID with longer reading range and two-way active tags (Myerson 2007) which allow efficient data and information capture and better inventory management and control (Myerson 2007).

It has been commented by Fountas and Blackmore (2005) that precision agriculture can be "information intensive" and requires increased learning and skill proficiency (Kitchen *et al.* 2002). There have been however developments in sensor technology that has increased the availability of information relevant to monitoring animals, their environment, and therefore their production, growth and health (Frost *et al.* 1997). The application of integrated monitoring systems (sensors, databases and mathematical models) when combined and interpreted enable the maximum potential value to be derived from these information (Frost *et al.* 1997). Monitoring of feeding, environment, reproduction, health, growth, marketing, transport and quality has increasingly become of commercial interest (Frost *et al.* 1997). Customer requirements are increasingly defined such as those seen in the red meat industry which pays producers more for animals of a particular weight, conformation and composition (Frost *et al.* 1997). Growth curves and histories of animals weights (actual growth curve compared with predicted) indicate how an animal should grow and therefore non performing animals can be identified as well as values for immeasurable variables to be deduced (Frost *et al.* 1997).

2.3.3. Ultrasound determination of fat depth

Identifying profitable animals and when to market is a complex challenge (Ibarburu and Lawrence 2005). The profits of a beef cattle enterprise are affected by factors such as feed conversion, average daily gain and carcass premiums and discounts at slaughter which are impacted on by an animal's growth and composition. Commercial beef carcasses are mostly traded based on measures of weight and fatness (Johnson and Vidyadaran 1981). Fat thickness measurements over the M. *longissimus* at the 12-13th rib site are indicators of carcass composition, saleable beef yield (Hopkins *et al.* 1993; Johnson 1987) and fat trim (Johnson and Ball 1989). Factors that have the potential to influence the economic value of a beef carcass are genotype (through the deposition of fat relative to a carcass weight, and influenced by "maturity type"), breed, sex (Ball and Johnson 1989) and castration status and nutrition (Priyanto *et al*. 1999). Each factor exerting its effect by altering the relative growth patterns of muscle, bone, and fat (Priyanto *et al*. 1999).

Ultrasound technology is a non-invasive procedure that uses an ultrasonic contact transducer and an ultrasonic analyser. Ultrasound technology can accurately assess carcass traits of finished cattle which can be beneficial at key points along the marketing chain (Aiken 2004). Objectively measured ultrasound can be combined with observable measurements to predict the days on feed required to reach a final carcass compositional end point target (Peterson *et al.* 2003). Ultrasound feedlot sorting systems have the potential to increase profitability through increasing the accuracy of sorting and grouping cattle to increase carcass value and quality (Garmyn *et al.* 2003). Four primary traits measured with ultrasound technology are Backfat Thickness (thickness of subcutaneous fat between the 12th and 13th rib over the longissimus muscle), *Longissimus* Muscle Area (the cross-sectional area of the longissimus muscle at a point between the 12th and 13th rib), Intramuscular Fat (intramuscular fat measured in the longitudinal image of the longissimus muscle over the 12th rib) and Rump Fat *(gluteus medius* fat depth measurements) which can be used to predict yield and marbling scores (Williams 2002). Sorting systems can incorporate ultrasound technology to increase the accuracy of their prediction equations (Koontz *et al.* 2000). The use of ultrasound technology in feedlots has the capacity to explain 15 and 25 percent of variation in carcass fat thickness where as manual measurements (rib palpation) explain between 5 and 12 percent (Cooper *et al.* 1999). Moreover it has been shown by Brethour (2000a) that ultrasound backfat measures could be used to predict the number of days to reach a target carcass backfat level and marble score (Brethour 1990) which can be used to maximise profit (Koontz *et al.* 2000; Ibarburu and Lawrence 2005).

2.3.4. Growth and composition models

Growth and composition models attempt to sort cattle into homogeneous groups to increase uniformity and profitability (Tedeschi *et al.* 2004). Growth models are required to predict growth rates, body weight and composition of each animal in a pen on a daily basis as accurately as possible in order to have satisfactory predictions of cost of gain, breakeven sale price, and days to finish each day during growth (Tedeschi *et al.* 2004). Several growth models have been developed to predict growth and composition which include Lofgreen and Garrett (1968) and Fox *et al.* (1992); models that use growth rates and animal characteristics Keele *et al.* (1992) and Williams *et al*. (1995) as well as those based on DNA accretion curves and protein to DNA ratio (Oltjen *et al.* 1986a and 2000) and Di Marco *et al.* (1989). The Cornell Value Discovery System (CVDS) predicts growth rate, accumulated weight, days required to reach target body composition, carcass weight, and composition of individual beef cattle fed in group pens (Tedeschi *et al.* 2006).

2.3.5. Model predictions

The beef industry is beginning to manage and market cattle individually in an effort to reduce excess fat, increase consistency and quality, enhance productivity, and increase economic returns (Tedeschi *et al.* 2004). Individual cattle management systems (ICMS) are being developed to manage individual animals to their optimum endpoint, these incorporate live and carcass cost of gain and discounts (Tedeschi *et al.* 2004). Dynamic mechanistic models have been used to predict beef cattle growth and composition. The Davis Growth Model (DGM) (Oltjen *et al.* 1986b) predicts protein accretion based on DNA synthesis and frame size, heat production from empty body weight, and fat accretion from the difference between metabolisable energy intake and the energy in protein gain plus heat (Oltjen *et al.* 1986a). The DGM has been further extended by McPhee *et al.* (2008) to incorporate equations that allow partitioning of fat from percentage inclusion to quantitative weights. Tedeschi *et al.* (2004) has accounted for 89% of the variation in average daily growth (ADG) using the CVDS and 83% of the variation estimating body weight. Additional models were able to predict accumulated body fat (84% of the variation) (Tedeschi *et al.* 2004).

2.3.6. Sorting

Sorting increases the uniformity of animals within a group which helps to increase the feeding precision and meet their requirements, rather than average feeding (Oltjen *et al.* 2000), furthermore sorting programs are essential as production increases its value based focused.

Animals that are overweight and have excess fat are penalised and incur additional feed costs due to overfeeding. Coordination from producer to consumer within a supply chain has the opportunity of having access to private non partner antagonistic information (Schneeweiss and Zimmer 2004) which can be used in conjunction with growth and composition equations to sort cattle.

Sorting animals prior to slaughter has the potential to decrease variability and increase the number of carcasses that meet specification. Sorting allows cattle production to reduce meat quality discounts, increase meat quality premiums, increase beef carcass quality, more efficiently use feed resources, and increase profits (Koontz *et al.* 2000). Carcass characteristics in live animals can potentially allow sorting and selecting cattle for carcass merit (Williams 2002) and to be grouped into management lot sizes by carcass merit (Koontz *et al.* 2000). Sorting is an attempt to increase allocative efficiencies by managing lot-sizes of similar endpoint animals. Lot-sizing reduces costs and increases returns while trying to satisfy the customers' requirements with limited capacity (Xie and Dong 2002). Sorting animals into groups helps manage the production lot-sizes that, over time, progress through the consecutive production stages. Incorporating capacity or lot-sizing constraints can be complex incorporating time-varying characteristics (Xie and Dong 2002).

It is argued by Garmyn *et al.* (2003) that marketing entire pens as mixed groups results in lower quality, over-finished or heavy carcasses. Value-based marketing systems require a cost-effective tool that can predict future carcass merit and sort cattle into outcome groups that will produce a more uniform product (Garmyn *et al.* 2003). Sorting by an increasing number of groups can increase the overall uniformity of each sort and reduces outliers, 3-way sorting has the potential to eliminate most outliers and maximises the profit of individual animals each animal (Garmyn *et al.* 2003). Properly implemented supply chain management increases coordination among firms at successive stages of production (Crook and Combs 2007). In a supply chain alliance which incorporates information transfer (i.e. pedigree data and historical growth data) and the background of animals are more efficiently incorporated into prediction models and therefore more efficiently sorted. Furthermore the value of sorting technologies means that individual animals are incorporated into a global supply chain optimisation strategy (Gheidar Kheljania *et al.* 2007). While it is argued by Gheidar Kheljania *et al.* (2007) that global optimisation is complex, incorporating prediction models and sorting strategies into a supply chain alliance means the animals effectively carry their information from producer to final customer. Furthermore optimisation strategies become more efficient as prediction models contain information based on a whole-of-life strategy and are allocated to the final customer as opposed to intermittent customers.

2.3.7. Optimal allocation decisions

The final price of fed cattle plays the largest role in influencing decisions to place cattle on feed (Griffith *et al.* 2004). Prices are higher for quality cattle that have less variation (Muth *et al.* 2008). The opportunities to use *Co-ordination models* allow the best mix of resources or cattle in the beef industry. These optimise the benefits of all the members and alignment of decisions between entities of a supply chain (Gheidar Kheljania *et al.* 2007). Therefore strategically managing animals, particularly the least profitable animals within feeding programs can increase the average profit of entire pens (Ibarburu and Lawrence 2005).

Cattle are often fed to a point at which their market price is equal to the cost of an additional unit of gain and marketing them before discounts are received for overweight carcasses

(MacDonald 2006). Figure 14 illustrates a feedlot profit model where all animals are purchased and sold as a single group (Amer *et al.* 1994). The present value of the total returns curve (TR) increases over time at a decreasing rate, indicating the tendency for older carcasses to develop attributes that incur discounts on the market price per kilogram of beef sold, a reduction in growth rate as animals approach maturity, and a reduction in the number of animals that could originally have been purchased. The present value of total cost (TC), Figure 14, increases at an increasing rate over time because of the increasing feed requirements to maintain animals at higher weights (Amer *et al.* 1994). The present value of profits (PV[π]) is maximized when the difference between the present values of TR and TC is maximised (Amer *et al.* 1994).

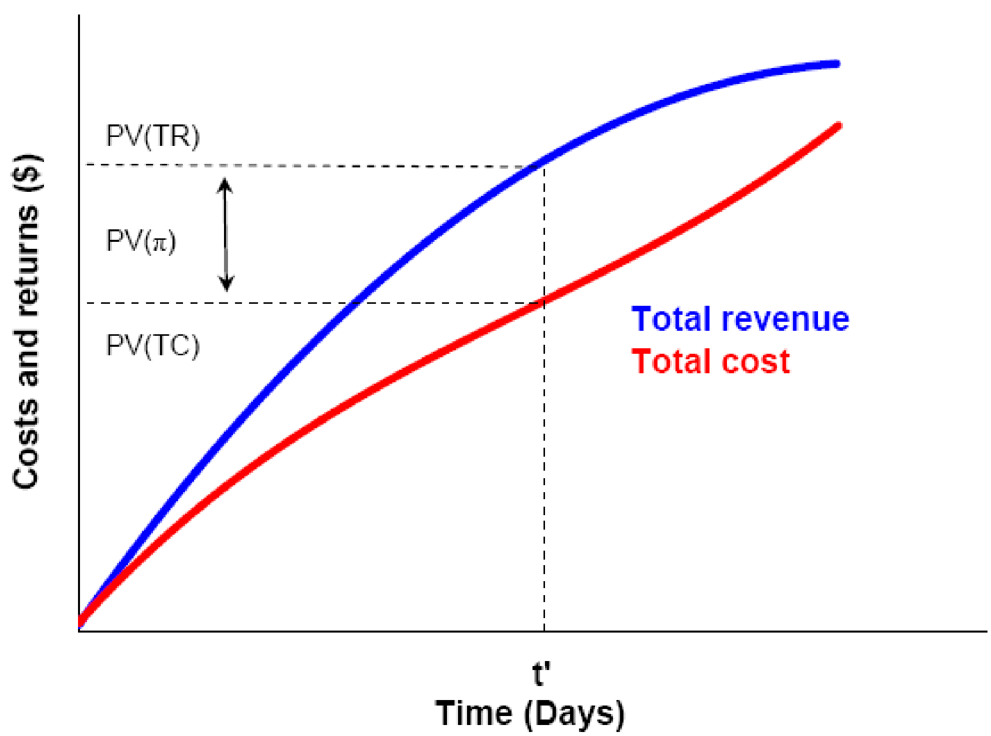

Figure 14. The present value (PV) of total returns (TR) minus total costs (TC) for a feedlot over time (t) and their difference, the present value of profits (PV(π)) at time t', adapted from Amer *et al.* (1994).

Garmyn *et al.* (2003) used ultrasound and computer technology to group cattle into uniform market groups by combining initial body weight, estimated backfat thickness, *longissimus dorsi* muscle area, percentage intramuscular fat, average daily gain and rib eye shape to predict days on feed needed to reach optimum carcass composition in steers. The profit equation was determined by carcass value, less the cost of feed, implant, and ultrasound and the initial value of the steer and found quality premiums were \$0.02 per kg carcass weight higher ($P = 0.05$) for sorted steers, and carcass value was \$47.75 higher ($P = 0.001$) per head for sorted steers (Garmyn *et al.* 2003). Sorting resulted in a steers with better distribution of carcass quality grades; however, additional days on feed and increased feed costs limited the profitability of the sorted steers (Garmyn *et al.* 2003).

This review has shown there are opportunities for precision management and optimal allocation of animals in feedlots. Incorporating “technical efficiency” and “allocative efficiency” can increase the efficiency of feedlots through more intensive resource management. Moreover there is an ability to use growth and composition models to predict growth, body weight and composition of individual animals which can be used to sort animals. This increases the ability to manage feedlot animals in sorted uniform groups and reduces the number of animals out of specification.

Overall, the literature reviewed has shown that traditional *supply push* methods of trading cattle are information poor in terms of upstream feedback and downstream customer requirements; furthermore the purchase of animals through price determination and price discovery has lead to low prices and high variability. Coupled with inefficient allocation of individual animals at feedlot entry has led to a high number of carcass traits out of specification which has resulted in large costs for the Australian beef industry due to non compliant carcass traits. Integrated supply chains help to increase the level of information flow between producers and consumers which provides greater capacity to resource plan, address customer relationship management and implement customer driven production objectives which adds value. Properly implemented supply chain management helps coordinate the successive stages of production by aligning decision making between the chain participants.

It is possible to implement a component based pricing system and optimally allocate animals at induction using sorting procedures which would optimise resource selection, use and economic efficiency. An economic assessment through analyses of carcass traits and carcass value would provide the component value of induction traits. This allows the value of an animal to be determined at induction based on its carcass potential. Growth and composition models can be used to sort cattle at induction into homogenous groups to increase uniformity and profitability. By predicting growth rate, body weight and composition of individual animals daily theses models can be used to calculate cost of gain, breakeven pricing and days to reach specific carcass trait characteristics. Furthermore individual cattle management systems would increase the number of animals that reach optimal endpoints by sorting animals prior to slaughter such as at feedlot induction. This has the potential to decrease variability and increase the number of carcasses that meet specification by increasing the allocative efficiencies through managing lot sizes that have the potential to reach similar end points.

3. The costs associated with non compliance in Australian beef carcasses

This chapter introduces principles of resource management within Australian beef feedlots and the costs associated with non compliance. Suppliers who lack a clear understanding of their consumer's requirements have poorly defined production objectives. This can result in supply push leading to inefficiencies due to non coordinated production oriented deliveries.

3.1. Abstract

Strategic sourcing of cattle that meet market specification is a critical challenge of firms (Talluri and Narasimhan 2004) when purchasing animals for beef production. Transactions between buyers and sellers are reliant on commercial relationships (Quayle 2006) that are based on supplier capabilities (White 1996; Wincel 2004) and supplier competencies (Chiesa and Manzini 1997; Hodgson 1998; Javidan 1998) with the view to minimising failure rates (Dobrev *et al.* 2004). The potential for a businesses output to be profitable is reliant on their uniqueness (Zhang *et al.* 2003) and capacity to create value for their customer (Chiesa and Manzini 1997). Sethi *et al.* (2005) argue that products out of specification are a source of customer irritation and are costly to clients and manufacturers. Missing target specifications has the potential to result in a large discount in carcass value. Costs associated with carcass weight and external fat depth that is out of specification impact both the ability of suppliers to meet customer requirements (Sethi *et al.* 2005) and levels of productivity or slaughter rates (Gum and Logan 1965) that are nearer to the processor's cost minimising level of production (Anderson *et al.* 2003). When production systems account for the whole production chain it becomes possible to remove more waste from the total system (Wincel 2004).

This analysis used a subset of Australian beef industry feedlot data from two long fed feedlots to assess both the costs and causes of carcasses out-of-specification. The economic value associated with products that are out-of-specification can be illustrated by the Taguchi Quadratic Loss Function (Patil *et al.* 2002), which fixes an economic value out-of-specification. This was done using a combination of carcass specifications (MLA 2004) and industry grid prices (D. Llewelyn, pers. comm., 12 February 2007; T. Suzuki, pers. comm., 12 February 2007). This analysis showed that at the nominated hot carcass weight specification (300kg - 400kg) in the short fed export market there were 28 per cent outside of specification and the long fed export market (380kg - 450kg) 29 per cent were outside specification. A HP8 specification of 10mm-26mm showed 16 per cent outside of specification. At the nominated AusMB specification (3+) 70 per cent are outside of specification. Using the grid pricing structure from Table 5, page 70 and a long fed average carcass weight of 420kg, it can be calculated that 70 per cent of these industry cattle that are destined for the long fed market incurred a loss of $105/head due to marble scores that are out-of-specification. These results demonstrate that there is a large amount of variation in cattle across beef production systems which have lead to a reduction in opportunities for precision management and value based marketing

3.2. Introduction

For some years now, well-defined carcass specifications have existed for Australian cattle targeted at particular market endpoints. For example, as shown for a very simplified specification in Table 2, cattle targeted at this particular short fed domestic market should be on feed for around 100 days, should have a hot carcass weight of between 300 and 400 kgs, and should have a P8 fat depth of between 10 and 27 mm. Cattle targeted at this particular long fed export market have a different range of preferred values for the key quality characteristics. Cattle that have not been fed sufficiently long, or are too light or too heavy, or are too fat or too lean, or are not sufficiently marbled, are “out-of-specification” or “non-compliant”. They will be penalized by the processor through price discounts because they will have to be re-allocated to lower value markets or it will cost more in processing to fit them into the specified market.

A complete but dated summary of various market specifications is available in Allerton (1999), while more recent versions are available through Meat and Livestock Australia (MLA 2004), McKiernan *et al.* (2007) and individual beef processors. In general, more stringent specifications apply to cattle designed for the higher valued export markets and for cattle that are targeted at achieving a Meat Standards Australia (MSA) quality grade in the domestic market (MSA 2007).

Table 2. Feedlot cattle exit specifications (adapted from MLA 2004)

Trait	Short fed	Long fed
Days on feed	100	220 +
Hot carcass weight (kg)	300 – 400	380 – 450
Hot P8 fat depth (mm)	10 – 27	10 – 40
Marbling score	NA	3+

Anecdotal evidence suggests that a significant proportion of Australian cattle do not meet the required specifications for their target market. Since approximately the same costs are incurred in managing and feeding animals that do not meet specifications as those that do meet specifications, a substantial cost is attached to this non-compliance to specification.

Some experimental evidence is available to support this view. For example, Edmondston *et al*. (2006) showed that variation in individual carcass value in northern Australian production systems is significant, with a range of about $210 (animals from the top and bottom 10 per cent received a $68 profit and a $142 loss respectively). Similarly, Polkinghorne (2006) estimated the variation present in carcass yield and quality resulted in a difference of $2.50/kg of carcass weight or a net value difference of up to $700 for individual carcasses when using both yield measurements and the MSA grading model and value differences between grades of $23/kg for ‘‘3 star’’, $39/kg for ‘‘4 star’’ and $50/kg for ‘‘5 star” McKiernan *et al*. (2007) provided estimates of compliance to a major NSW processor grid for 100-day grain fed steers of different breeds and subjected to different nutritional treatments prior to feedlot entry. Table 4.1.12 from their report is reproduced below as Table 3. Compliance was around 85 per cent for the weight and fat cover criteria, but as low as 20 per cent when the much more stringent fat colour criterion was included. There was a $0.10/kg carcass weight difference in price across these animals which translated into a difference of $146 in carcass value. For the much tighter “preferred” specifications, compliance was much lower.

Table 3. Comparison of pre-feedlot growth treatments over all breed types using adjusted mean feedlot entry weights for percentage compliance to standard and preferred grid specifications for weight and P8 separately and combined, for fat colour and for all three traits combined (from McKiernan *et al*. 2007)

	Slow growth	Fast growth
% within grid weight specififcation	87.6	91.3
% within grid P8 specification	96.1	94.6
% within grid weight and P8 specification	84.6	86.6
% within grid fat colour specification	25.5	32.1
% meeting all grid specification	20.5	29.8
% within preferred weight specification	20.8	55.5
% within preferred P8 specification	59.8	60.5
% within preferred weight and P8 specification	26.6	34.4
% within grid fat colour specification	25.3	32.1
% meeting pref specification	3.4	11.7

Using data obtained from the US National Beef Quality Audit, Savell (2001) and Schroeder and Kovanda (2003) estimated that noncompliance resulted in “lost opportunity" per steer and heifer slaughtered of $US279.82 in the year 1991. In Table 4, Savell (2001) partitioned these losses into four causes; waste (excessive fat and incorrect bone to muscle ratio), taste (insufficient marbling, age and gender including castrates and calves), management (pathology such as livers and other infections, bruises as well as dark cutters) and finally weight (animals under or over weight specifications).

Table 4. The estimated “lost opportunity” per individual steer and heifer slaughtered in the US in the year 1991 (from Savell 2001).

Cause	**Estimated loss (US$)**	**Estimated loss (%)**
Waste (fat and muscle to bone ratio)	219	78%
Taste (marbling and age)	29	10%
Management (bruising and dark cutters)	27	10%
Weight (too light or heavy)	5	2%
Total loss/animal	280	

The existing Australian estimates of the cost of compliance are based on relatively small numbers of experimental cattle. Mandatory reporting of data as in the US National Beef Quality Audit is not required in Australia. However the authors have been granted access to two large industry data sets comprising in excess of 40,000 carcasses. We use this industry data to provide new estimates of the cost of non-compliance with typical Australian beef market specifications.

3.3. Materials and methods

Risks in meat production are substantial (Hayes *et al.* 1998), the most common risk being product diversification. This has resulted in producers becoming non-specialists (Hayes *et al.* 1998). The cost of missing specifications when trading in variable markets causes problems in quality, cost and delivery of products (Patil *et al.* 2002). Economic values associated with products that are out-of-specification can be illustrated by the Taguchi Quadratic Loss Function, which fixes an economic value on quality loss (Patil *et al.* 2002). Figure 15 illustrates the quality loss in dollars L(y) due to product variation; m is the target value of the quality characteristic and k is an economic quality loss constant.

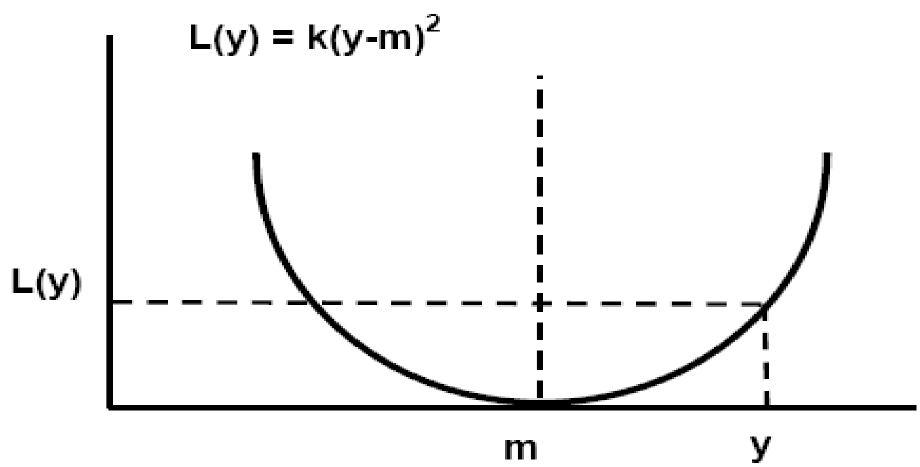

Figure 15. Taguchi quadratic quality loss function.

Estimating the Cost of Non-Compliance

The Taguchi loss function and its application in the Australian beef industry were investigated using a combination of carcass specifications (MLA 2004), industry grid prices (D. Llewelyn, pers. comm., 12 February 2007; T. Suzuki, pers. comm., 12 February 2007) and two large Australian processor datasets indicated as dataset Group A and dataset Group B. Both of the groups predominantly operate in the long fed export market. The combined Group A and Group B dataset included approximately 20,000 short fed animals (108±5 days on feed) and 20,000 long fed animals (220 ± 3 days on feed). The target value used for the Taguchi loss function was the first carcass trait value within the specification window defined by MLA (2004). The particular carcass specifications used are shown in Table 2 for short fed and long fed cattle and indicate the specifications for hot standard carcass weight (kg) (HSCW), hot P8 fat depth (mm) (HP8), and AUSMEAT marble score (AusMB). Table 5 (page 70) also indicates the pricing structure from an industry grid on an "over the hook" basis.

A modeling scenario of the economic costs to industry was performed based on the Taguchi loss function. This modeled the economic cost of animals that were outside of specification when compared to the minimum movement required (for the trait of interest) to the first instance within specification. In addition, the out-of-specification costs individual animals were analysed using a generalized linear models. These models included dependent variables for hot carcass weight and hot P8 fat depth (short fed export market) and hot carcass weight and marble score (long fed export market).

3.4. Results

The distribution of HSCW for short fed animals in the two industry datasets, Figure 16, range between 260kg - 500kg. At the nominated HSCW specification (300kg - 400kg) there are 72 per cent of the industry animals within specification and 28 per cent outside of specification. Figure 17, page 71 shows that in line with the Taguchi loss function, as carcasses move further out of specification the loss per animal increases. The loss for an out-of-specification carcass was very small ($0.25) at 410kg HSCW, however when carcass weights increased to 500kg the loss per animal was around $60.

Table 5. Over the hook beef cattle grid prices for the short fed and long fed markets (D. Llewelyn, pers. comm., 12 February 2007; T. Suzuki, pers. comm., 12 February 2007).

Trait	Trait specification, indicator price and price differential											
Short fed export market												
Hot carcass weight (kg)[A]	250	270	290	310	330	350	370	390	450	470	490	510
Indicator price ($)	2.90	3.10	3.20	3.30	3.50	3.50	3.50	3.35	3.10	3.00	2.90	2.80
Hot P8 fat depth (mm)[A]	0	5	10	15	20	25	30	35	40	45	50	55
Indicator price ($)	3.45	3.45	3.50	3.50	3.50	3.45	3.45	3.40	3.35	3.30	3.25	3.20
Long fed export market												
Hot carcass weight (kg)[A]	370	380	390	400	410	420	430	440	450	460	470	480
Indicator price ($)	2.90	3.10	3.20	3.35	3.50	3.50	3.50	3.35	3.10	3.00	2.90	2.80
AUSMEAT marble score[B]	0	1	2	3	4	5	6					
Indicator price ($)	3.50	3.50	3.50	4.00	4.50	4.50	5.50					

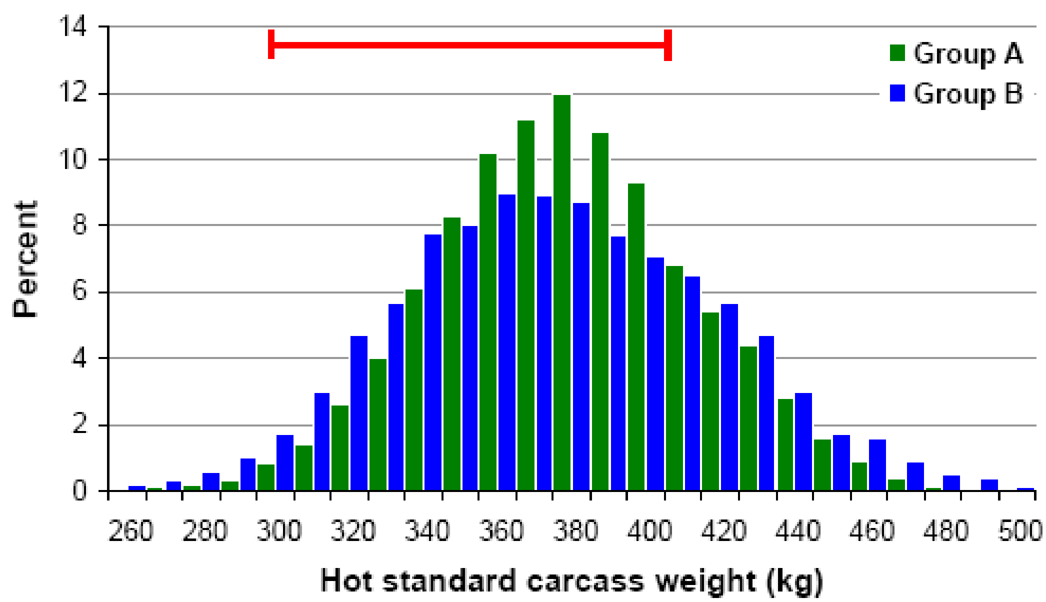

Figure 16. Distribution of hot standard carcass weight (kg) for the short fed export market (market specifications are indicated by the horizontal line).

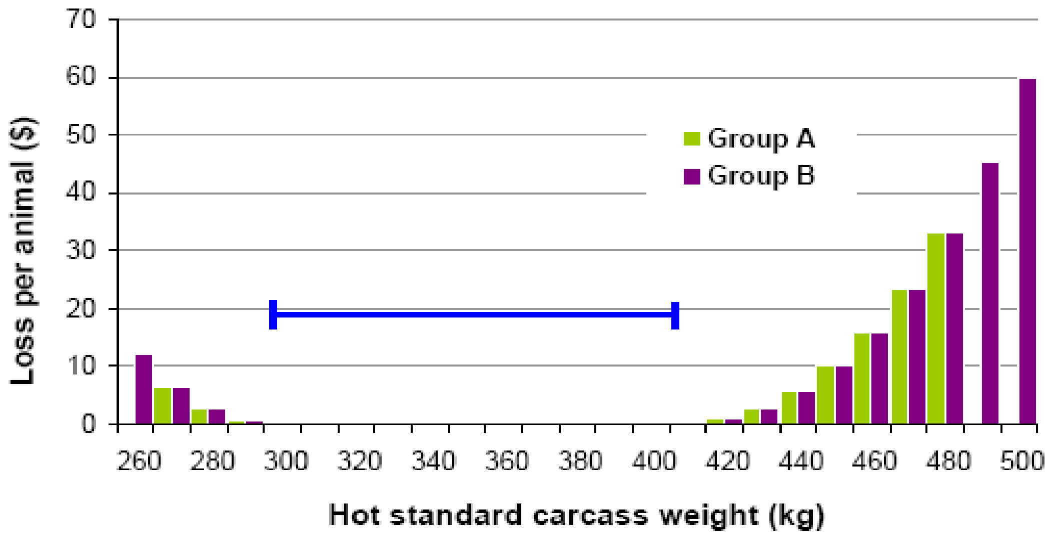

Figure 17. The economic cost ($) for out-of-specification hot standard carcass weight (kg) within the short fed export market (market specifications are indicated by the horizontal line).

The distribution of HP8 for short fed animals in the industry datasets, Figure 18, range between 2mm – 46mm. At the nominated HP8 specification (10mm-26mm) there are 84 per cent of the industry animals within specification and 16 per cent outside of specification. Figure 19 shows that the loss for out-of-specification HP8 fat depth (calculated at a carcass weight of 350kg) was much greater in the fatter animals. The loss per animal for 28mm HP8 was only $16.55, however this loss increased to around $80.00 at 46mm HP8.

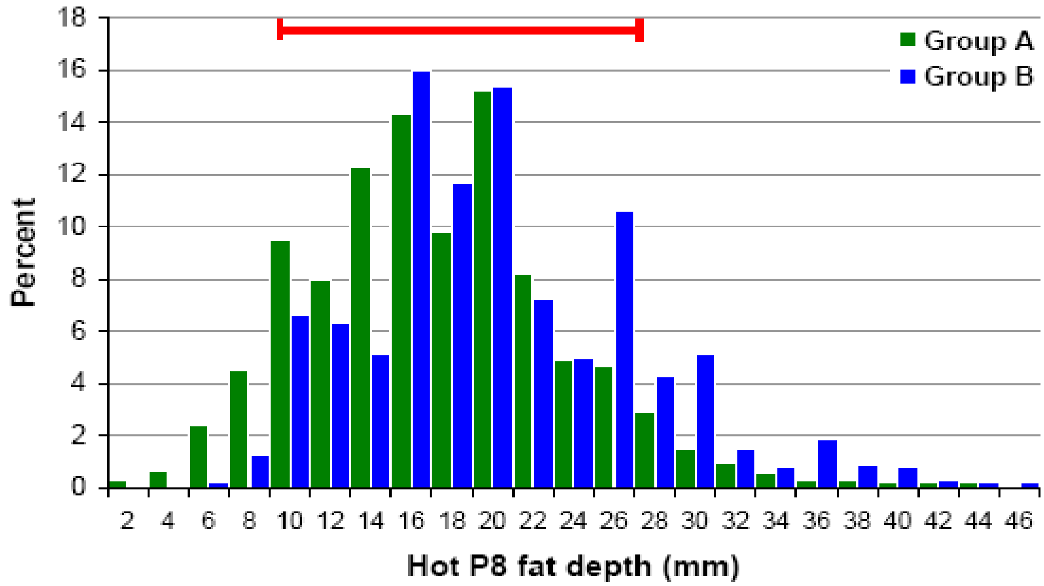

Figure 18. Distribution of Hot P8 fat depth (mm) for the short fed export market (market specifications are indicated by the horizontal line).

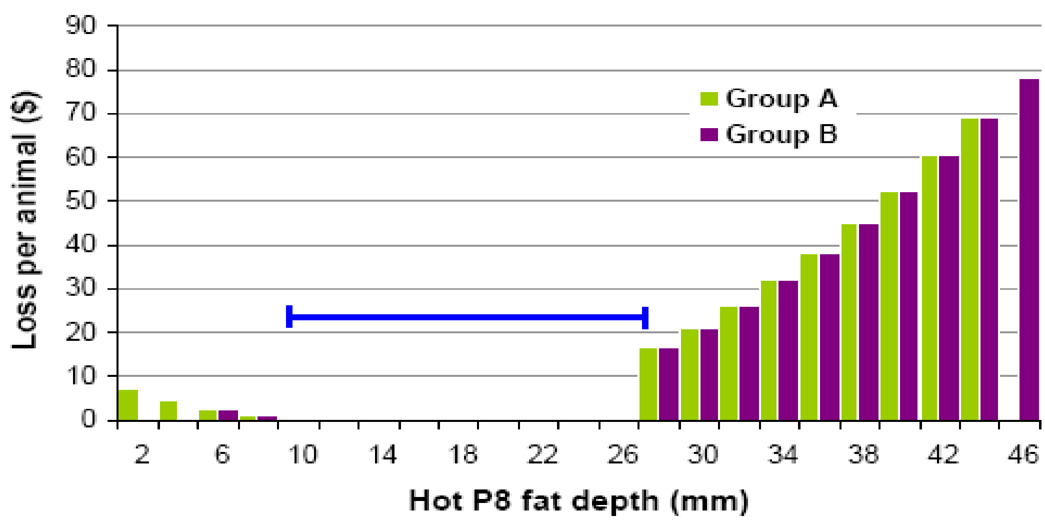

Figure 19. The economic cost ($) for out-of-specification hot P8 fat depth (mm) for the short fed export market (market specification is indicated by the horizontal line).

The distribution of HSCW for long fed animals in the industry datasets, Figure 20, range between 340kg – 540kg. At the nominated HSCW specification (380kg - 450kg) there are 71 per cent of these animals within specification to obtain the maximum price and 29 per cent outside this specification. Figure 21 shows that the loss for out-of-specification HSCW was greater in the heavier animals. The loss per animal with a heavy HSCW (540kg) was $146.00.

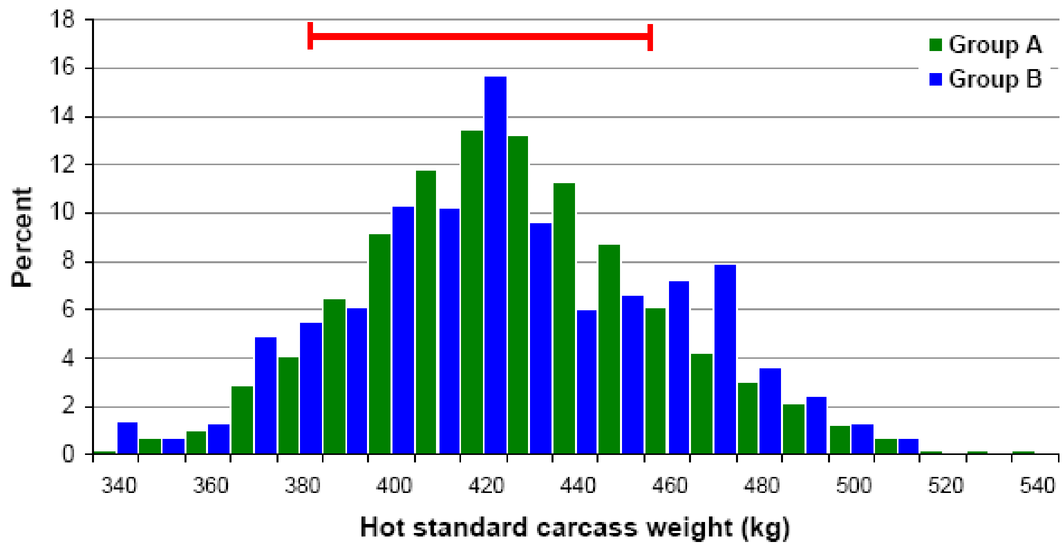

Figure 20. Distribution of hot standard carcass weight (kg) for the long fed export market (market specifications are indicated by the horizontal line).

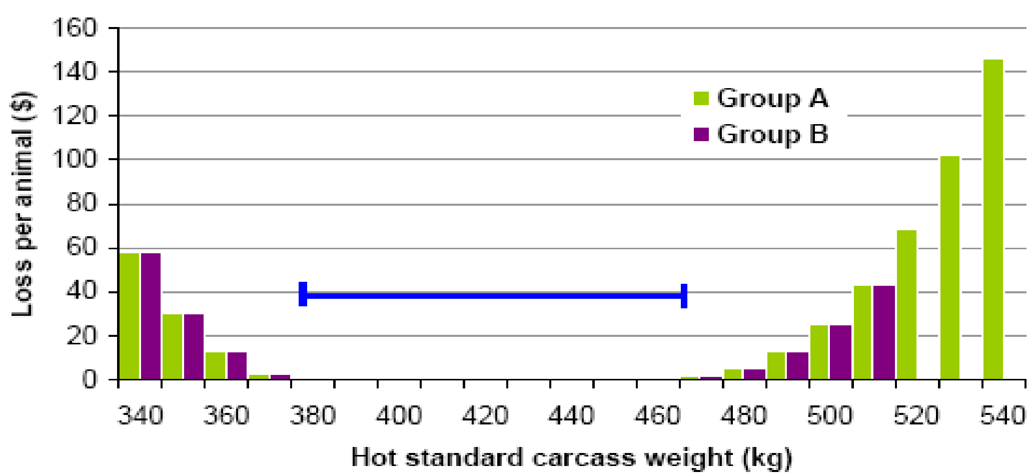

Figure 21. The economic cost ($) for out-of-specification hot standard carcass weight (kg) for the long fed export market (market specifications are indicated by the horizontal line).

The distribution of marbling for long fed animals in the industry datasets, ranged between 0-6 (Figure 22). At the nominated AusMB specification (3+) there are only 30 per cent of the animals within specification while 70 per cent are outside of specification. Using the grid pricing structure from Table 5 (page 70) and a long fed average carcass weight of 420kg, it can be calculated that 70 per cent of these industry cattle that are destined for the long fed market incurred a loss of $105/head due to marble scores that are out-of-specification.

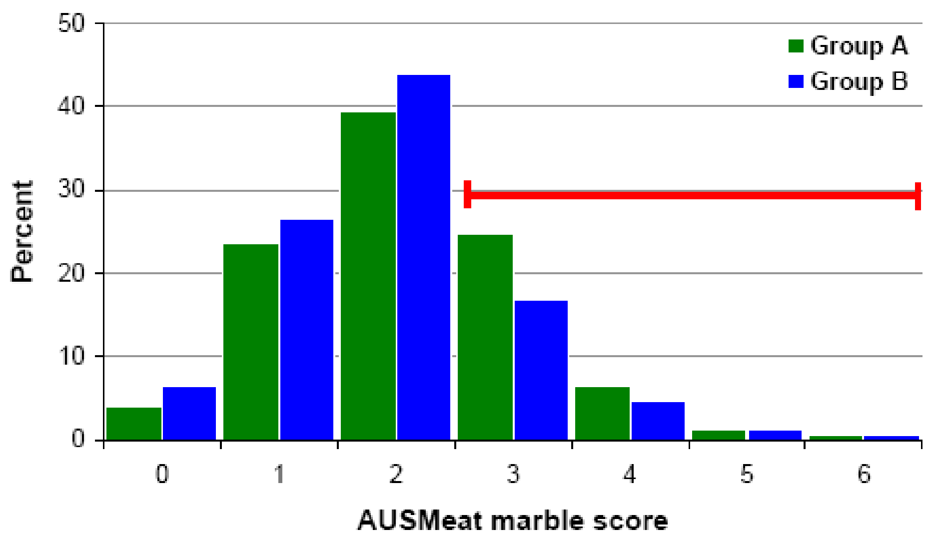

Figure 22. Distribution of AUSMeat marble scores for the long fed export market (market specifications are indicated by the horizontal line).

Further calculations using the short fed cattle data (n~20,000) show that the cost incurred for delivery of out of specification for HSCW totals more than $31,000 or an average per animal of $5.50 for the 28 per cent that do not comply with the HSCW specification. However there are also substantial differences across the two data sets. The mean loss for Group A cattle was $4.25/head or $12,300 in total, while the mean loss for Group B cattle was $6.00/head or $18,000 in total. This is shown in Figure 17, where there are heavier cattle in the Group B data. Similarly, total costs for non-compliance to the HP8 specification in the short fed data were around $64,000 or $17.50 per animal for the 16 per cent out of specification, calculated at an average carcass weight of 350kg. As shown in Figure 19, Group A incurred less costs for carcasses out of specification than Group B. The mean for Group A was $13.35/head or a total loss of about $20,000, compared to the Group B mean of $25.50/head or a total loss of $44,600.

Long fed animals in these data (n~20,000) incurred an out of specification cost totaling $62,800 or an average of $11.00 per animal for the 29 per cent that did not meet the HSCW specification. In this case there was little difference across the two component data sets in terms of cost per animal (Figure 7). The mean cost for Group A noncompliant animals was $11.50/head for a total cost of $28,000, while the mean cost for Group B noncompliant animals was $9.70/head or $32,000 in total.

The largest cost in the long fed data set was for the 70 per cent of animals that were out of specification for marble score: the total estimated cost was around $1,470,000 or an average per head cost of $105 calculated at an average carcass weight of 420kg. Again, the losses were very similar by Group - Group A totaled $704,000 and Group B $756,000. It should be noted that these loss estimates are based on an average carcass weight, however more realistically the fatter carcasses would also be heavier.

Furthermore the calculated loss for out of specification is additive. For the average short fed animal out of specification for both weight and fat score, the loss would be $23, while for the average long fed animal out of specification for both weight and marble score, the loss would be $116. Note also that these calculations do not incorporate any differences in variable costs (i.e. feeding) or fixed costs between compliant and noncompliant animals.

This analysis showed that contributions to out-of-specification costs (Table 6) were primarily due to pre-feedlot factors. Induction weight (kg/live) (P<0.001) and producer effects (P<0.001) significantly contributed to out-of-specification costs in both the short and long fed export markets. Within the short fed export market there was an additional effect of HGP implant (P<0.01) on HP8. Out-of-specification costs were for HSCW in the long fed export market was effected by days on feed (P<0.01) and AusMB was significantly effected by both days on feed (P<0.001) and implant (P<0.01). Breed, illness, season and year were not significant. The *induction allocation* (market allocation decision at induction to short, medium or long fed markets by feedlot managers and staff) while not statistically significant (Table 6) in this analysis did indicate feedlot managers initial market allocation decisions when adhered to decreased out-of-specification costs but this effect was small. Factors affecting the traits HSCW, HP8 and AusMB are analysed in greater detail in chapter 5, page 97.

Table 6. Factors affecting out-of-specification costs for the short fed export and long fed export markets. The subset of data used was obtained across two industry datasets (n=20,000).

Market	Short fed	Short fed	Long fed	Long fed
Effect	HSCW(kg	HP8	HSCW	Marble score
Induction weight (kg/live)	***	***	***	***
Days on feed	NS	NS	**	***
Implant	NS	**	NS	**
Producer	***	***	***	***
Breed	NS	NS	NS	NS
Illness	NS	NS	NS	NS
Induction allocation	NS	NS	NS	NS
Year	NS	NS	NS	NS
Season	NS	NS	NS	NS

, *, NS P<0.01, <0.0001, not significant respectively

3.5. Discussion and implications

The industry data analysed in this paper suggested that the cost of non compliance to Australian beef market specifications were substantial. Out of specification costs for hot carcass weight and external fat depth (hot P8) in the short fed market averaged $5.50/head and $17.50/head, but may be as high as $60/head and $80/head, respectively. The costs for out of specification carcass traits in export markets for carcass weight are an average of $11.00/head, but could be up to $145/head, and for marble score are an average loss of $105/head for marble scores below the required AUSMeat marble score 3. Thus, for the 40,000 animals in these two datasets, the minimum total cost of non-compliance was around $1,628,000, or around $40/head across all animals.

Out of specification costs are due to inefficient sourcing and allocation of animals to their optimal market end points. Strategic sourcing of cattle that meet market specification is a critical challenge of firms (Talluri and Narasimhan 2004). The results from Figure 16 to Figure 22 demonstrate that there is a large amount of variation in cattle across beef production systems which have lead to a reduction in opportunities for precision management and value based marketing. Sethi *et al.* (2005) argue that products out of specification are a source of customer irritation and are costly to clients and manufacturers. Missing target specifications has the potential to result in a large discount in carcass value. Costs associated with carcass weight and external fat depth that is out of specification impact on both the ability of suppliers to meet customer requirements (Sethi *et al.* 2005) and levels of productivity or slaughter rates (Gum and Logan 1965) that are nearer to the processors cost minimising level of production (Anderson and Kimberly 2001).

There are opportunities for the Australian beef industry to make changes to quality and yield grades of cattle and add value to cattle through the use of information and technology. Quality and yield grade explain much of the variation in profits when cattle are priced on a grid system (Greer and Trapp 2000). Opportunities for management systems of recording quality and yield data have arisen such as the introduction of the National Livestock Identification Scheme; further gains can be made by integrating information through advanced technology in the form of data capture, monitoring and transfer. The availability of growth and composition models and equations allow prediction of carcass endpoints and alignment of these carcasses to optimal markets. These tools allow the beef industry to increase productivity by implementing value-based marketing, or trading based on the merits of an individual carcass. It becomes possible to sort cattle at induction or prior to slaughter to meet the optimal end points, thus ensuring carcass uniformity (Tatum *et al*. 1999).

The emergence of value-based marketing systems facilitate clear specifications for market targets for cattle (Tzokas and Saren 1999), help information transfer along the production chain (Edmondston *et al.* 2006; Cross and Savell 1994), increase the accuracy of allocation of cattle with regard to the genetics and management used by the producer, and allow sorting of individual cattle to specific target markets (rather than selling on the average) which results in value creation along the supply chain and increases the profit earned from individual animals.

If initial composition and potential changes over the feeding period can be predicted with sufficient accuracy it would be possible to use sorting strategies to optimize the allocation of animals into groups to improve production efficiency and product consistency. Slaughtering groups of cattle with a common endpoint increases carcass uniformity (Tatum *et al.* 1986;

Trenkle 2001) and if managed correctly will increase the proportion of carcasses that meet market specifications at slaughter.

Better information sharing and coordination between all firms from seed stock and retail sectors of the industry has the potential to achieve optimal slaughter allocation and help ensure beef palatability and consistency (Tronstad and Unterschultz 2005). There are economic benefits of being able to determine animal growth paths and therefore optimal slaughter allocation.

3.6. Conclusion

In conclusion, it can be seen that if cattle were more efficiently allocated to management groups that resulted in more uniform carcass traits it would increase the ability to manage animals so that they would more often meet market specifications and therefore decrease the cost of non-compliance.

4. Factors effecting temperature at pH of 6.0 in Australian beef carcasses

The Meat Standards Australia grading system is a total quality management system that can predict the eating quality of beef (Thompson 2002). The process of total quality management creates higher customer demands, more consistent delivery of a quality product (MLA 2006), higher reliability (Schnetzler *et al.* 2007) and reduces costs (Tsung-Hui and Jen-Ming 2005; Cachon and Lariviere 2005; Chauhan and Proth 2005). Information feedback systems move product and sales philosophies to a marketing philosophy (Kotler and Keller 2006) which helps meet consumer preferences by an increase in carcasses meeting specification with greater consistency Tronstad and Unterschultz (2005).

4.1. Abstract

A critical control point in red meat production is the temperature at which muscle goes through rigor (pH6.0). This is influenced by glycogen reserves at slaughter. Muscle pH is a function of the initial levels of glycogen and the losses due to stress during the immediate pre-slaughter period and chilling rate (Thompson 2002). After slaughter, glycogen conversion to lactic acid continues until the enzymes effecting glycogen breakdown are inactivated due to pH levels within the muscle (Lawrie 1998). Slow rates of pH decline in muscle relative to temperature decline (where pH is greater than 6 and temperature is less than 12^{o}C) results in muscle shortening or cold shortening; muscle temperature becomes too cold (Locker and Hagyard 1963; Daly 2005). Cold shock produces severe muscle contractions, and therefore, tough meat (Marsh and Leet 1966). Alternatively a rapid pH decline (where pH is less than 6 and temperature is greater than 35^{o}C) damages the proteolytic enzymes that are essential for post mortem tenderisation through ageing (Koohmaraie *et al.* 1986; Daly 2005) and excessive protein denaturation resulting in increased drip loss (Daly 2005).

This analysis investigated factors which impact on glycolytic rate in beef carcasses indicated by temperature at a muscle pH of 6.0 ($Temp_{pH6}$) using the Meat Standards Australia (MSA) abattoir audit database collected from the years 2003 to 2005. This analysis showed that $Temp_{pH6}$ was affected by a number of factors which explained 42% of the variation in the MSA abattoir audit database. For the three year data collection period $Temp_{pH6}$ declined by $1^{o}C$/year (P<0.01) .The analysis of $Temp_{pH6}$ showed State and Abattoir nested within State were highly significant (P<0.001). $Temp_{pH6}$ increased by $1^{o}C$ for each 50kg increase in carcass weight $Temp_{pH6}$ increased by $1.4^{o}C$ for each 10mm increase in rib fat (P<0.001). Estimated percentage B*os indicus* (EPBI) interacted with season (described using a sine function P<0.001). The amplitude of the sine function for the 25 and 50 EPBI groups was $0.6^{o}C$ and $1.2^{o}C$ $Temp_{pH6}$ with the peak amplitude in summer/spring, or an annual amplitude of $1.2^{o}C$ and $2.4^{o}C$ for 25 and 50 EPBI. Electrical inputs such as stimulator duration (sec), (P<0.10) increased $Temp_{pH6}$ by $1.28^{o}C$ over the 0 to 60 seconds usage range. Stimulator current (mAmp), P<0.001 increased $Temp_{pH6}$ by $2.4^{o}C$ over the 0 to 800 mAmp usage range. It has been reported by Lee *et al.* (1997) that an important production mechanism was information flow as well as information sharing (Sethi *et al.* 2005; Burkink 2002). This analysis indicates that information sharing within a total quality management system such as the MSA grading system has led to changes that will facilitate more optimal $Temp_{pH6}$ for beef eating quality.

4.2. Introduction

It has been proposed by Tatum (1999) that total quality management is an approach that could address the incidence of poor quality in beef. Amaldoss *et al.* (1984) showed that the ability of a firm to compete and add value that matches customer specification (Thompson 2001) is best achieved through determining what is required by customers and what a firm's production objectives should be (Drucker 1976). Using total quality management the Meat Standards Australia (MSA) grading scheme has identified critical control points within the beef supply chain that affect beef palatability and these principles when used have the capacity to increase beef sales (Polkinghorne 2006) and increase the value of carcasses (Polkinghorne 2006; Rodgers 2007) given consumers willingness to pay more for higher quality beef (Sitz *et al.* 2005).

At slaughter carcass muscle continues to metabolise, using muscle glycogen to replenish energy stores in the muscle. This process, known as post-mortem glycolysis, results in a build up of lactate and associated hydrogen ions which gradually lowers muscle pH. Glycolysis is eventually halted by either depletion of the substrate glycogen, or when the pH of the muscle becomes acidic enough to deactivate the enzymes associated with post-mortem glycolysis (Thompson *et al.* 2006a). When glycolysis ceases, adenosine triphosphate (ATP) is no longer replenished. Rigor mortis in the muscle is defined as the stage when muscle energy has been totally depleted (Bendall 1969). The temperature at which the muscle enters rigor will impact on the degree of muscle shortening. In-vivo studies by Devine *et al.* (2002), and Thompson *et al.* (2005) showed minimal shortening occurs in the range of 15 to 20^{o}C.

The Meat Standards Australia (MSA) grading scheme has defined the optimal window for pH decline as a function of pH and temperature. As discussed by Thompson (2002) carcasses which go through pH6 at a temperature above 35^{o}C are considered to be at risk of rigor toughening, whilst those that go through pH6 at a temperature at less than 12^{o}C are considered to be at risk of cold shortening. As part of maintaining accreditation for MSA, abattoirs regularly check pH and temperature declines in groups of 15 carcasses and make adjustments to electrical inputs to ensure that the carcasses being processed for MSA continue to meet the pH/temperature window. As discussed by Thompson *et al.* (2006a) there is little information on those factors which impact on glycolytic rate in beef carcasses. Daly (2005) reported that higher muscle glycogen concentrations increased glycolytic rate. Factors that impede heat dissipation such as increased carcass weight (Daly 2005) and fat thickness (Koohmaraie *et al*. 1988) have also been shown to increase glycolytic rate. Similarly different electrical inputs which speed up the process of glycolysis will also impact on temperature at rigor (Simmons *et al.* 2006; Ledward *et al.* 1986; Daly 2005).

This analysis uses pH and temperature data from the MSA audits to quantify the effect of factors such as abattoir, carcass traits and seasonal effects on glycolytic rate in beef carcasses in a commercial environment.

4.3. Materials and methods

MSA Abattoir Audit Database

Over the period of 2003 to 2005 accredited MSA graders collected approximately 12,364 individual pH declines as part of the regular audit procedure for MSA. Each audit comprised selecting a group of 10 to 15 carcasses which were typical of the kill being processed through the abattoir at that time and recording pH/temp and time in the posterior striploin in individual carcasses until the pH dropped below 6.0. The audit data was matched with grade data held in the MSA data base using abattoir, kill date and carcass number. Of the 12,364 records approximately 6,528 records were initially matched, with 2,500 records then excluded due to inconsistencies and missing data. Animals with an estimated B*os indicus* content of 100% were removed since they existed on only one day and their numbers were low (n=9). Estimated High ultimate pH (above 5.7) carcasses were removed, as well as abattoirs that had low numbers or insufficient representation across the time period. The final dataset (n=3,817) comprised data from 22 slaughter floors across Australia.

Grade data comprised estimated B*os indicus* content (EPBI), sex (steer of heifer), method of carcass suspension (tenderstretch or achillies hung), carcass weight (CWT), ossification score, marble score (Romans *et al.* 1994), 12/13th rib fat (RFT) and ultimate pH. In addition the electrical inputs (current and duration of application) at the immobilizer hide puller and stimulator (if used) was recorded.

Calculation of $Temp_{pH6}$

Temperature at pH 6 was calculated using a two point interpolation method (equation 3). $Temp_A$ and pH_A represent the first temperature and pH measurement above pH6, and $Temp_B$ and pH_B represent the first measurement taken below pH6.

Equation 3. Equation to measure temperature at pH 6.

$$Temp@pH6 = Temp_A - \left(\frac{pH_A - 6}{(pH_A - pH_B)/(Temp_A - Temp_B)} \right)$$

This procedure was automated using a routine written in Excel.

Estimation of the seasonal effect

A sine function was used to model seasonal components. The function is shown in equation 4.

Equation 4. Equation to describe seasonal oscillations in temperature at pH6.

$$y = d.\sin(\omega t + \varphi)$$

Components of the sine function are

d = the amplitude of the sine oscillation (^{o}C),

ω = annual frequency in radians (2π/period days^{-1}),

t = time in days (days),

φ = phase shift of each oscillation (radians).

An annual frequency of 365 days was assumed and the sine function was rewritten in the form *Y=a.sin(u) + b.cos(v)*

where *u=cos((*2π/365)**t)* and *v=sin((*2π/365)**t)* (Greer and Hancox 1966). The two parameters *u* and *v* were then fitted as covariates in the linear models. The significance of adding the sine function to these models was assessed as the combined F ratios for *u* and *v*. The amplitude and phase shift of the function was calculated from the slopes *a* and *b,* where $d=\sqrt{(a^2+b^2)}$ and $\varphi = \tan^{-1} b/a$.

Statistical analysis

A general linear model (SAS 1997) which contained fixed effects (state, abattoir nested within state, hang and sex) and covariates (EPBI, US Marble score and ossification scores, CWT, RFT and ultimate pH), seasonal time trend (kill date and the parameters *u* and *v* of the sine function described above), and electrical inputs (stimulation duration and current) was used to assess the impact on $Temp_{pH6}$ of these factors. First order interactions were tested and, where significant, the transportability between sub-classes within the data set tested by using the final model on subsets. Non-significant interactions and covariates were sequentially deleted (P>0.05). Curvilinear terms for the covariates were tested but were not significant (P>0.05).

The final model for $Temp_{pH6}$ comprised terms for state, abattoir nested in state, CWT, RFT, kill date, the seasonal terms *u* and *v* and their interaction with EPBI; and stimulation duration and current. Least square means were predicted for state and abattoir within state, adjusted for all terms in the model.

4.4. Results

Data used in the analysis are summarised in Table 7. The B*os indicus* content of these data are shown in Figure 23.

Table 7. Means, standard deviations and maximum and minimum values for carcass traits and electrical inputs from the MSA abattoir audit database (n=3372).

Traits	Average	Std Dev	Min	Max
Carcass traits				
$Temp_{pH6}$	29	5	15	42
CWT (kg)	252	61	143	484
RFT (mm)	9	4	1	32
Electrical inputs				
Stim current (mAmp)	272	230	0	800
Stim Duration (sec)	13	12.1	0	60

Figure 23 shows that the distribution for estimated percentage *Bos indicus* was highly skewed. The final model was therefore run on data subsets for the sub-classes, 0, 25 and 50 percent B*os indicus* respectively.

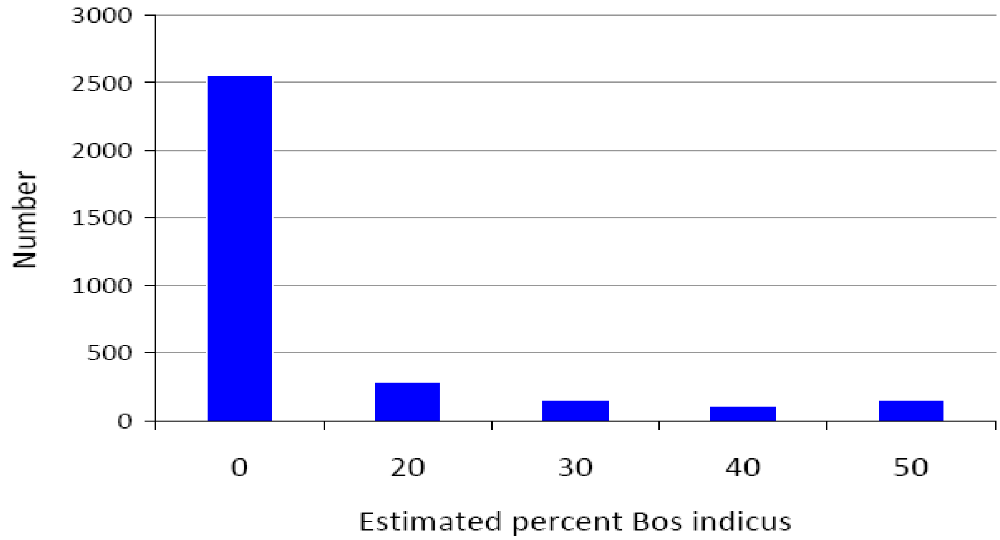

Figure 23. Number of animals within the estimated percentage B*os indicus* from the MSA abattoir audit database.

Sources of variation for the final model are shown in Table 8. The final model had an R^2 value of 0.47 and a root mean square error of 3.27.

Table 8. F ratios, numerator and denominator degrees of freedom, regression coefficients and standard errors for $Temp_{pH6}$ as affected by State, abattoir within State, carcass weight (CWT), rib fat (RFT), kill date, seasonal oscillations (*u, v*) and stimulator duration (sec) and current (mAmp).

Independent variables	NDF, DDF	F ratio		Regression Coefficient	Standard error
State	4, 3294	11	***		
Abattoir in State	17, 3294	48	***		
CWT (kg)	1, 3294	159	***	0.021	0.002
RFT (mm)	1, 3294	59	***	0.135	0.019
Ossification	1, 3294	8	NS	0.000	0.000
Kill Date	1, 3294	171	***	-0.003	0.002
EPBI	1, 3294	0	NS	0.007	0.007
U	1, 3294	3	NS	-0.157	0.086
V	1, 3294	6	*	-0.205	0.087
*EPBI * U*	1, 3294	6	**	-0.017	0.007
*EPBI * V*	1, 3294	4	*	0.013	0.007
AusMB	1, 3294	2	NS	0.050	0.018
Stim current (mAmp)	1, 3294	13	***	0.016	0.008
Stim Duration (sec)	1, 3294	4	*	0.003	0.000

NS, *, **, *** not significant, P<0.05 <0.01 and <0.001, respectively

CWT (carcass weight), RFT (rib fat), *u* and *v* (components of the seasonal function) and Stim (stimulation)

State and abattoir effects

The predicted means and standard errors for the fixed effects State and abattoir nested within state are shown in Table 9 and Table 10. These predicted means indicate $Temp_{pH6}$ was highest in Western Australia and lowest in South Australia but there was large variability of the predicted means for $Temp_{pH6}$ within state. Table 10 shows the predicted means and standard error for abattoir within state and highlights the large variability within states.

Table 9. Predicted means for $Temp_{pH6}$ by state after adjustment for kill date, carcass weight, rib fat, estimated B*os indicus* content, stimulation and seasonal effects.

State	$Temp_{pH6}$	(max SE)
NSW	29.5	0.1
QLD	29.7	0.2
SA	28.6	0.3
VIC	30.3	0.2
WA	30.5	0.2

Table 10. Predicted means for $Temp_{pH6}$ by abattoir after adjustments for kill date, carcass weight, rib fat, estimated B*os indicus* content, stimulation and seasonal effects.

Coded abattoir	State	$Temp_{pH6}$	(max SE)
B	NSW	32.0	0.4
C	NSW	32.4	0.3
D	NSW	23.5	0.5
E	NSW	30.2	0.3
F	QLD	33.5	0.3
G	QLD	32.2	0.3
H	QLD	27.2	0.8
I	QLD	27.4	0.4
J	QLD	30.8	0.4
K	QLD	27.1	0.5
L	SA	32.7	0.5
M	SA	24.6	0.3
N	VIC	30.8	0.2
O	VIC	29.6	0.5
P	VIC	31.7	0.5
Q	VIC	29.2	0.5
R	WA	31.7	0.3
S	WA	30.5	0.3
T	WA	30.2	0.5
U	WA	31.0	0.6
V	WA	28.8	0.3
W	WA	30.6	0.5

Carcass Traits

There was an increase in $Temp_{pH6}$ of 0.02°C /kg carcass weight ($P<0.001$, Table 8), or an increase of 1°C for each 50kg increase in carcass weight. $Temp_{pH6}$ also increased as rib fat increased ($P<0.000$, Table 8), by 1.4°C for each 10mm increase in fat depth.

Time and seasonal trends

The final model indicated that over the years 2003, 2004 and 2005 $Temp_{pH6}$ declined ca. 1°C per year (Table 8) or ca. 3°C over the period of data collection, as illustrated in Figure 24.

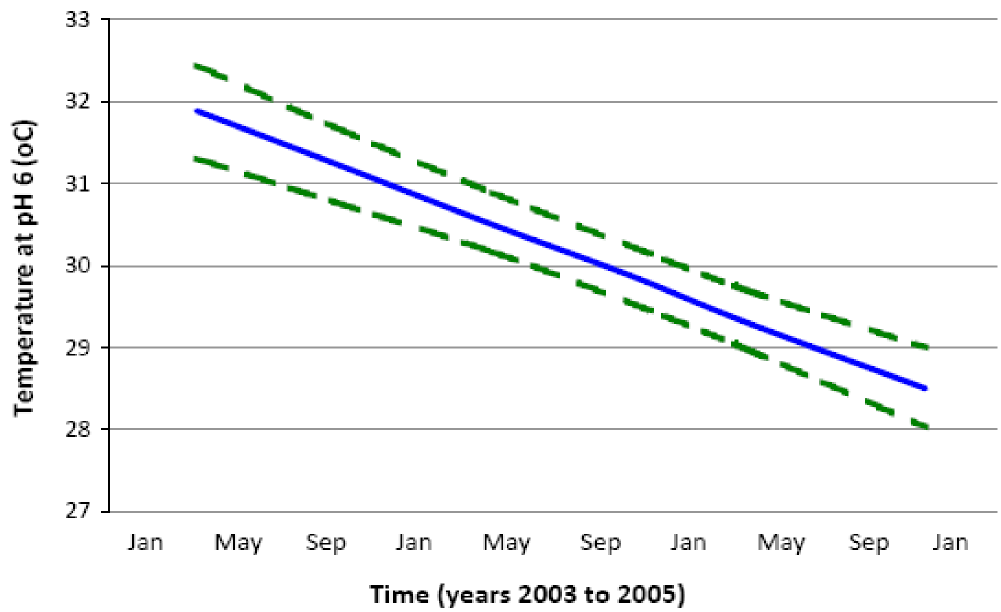

Figure 24. Plot of the effect of kill date on Temp$_{pH6}$ from the MSA abattoir audit database model. The plot shows the 95% confidence interval around the predicted mean.

The interaction of EPBI and seasonal effects was highly significant ($P<0.001$, Table 8). The interaction incorporated the covariates *u* and *v* and their interactions with EPBI. The coefficients from these were used to estimate the amplitude and phase shift of the seasonal oscillation, as described in the methods section. The magnitude of these effects is illustrated in Figure 25, and shows that as EPBI increased so did the magnitude of the seasonal oscillation. The amplitude of the predicted effect for 25% and 50% B*os indicus* groups was 0.6^{o}C and 1.2^{o}C, respectively during the winter months. The 0 percent EPBI showed a small seasonal change over the period of data collection.

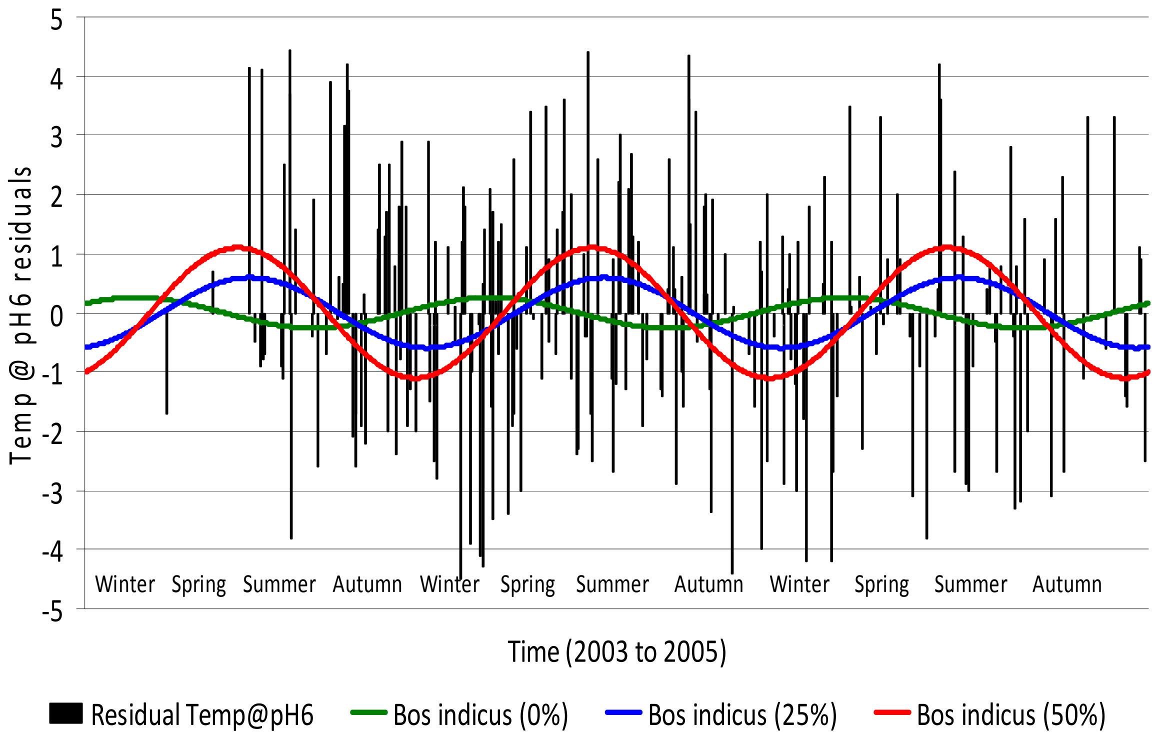

Figure 25. Plot of the predicted seasonal effects on $Temp_{pH6}$ by Bos indicus percent and $Temp_{pH6}$ residuals prior to the fitting of seasonal oscillation for the MSA audit database. The model contained terms for State, abattoir in state, hang method, carcass weight, rib fat, kill date, seasonal and stimulator duration (sec) and stimulator current (mAmp).

Electrical inputs

An increase in stimulator current (mAmp) resulted in an increased $Temp_{pH6}$ by 2.4°C ($P<0.001$) across the data range (0 to 800 mAmp). The effect of stimulator duration approached significance ($P=0.05$). Across the range of stimulator settings there was a 1.28°C increase in $Temp_{pH6}$ as duration increased between 0 and 60secs.

A summary of factors that impact on $Temp_{pH6}$ are shown in Table 11. These indicate the change in inputs that would bring about a 1°C change in $Temp_{pH6}$.

Table 11. Summary table of the factors affecting $Temp_{pH6}$.

Trait	Change in trait	Change in $Temp_{pH6}$
Kill date (year)	1	1
Hot carcass weight (kg)	50	1
Rib fat (mm)	7	1
EPBI by Spring/Summer	50	1
EPBI by Autumn/Winter	50	-1
Stim current (mAmp)	330	1
Stim Duration (sec)	47	1

4.5. Discussion

This analysis showed that there was a definite seasonal pattern on $Temp_{pH6}$ which interacted with estimated B*os indicus* content. During the winter months $Temp_{pH6}$ was 0.6°C and 1.2°C lower than the yearly average for 25% and 50% estimated B*os indicus* cattle, respectively, and was increased by these amounts in the summer months. These amplitudes equate to a difference between the peaks and troughs throughout the year of 1.2 and 2.4°C for the 25 and 50 percent B*os indicus* groups respectively. The skewed nature of the B*os indicus* content in these data indicates that validation of the seasonal oscillation in high B*os indicus* cattle is required. Moreover it should be noted that the highest proportion of B*os indicus* by state was Queensland, ca. 45% of animals within Queensland had an EPBI of 18%. It has been shown by Wynn *et al.* (2000) that northern feedlots have clear seasonal oscillations in feed intake which they attributed to seasonal variation in day length and air temperature. Australian pasture quality and quantity varies throughout the year (Hilder 1956) which affects intake and digestibility (Hutchinson 1956). Feed intake and utilisation varies with season across species such as cattle (Siebert and Hunter 1978; Lemerle *et al.* 1980; Hinch and Thwaites 1984), goats (Walkden-Brown *et al.* 1990), deer (Weber and Thompson 1995) and sheep (Ball *et al.* 1996). In these data carcasses of 25% and 50 % EPBI were about 1mm and 2mm (external fat depth) leaner and 4kg and 8kg lighter in the winter months indicating the possibility that the reduced feed intake in winter (Young 1976) would have the potential to lower glycogen levels and thus also lower glycolytic rate (Daly 2005; Wulf *et al.* 2002) with a consequent increase in muscle pH (Immonen and Puolanne 2000).

Post-mortem pH changes are directly related to post-mortem temperature, a high temperature promoting a more rapid decline in pH (Lee 1986), rapid post-mortem glycolysis induced by elevated temperatures (Lee and Ashmore, 1985). As carcass weight increased there was an increase in $Temp_{pH6}$. This analysis showed that an increase of 50kg carcass weight resulted in an increase in $Temp_{pH6}$ of $1^{o}C$. Increases in carcass temperature in heavier carcasses have been found by Lochner *et al.* (1980), Klont *et al.* (1999) and Klont *et al.* (2000) and has been argued by Thompson *et al.* (2006b) this may largely be due to heat inertia in the heavier carcasses. Lighter lean carcasses have greater surface area to volume ratios allowing greater loss of heat from bodies; moreover minimal fat cover reduces insulation which permits greater temperature loss (Daly 2005). Daly (2005) and Bruce and Ball (1990) have argued that that carcass weight was an important determinant of enzymatic rate and therefore glycolytic rate. When temperature fall was included in statistical models, the significance of the effect of carcass weight was weakened (F ratios were reduced from 22 to 9) Daly (2005). Daly (2005) found a linear relationship between carcass weight and $Temp_{pH6}$ with an increase in $Temp_{pH6}$ of $3.5^{o}C$ associated with an increase of 50kg carcass weight, when temperature fall was included this was reduced where a 50 kg increase in carcass weight produced only a $0.5^{o}C$ increase in temperature at pH 6 Daly (2005).

$Temp_{pH6}$ also increased with higher rib fat. The analysis of the MSA database indicated a 10mm increase in RFT increased $Temp_{pH6}$ by ca. $1.5^{o}C$; cattle in the MSA database had an average of 9mm RFT. These results were similar to Daly (2005) who showed that an increase in P8 fat depth of 9mm would increase $Temp_{pH6}$ by 1°C. Subcutaneous fat cover acts as an insulator and retards the rapid rate of temperature decline in carcasses (Smith *et al.* 1976; Lochner *et al.* 1980; Tatum *et al.* 1982; Purchas 1990; Wulf *et al.* 1997; Koohmaraie *et al.* 1988 and Lochner *et al.* 1980). Koohmaraie *et al.* (1988) found in predominantly Hereford Angus cross steers that rib fat thickness influenced carcass temperature, and further showed that removal of fat cover reduced the longissimus muscle temperature at 6, 9 and 12 hours post-mortem compared to muscle temperature of the control animals.

Skeletal muscle stimulation can produce strong contractions (Moreno-Aranda and Seireg 1981) dependent on muscular pH immediately after slaughter and the application of electric current (Zywica and Banach 2007). It has been shown by Petrofsky *et al.* (2008) in humans that there is a relationship between duration of stimulation, thickness of the fat layer as well as variable current (Amps) required to produce levels of effective skeletal muscle stimulation. These data indicate the impact of electrical inputs on postmortem metabolism measured as $Temp_{pH6}$ was linear for both duration (seconds) and current (mAmp), with higher levels of duration and current resulting in higher $Temp_{pH6}$. It has been reported by Solomon (1986), Eilers *et al.* (1996) Hwang *et al.* (2003), Hopkins *et al.* (2006) and Roth *et al.* (2006) that electrical stimulation increases the rate of post-mortem glycolysis.

An increase in stimulator duration (s) was shown to increased $Temp_{pH6}$ by 0.25°C/20s however these data indicated that stimulator duration past ca. 20s was less often used and had large standard errors. Simmons *et al.* (2006) reported that an increase in stimulation duration (s) resulted in an increase in the rate of muscle and nerve response at lower Hz (15Hz) causing muscle fatigue and a drop in muscle pH, however work by McKeith *et al.* (1980)

concluded there was no significant benefit from longer stimulation duration (2 min vs 1 min) with regard lean meat colour.

These data indicated $Temp_{pH6}$ increased by $1^{o}C$ for every 400mAmp. Despite temperature not being reported in experiments conducted by Solomon (1986), it was shown that there was a decrease of ca. 1.1 pH units per 1 amp (1000 mAmp) 3 and 5 hours post slaughter in Angus heifers. Channon *et al.* (2003) tabled differences in porcine between control (no stimulation) 50, 200 and 400 mAmp. The muscle pH pre-rigor was significantly lower in carcasses in the 200 and 400 mAmp from 40min and 8hr post slaughter; carcasses receiving 200 and 400 mAmp were ca. $30^{o}C$ at pH6 and both the control and 50 mAmp were ca. $10^{o}C$ at pH6.

The effect of MSA plant in the analysis indicates the variability in management practices; and the design and operation of the slaughter chain. While variation in cooling rates in carcasses exist due to factors such as carcass weight and fat cover they are also impacted on by temperature control (Gill 1996), relative humidity and air flow patterns within chiller (Jeremiah and Gibson 2001; Lochner *et al.* 1980; Ferguson *et al.* 2001). It is argued by Lochner *et al.* (1980) that air temperature data, either alone or combined with air velocity measurements, permit the chilling rate to be inferred only in vague comparative terms between chillers, and that collation of results becomes difficult. Bowling *et al.* (1977) have recognised that variation that may exist between the management and design and operation of cool chains commenting that sides chilled in different coolers while subject to question can be compared if the management of ambient temperature, relative humidity and air velocity are similar. The term Plant within state was used to account for such management of chiller temperature, humidity and air velocity.

4.6. Conclusion

The analysis of the MSA abattoir audit data clearly showed there were several factors that impact on $Temp_{pH6}$. The change in $Temp_{pH6}$ over time (*Killdate*) has inferred that participating production floors have made management changes to better meet consumer eating quality specification as impacted on by $Temp_{pH6}$ during the 3 years, and, that the MSA grading system has led to a better understanding by suppliers of their customer requirements thereby promoted a greater customer driven organisation. It is therefore concluded that a system of total product quality management has improved the temperature at which carcasses attain rigor which helps to improve eating quality. It appeared that both carcass weight and fat thickness were operating via heat inertia which impeded heat dissipation and accelerated pH decline. The seasonal oscillations showed a higher $Temp_{pH6}$ in summer and a lower $Temp_{pH6}$ in the winter. These were important outcomes that could be managed by abattoirs through chiller temperature management. Increased electrical inputs for stimulator duration and stimulator current also increased $Temp_{pH6}$ however this effect was small.

5. The effect of traits at induction and health status on hot carcass weight, marbling and fat depth in cattle processed through the case study feedlot during an 11 year period

This chapter introduced a case study to test the methods Australian beef feedlots could use to improve technical and allocative efficiency at induction through better resource use. Quantifying the impact of induction traits on the carcass traits growth, marble score and external fat depth allows precision management of animals at induction and helps to achieve optimal slaughter allocation, which inturn can increase the value of animals.

5.1. Abstract

Feedlot data were collected by the case study feedlot over a period of 11 years (February 1996 to January 2007), as well as the associated carcass data from the case study abattoir (ca. n = 32450 animals). These two data sets were merged to perform a series of analyses that tested for factors which affected growth rates (hot carcass weight adjusted to the same induction weight), marble score and external fat depth (both adjusted to the same hot carcass weight and days on feed). These were used as indicators of quantity, quality and yield traits, respectively. The dataset was analysed within market groups defined by days on feed, 60-100, 101-140, 141-175 and 176-220 days and also across the whole dataset. Comparisons between producers/suppliers were made on the predicted producer means for growth, marble score and external fatness firstly as correlations within producer (for deliveries of >30 head) between market groups and secondly between each producer in an overall analysis.

The largest effect on growth was days on feed and type of HGP implant used. Growth rate was highest (ca. 1.1 kg/day) in the short fed group (60-100 days) and lowest (ca. 0.4kg/day) in

the long fed group (176-220 days). HGP implants increased growth rate in all groups, except one. The overall analysis showed animals with an induction weight of less than 280kg grew slower than animals with heavier induction weights. Illness (pneumonia and lameness) decreased HSCW. Marbling was affected by the use of HGP implants, causing a decrease in the order of half a marble score. Marble score increased as HSCW increased but plateaued as carcass weights reached ca. 440kg. The largest effect on external fatness was carcass weight which increased external fatness 6mm for every 100kg of hot carcass weight.

Deliveries from individual producers responded similarly at different lengths of feeding, that is producers who delivered fast growing animals into one market group also had fast growing animals in other market groups, but this relationship weakened as groups became more dissociated (i.e. market group 101-140 v. 141-175 were more highly correlated than market group 101-140 v. 176-220). Producers with less desirable animals could be identified, with potential benefits accruing from advice/interaction with the case study feedlot on changes to their production system.

5.2. Introduction

An animal's performance in a feedlot environment varies greatly and impacts on the profitability of a feedlot enterprise. The performance of an animal can be considered a function of growth (Hedrick *et al.* 1994), feed efficiency (Herd and Bishop 2000), carcass quality (Egan *et al.* 2001), carcass yield (Kempster *et al.* 1982; Polkinghorne 2006), breed (Franke 1997) and losses due to both direct and indirect health issues (Smith 1998; Malcolm 2003). The relative importance of these factors will vary with the type of market targeted (Muth *et al.* 2008; Priyanto *et al.* 1999). For a long fed market with a focus on marbling

(Allerton 1999), achievement of a minimum marbling standard may be considered the most important economic driver (Chappell 2001), whereas growth may not be considered as important. While marbling is an important aspect of value-based marketing (Fausti *et al.* 1998) for long fed cattle, the reverse may apply in the short fed market where the emphasis would be on growth, with marbling often unimportant.

An animal's growth, carcass traits and health will vary with management both within the feedlot and during backgrounding, as well as with its genetics (Arthur *et al.* 2001; Herd *et al.* 2003). Given that feedlots collect induction and carcass traits from individual animals there is an opportunity to examine how these traits impact on the growth, carcass quality and yield characteristics of the animal, and whether these can be attributed to either management, environmental or genetics affects.

Data from the case study feedlot (Queensland) and the case study abattoir are routinely collected. These data were joined to allow an analysis that quantified the relevant factors contributing to variation in growth, marbling and external fatness of carcasses. The effect of individual producers on an animal's performance was also estimated in order to assess their impact and potentially encourage producers to improve performance as well as show which markets individual producers were most suited to.

5.3. Materials and methods

The Case Study Abattoir Database

Feedlot induction and associated slaughter data were collected on cattle (n=94,184) over an 11 year period from February 1996 to January 2007. The data comprised 3 relational database tables which included slaughter data (kill floor), kill data (chiller data) and animal history data (feedlot data). These database tables were joined into a single table for analysis.

Data were screened for outliers and the anomalies were assessed by the case study feedlot management against known management practices. Obvious errors were removed from the original data set. This reduced the dataset to 93,380 records, comprising 93,219 steers and 161 heifers. Due to missing entries for many of the measurements and traits of interest such as Breed type (ca. 19000), frame score (ca. 32000) and implant status (ca. 39000), the final data set used for the analyses contained complete records for 32,453 steers.

Within the dataset there were breeds whose classification was ambiguous and records of illness that occurred singularly, or in low numbers. The classification for breed was standardised (e.g. *A, AA, Ang, Angus* became Angus; Angus and Hereford were then categorised as British breed for analysis). Illness categories were standardised as much as possible. A new category, '*Other*' was defined as all illnesses with a frequency less than 10% of total illnesses and included records such as swollen jaw, swollen leg, etc.

Animal history data included measurements and attributes from feedlot induction (date, breed, producer, induction weight, frame score, dentition and HGP implant status), as well as exit date and health status while in the feedlot. Slaughter and kill data comprised hot standard carcass weight, dentition, body score, meat colour, fat colour, marble score, hot P8 fat depth. A complete description of all traits and their acronyms is given in Table 12. The difference between induction date and exit date was used to calculate the number of days on feed. Sick animals were treated and maintained on their rations in the feedlot until they made the case study feedlot exit weight range.

The data used for analysis (n=32,453 records) were further classified as into one of four *market categories* based on days on feed. Animals were allocated to a *market group* at induction on the basis of intended approximate days on feed. The four *market groups* comprised animals fed 60 to100, 101 to 140, 141 to 175 and 176 to 220 days.

Table 12. Description of continuous and discrete traits included in the analysis of hot carcass weight, marble score and external fat depth.

Acronym	Description
	Continuous
INDATE	Date of induction into the feedlot, expressed in Julian days.
INWGT	Live weight at entry into the feedlot, kg.
DOF	Number of days on feed.
EXDATE	Date of exit to slaughter from the feedlot (days).
HP8	Subcutaneous rump fat thickness (mm) at the P8 site, assessed on the hot carcass.
HSCW	Hot carcass weight (kg).
	Discrete
BREED	Bos indicus, Bos indicus cross, British, British cross, European, European cross and Crossbreds - based on phenotypic classification
INFRAME	Induction frame score, a measure of hip height in the crush starting at 117cm (score 0) to 145cm (score 7), incrementing by 4cm.
INDEN	Induction dentition based on the eruption of incisor teeth and classed as 0, 2, 4, 6, or 8 teeth. Animals classed with uneven numbers of incisor teeth were allocated to the next highest dentition group.
IMPLANT	None, Revalor, Synovex, Synovex Plus. Treatments were administered at induction.
ILLNESS	A record of health while in the feedlot grouped into illness types including shy feeders, pink eye, swollen pizzle, buller, lame, pneumonia and other (a collection of illnesses with frequencies less than shy feeder, e.g. sore jaw, foot and leg swelling).
AusMB	AUS-MEAT marble score on a scale of 0-6 assessed in the chilled carcass.
PIC	Producer identification code.

Various HGP implant strategies were used (Table 13). If an HGP implant was used, animals were implanted at induction. It was possible to make comparisons between untreated and implanted cattle on ca. 9,200 instances. Untreated animals targeting a range of DOF market categories were represented throughout the data period, from 1997 to 2002 the predominant HGP was Synovex, while from 2002 to 2005 both Synovex plus and Revalor were used.

Table 13. Hormonal growth promotant implants used at induction in the case study feedlot and their active ingredients and functional life from the manufacturers recommendations.

Acronym	Implant	Functional life (days)	Active oestrogen	Active androgen	Other hormone
None	None				
Rev-S[IV]	Revalor-S	100-120	20mg Oestradiol	200mg trenbolone acetate	
Syn-S[FD]	Synovex-S	100-120	20mg Oestradiol		20mg progesterone
Syn-P[FD]	Synovex-Plus	100-120	28mg Oestradiol benzoate	200mg trenbolone acetate	

IV: Intervet Inc. Millsboro, Delaware 19966, USA.

FD: Fort Dodge Animal health, Division of Wyeth, Fort Dodge, Iowa 50501 USA.

Details of the sub-sets of data used in subsequent analyses are given in Table 14. The sub-sets of data had similar means and variances for all measurements when compared to the full data set.

Table 14. Means, standard deviation, minimum and maximum values by market group for the case study feedlot data subset.

Market group (days on feed)	Trait	Mean	Std dev	Min	Max
60-100 (n = 1,256)					
Pre slaughter					
	Induction weight (kg)	489	52	316	659
	Induction dentition	3	3	0	8
	Induction frame score	4	1	1	7
	Days on feed (days)	99	4	69	100
Post slaughter					
	Hot carcass weight (kg)	365	44	213	509
	Marble score	0.2	0.5	0	3
	Hot P8 fat depth (mm)	19	6	2	48
101-140 (n = 11,868)					
Pre slaughter					
	Induction weight (kg)	491	51	280	659
	Induction dentition	3	2	0	8
	Induction frame score	3	1	0	7
	Days on feed (days)	122	13	101	140
Post slaughter					
	Hot carcass weight (kg)	374	41	224	539
	Marble score	0.8	0.8	0	5
	Hot P8 fat depth (mm)	21	7	3	58
141-175 (n = 15,841)					
Pre slaughter					
	Induction weight (kg)	481	49	234	658
	Induction dentition	2	2	0	8
	Induction frame score	3	1	0	7
	Days on feed (days)	153	8	141	175
Post slaughter					
	Hot carcass weight (kg)	379	37	213	536
	Marble score	1.2	0.8	0	6
	Hot P8 fat depth (mm)	24	7	3	60
176-220 (n = 3,491)					
Pre slaughter					
	Induction weight (kg)	471	43	328	647
	Induction dentition	2	2	0	6
	Induction frame score	3	1	0	6
	Days on feed (days)	190	10	176	224
Post slaughter					
	Hot carcass weight (kg)	394	37	259	530
	Marble score	1.7	0.8	0	6
	Hot P8 fat depth (mm)	25	7	9	60

Statistical analysis

Data were analysed for the effect of both the animal and management factors on three dependent variables: hot carcass weight (HSCW), marbling score (AusMB) and P8 fat depth (HP8). Analyses were performed by market group (based on DOF categories) with an overall analysis on the full data subset (n=32,452). In total 15 analyses were performed (for the three dependent variables, HSCW, AusMB, HP8); HSCW, AusMB and HP8 in each of the four market groups as well as within an overall analysis (entire dataset).

Data were analysed using generalized linear models which contained both fixed effects and covariates. The model for all 3 dependent variables tested the effects of; PIC, BREED, DOF, HGP use, INDEN, INWGT, ILLNESS, INFRAME and EDATE. INWGT was included for analysis of HSCW, also HSCW included for AusMB and HP8. The adjustment of HSCW for INWGT effectively described GROWTH over the feedloting period. For market groups 101-140 days and 141-175 days and the overall analysis, IMPLANT nested within HGP status was tested. For market groups 60-100 and 176-220, HGP v non-HGP was tested (due to missing and unbalanced animal numbers within the market and implanted groups). First order interactions were tested and non-significant interactions and covariates ($P>0.05$) were sequentially removed. Non-significant ($P>0.05$) fixed effects were retained as main effects. Exit date was also retained in all models. Quadratic and cubic polynomial terms for induction weight and days on feed were tested and deleted if non-significant ($P>0.05$). The final models for each of the dependent traits for each of the induction groups are shown in Table 15 and Table 21.

Least squared means for each of the dependent variables BREED, IMPLANT, ILLNESS and INFRAME were predicted, adjusted for all other terms in the model. Means and standard errors were predicted for DOF, INWGT and the interaction between HGP implant (nested within HGP treatment) and DOF. Producer means (PIC) for growth (HSCW adjusted to the same INWGT), AusMB and HP8 (each adjusted to the same HSCW) were compared. The transportability of PIC effects were tested between market groups when the same PIC delivered to more than one market group using producer correlations. These correlations were performed using PIC with greater than 30 animals delivered, within the analysed dataset.

5.4. Results

All results presented for HSCW are essentially for growth in the feedlot, as HSCW was adjusted to a common INWGT. Sources of variation for growth, AusMB and HP8 are shown in Table 15 and Table 21.

Table 15. Factors affecting HSCW, marble score and hot P8 fat depth within market group and for the overall data sub-set from the case study feedlot. Included are R^2 value and root mean square error (RMSE) of the models. Empty cells indicate an effect not included in the respective model.

Market group (days on feed)	60-100	101-140	141-175	176-220	Overall
Number of animals	1,256	11,868	15,841	3,487	32,452
HSCW/KG					
HGP treatment	***			***	***
Implant		***	***		NS
Induction frame score	*	***	***	***	***
Breed class	NS	NS	NS	NS	NS
Induction dentition	NS	NS	NS	**	*
Illness type	**	***	***	***	***
Producer	***	***	***	***	***
Induction weight (kg)	***	***	***	***	*
Induction weight (kg)^2					**
Induction weight (kg)^3					**
Days on feed	***	***	***	***	***
Days on feed^2					***
Days on feed^3					***
Days on feed * Implant type nested in HGP					**
Exit date	NS	NS	***	***	*
Exit date^2					*
R^2	0.65	0.66	0.60	0.66	0.61
RSD	28.67	5.92	24.87	22.71	25.72

Market group (days on feed)	**60-100**	**101-140**	**141-175**	**176-220**	**Overall**
Number of animals		1,256	11,868	15,841	3,487
Marble score					
HGP treatment	*			***	***
Implant		***	***		NS
Induction frame score	NS	NS	**	NS	*
Breed class	NS	NS	NS	NS	NS
Induction dentition	*	***	***	**	***
Illness type	NS	*	**	NS	***
Producer	***	***	***	***	***
Days on feed		***	**		***
Days on feed^2					***
Days on feed^3					***
Hot standard carcass weight (kg)	*	***	***	**	***
Hot standard carcass weight (kg)^2					***
Exit date	*	NS	***	***	***
Exit date^2					***
R2	0.32	0.50	0.30	0.44	0.43
RSD	0.42	0.64	6.37	0.63	0.68

Market group (days on feed)	**60-100**	**101-140**	**141-175**	**176-220**	**Overall**
Number of animals	1,256	11,868	15,841	3,487	32,452
Hot P8 fat/ mm					
HGP treatment	NS			*	***
Implant		NS	***		**
Induction frame score	NS	***	***	NS	***
Breed class	NS	***	NS	NS	***
Induction dentition	NS	**	***	*	***
Illness type	*	NS	*	NS	**
Producer	***	***	***	***	***
Days on feed		***			***
Hot standard carcass weight (kg)	***	***	***	***	***
Hot standard carcass weight (kg)^2					**
Exit date	**	NS	***	***	**
Exit date^2					**
R^2	0.37	0.35	0.31	0.33	0.31
RSD	5.54	6.15	6.30	6.23	6.29

NS, not significant

*, **, ***, P<0.01, P<0.001 and <0.0001 respectively.

The effect of HGP implant status (IMPLANT) on growth, marbling and external fat depth within market group and overall

HGP implants significantly contributed to growth (adjusted HSCW) when analysed within market groups and as an overall analysis ($P<0.001$, Table 15), however the overall analysis fitted with an interaction between IMPLANT and DOF (Figure 26) shows that while animals implanted with Syn-S showed greater growth up to 100 DOF than non-implanted animals, there was little difference between these animals and those not implanted when DOF exceeded ca. 140 days. The differences between non implanted animals and those which received implants containing a combination of estrogen and trenbolone acetate (E2/TBA) were consistently ca 25kg heavier than non-implanted animals.

Implanted animals had ca. 0.5 lower marble scores than non-implanted animals ($P<0.0001$), with little difference between the different HGP implant types ($P>0.05$, Table 15). Differences in HP8 between implanted and non-implanted animals were generally not significant ($P>0.05$) and were small (Table 16).

Table 16. Adjusted HSCW, marble score and hot P8 fat depth categorised by HGP implant status. All dependent variables were adjusted for induction weight, days on feed, induction frame score, breed, induction dentition, illness, exit date and producer. Marble score and hot P8 fat depth were also adjusted for HSCW.

Implant	60-100	101-140	141-175	176-220	Overall
HSCW/kg					
None	349.0 ± 17.7	346.4 ± 4.7	366.2 ± 5.9	379.7 ± 5.4	358.9 ± 2.2
HGP	357.5 ± 7.9			396.9 ± 5.8	
Synovex		349.2 ± 7.8	384.9 ± 6.6		364.4 ± 3.0
Synovex Plus		358.0 ± 4.7	392.1 ± 6.0		381.2 ± 2.3
Revalor		364.8 ± 4.9	385.9 ± 6.0		381.9 ± 2.4
Marble score					
None	0.8 ± 0.3	1.1 ± 0.1	1.1 ± 0.2	1.6 ± 0.2	1.1 ± 0.1
HGP	0.2 ± 0.1			1.1 ± 0.2	
Synovex		0.4 ± 0.2	0.7 ± 0.2		0.5 ± 0.1
Synovex Plus		0.6 ± 0.1	0.7 ± 0.2		0.6 ± 0.1
Revalor		0.7 ± 0.1	0.5 ± 0.2		0.6 ± 0.1
Hot P8 fat depth/mm					
None	10.1 ± 3.3	19.9 ± 1.1	23.3 ± 1.5	22.6 ± 1.5	21.8 ± 0.6
HGP	14.9 ± 1.5			24.6 ± 1.6	
Synovex		22.6 ± 1.9	25.2 ± 1.7		23.1 ± 0.7
Synovex Plus		19.9 ± 1.1	24.0 ± 1.5		21.9 ± 0.6
Revalor		19.0 ± 1.2	25.9 ± 1.5		23.0 ± 0.6

The effect of days on feed (DOF) on growth, marble score and external fat depth within market group and overall

The analyses were conducted within market group and over all market groups. Growth rate decreased from ca. 1.0 kg HSCW in group 60-100, to ca. 0.4kg HSCW in market group 176-220 (Table 21). Within the overall analysis growth (HSCW adjusted to a common INWGT) the effect varied with days on feed (Figure 26). The difference between non implanted animals and those which received implants containing a combination E2/TBA were consistently heavier.

The effect of DOF on AusMB was significant within market groups 101-140 ($P<0.0001$) and group 141-175 ($P<0.001$); within these two groups AusMB increased ca. 0.4 and ca. 0.1

respectively. In the overall analysis AusMB increased in a non-linear fashion as DOF increased (Figure 27). This increase was ca. 0.4 AusMB (from 90 to 120 DOF), 0.3 AusMB (from 120 to 200 DOF) and 0.1 AusMB (from 200 to 210 DOF).

HP8 increased with DOF within market group 101-140 and in the overall analysis (P<0.0001). The regression coefficients (Table 21) indicated that there was an increase of 1mm of HP8 within group 101-140 every ca. 13 days on feed and a 1mm increase in the overall analysis for every 25 days on feed.

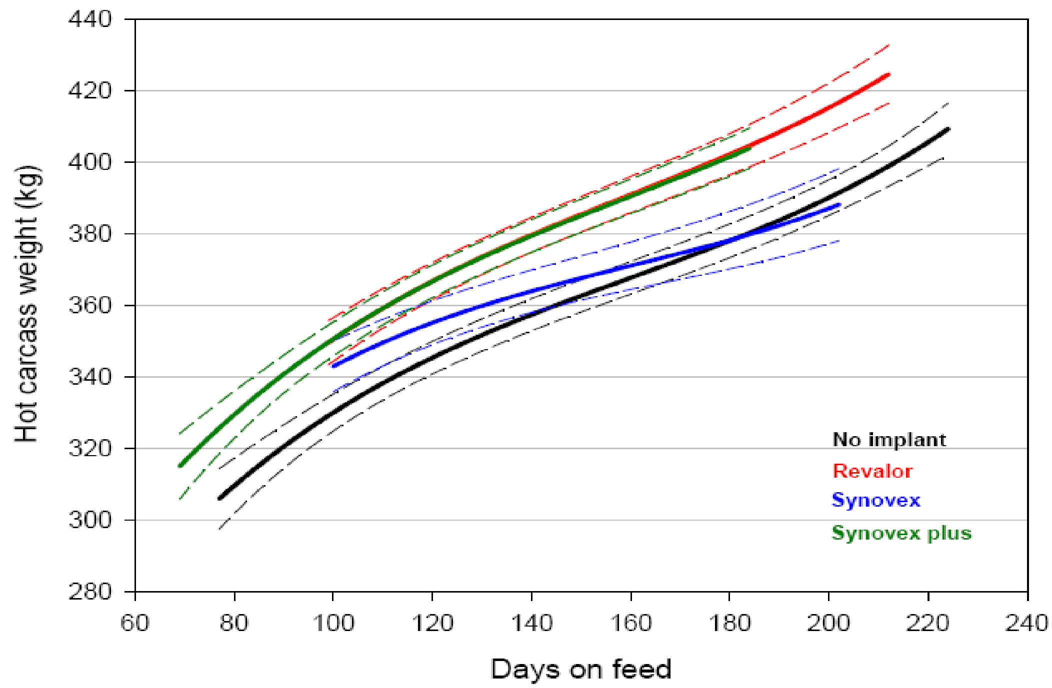

Figure 26. Hot standard carcass weight and its interaction with implant type from the overall analysis. 95 percent confidence intervals are shown around each treatment. Adjustment was made for days on feed, induction weight, induction frame, breed, induction dentition, illness, exit date and producer.

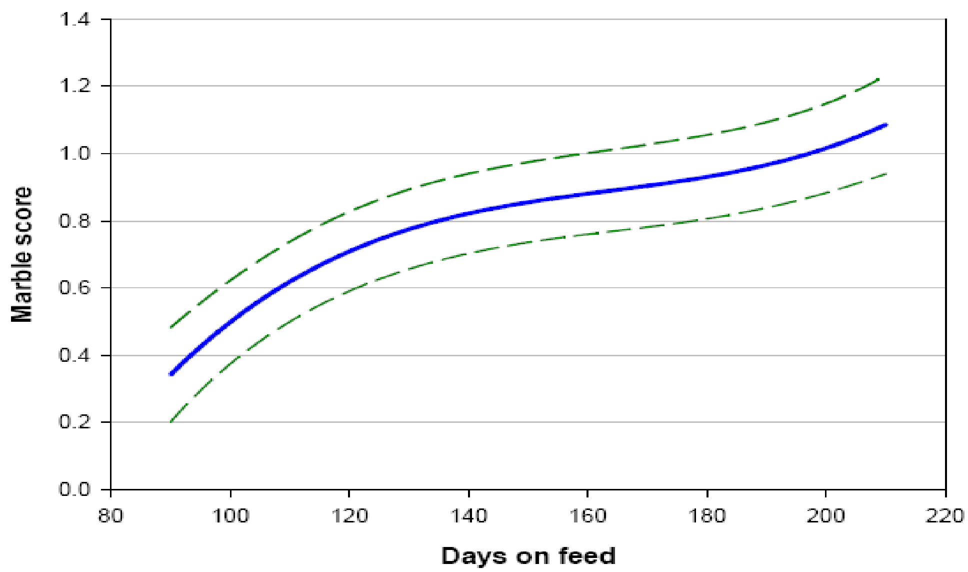

Figure 27. Marble score as affected by days on feed from the overall analysis (mean and 95 percent confidence interval). Adjustments were made for hot standard carcass weight, HGP implant status, induction frame score, breed, induction dentition, illness, exit date and producer.

The effect of induction frame score (INFRAME) on growth, marbling and external fat depth within market group and overall

Growth (adjusted HSCW) increased as INFRAME increased and as days on feed (indicated as market groups) increased, however there were high standard errors for frame scores 0 and 7 due to lower numbers within these categories. INFRAME adjusted for INWGT and DOF within BREED, showed a difference in the overall analysis ($P<0.0001$) of ca. 7kg HSCW from frame score 0 to frame score 6 (Table 17). The differences between INFRAME levels 0-7 were not uniform, and ranged from 4.7kg and 9.5kg, with the exception of frame score 0 to frame score 1 which was 1.7kg. Furthermore, there was a ca. 20 to 30kg difference within market group (lowest to highest, generally frame scores 1 and 6) attributable to INFRAME levels. The smallest incremental change for INFRAME occurred between market groups 60-

100 and 101-140 (ca. 3.0kg), whereas the differences between 101-140, 141-175 and 176-220 were ca. 30kg and 10kg respectively (Table 17).

Generally within market group induction INFRAME had only a small effect or no effect on AusMB. HP8 fat depth (mm) changed between induction group 60-100, 101-140, 141-175 and 176 and 220 between ca. 7, 4 and 0 mm, respectively (Table 17).

Table 17. Hot standard carcass weight, marble score and hot P8 fat depth categorised by induction frame score. Adjustments were made for induction weight, days on feed, HGP status/implant, breed, induction dentition, illness, and exit date. Producer Marble score and hot P8 fat depth were also adjusted for HSCW.

Induction frame score	60-100	101-140	141-175	176-220	Overall
HSCW/kg					
Frame score 0		341.2 ± 10.6	375.5 ± 8.4	369.6 ± 10.7	353.1 ± 5.3
Frame score 1	342.9 ± 21.9	343.4 ± 4.9	371.2 ± 5.2	381.3 ± 5.3	354.8 ± 2.3
Frame score 2	346.9 ± 11.5	349.3 ± 4.5	377.6 ± 5.0	385.9 ± 5.0	361.6 ± 2.0
Frame score 3	347.7 ± 10.7	353.7 ± 4.5	381.9 ± 5.0	391.8 ± 4.9	366.4 ± 2.0
Frame score 4	353.2 ± 10.5	357.5 ± 4.5	386.4 ± 5.0	397.4 ± 5.0	371.0 ± 2.0
Frame score 5	359.7 ± 10.7	361.6 ± 4.5	389.9 ± 5.1	402.6 ± 6.1	375.5 ± 2.1
Frame score 6	363.2 ± 11.0	366.5 ± 4.9	399.6 ± 6.5	389.4 ± 13.3	380.6 ± 2.7
Frame score 7	359.0 ± 15.4	363.7 ± 9.9	376.1 ± 28.2		376.0 ± 6.7
Marble score					
Frame score 0		0.9 ± 0.3	0.7 ± 0.2	1.1 ± 0.3	0.7 ± 0.1
Frame score 1	0.7 ± 0.3	0.7 ± 0.1	0.8 ± 0.2	1.4 ± 0.2	0.9 ± 0.1
Frame score 2	0.5 ± 0.2	0.7 ± 0.1	0.8 ± 0.1	1.5 ± 0.1	0.9 ± 0.1
Frame score 3	0.4 ± 0.2	0.7 ± 0.1	0.8 ± 0.1	1.5 ± 0.1	0.9 ± 0.1
Frame score 4	0.5 ± 0.2	0.7 ± 0.1	0.8 ± 0.1	1.4 ± 0.1	0.9 ± 0.1
Frame score 5	0.4 ± 0.2	0.7 ± 0.1	0.7 ± 0.1	1.4 ± 0.2	0.8 ± 0.1
Frame score 6	0.4 ± 0.2	0.7 ± 0.1	1.0 ± 0.2	1.5 ± 0.4	0.9 ± 0.1
Frame score 7	0.5 ± 0.2	0.6 ± 0.2	0.5 ± 0.8		0.7 ± 0.2
Hot P8 fat depth/mm					
Frame score 0		21.9 ± 2.5	24.7 ± 2.2	23.7 ± 2.9	22.9 ± 1.3
Frame score 1	11.3 ± 4.2	21.8 ± 1.2	25.7 ± 1.3	24.3 ± 1.5	23.7 ± 0.6
Frame score 2	14.0 ± 2.1	21.4 ± 1.1	25.3 ± 1.3	24.4 ± 1.4	23.4 ± 0.5
Frame score 3	13.4 ± 2.0	20.4 ± 1.1	24.4 ± 1.3	24.1 ± 1.4	22.6 ± 0.5
Frame score 4	12.7 ± 2.0	20.0 ± 1.1	23.6 ± 1.3	23.4 ± 1.4	22.1 ± 0.5
Frame score 5	12.3 ± 2.0	19.0 ± 1.1	22.6 ± 1.3	21.7 ± 1.7	21.0 ± 0.5
Frame score 6	10.3 ± 2.1	17.0 ± 1.2	21.5 ± 1.7	23.4 ± 3.6	19.4 ± 0.6
Frame score 7	13.5 ± 2.9	21.3 ± 2.3	29.0 ± 7.2		22.7 ± 1.6

The effect of breed (BREED) on growth, marbling and external fat depth within market group and overall

The analysis within market groups showed no significant effect of BREED on growth (adjusted HSCW) or AusMB ($P>0.01$). However, BREED significantly affected HP8 within the 101-140 group ($P<0.0001$). European and European cross cattle within this group had ca. 3.0 mm less HP8 than other breeds. Within the overall analysis there was a difference after adjustment for INFRAME and INWGT in growth of ca. 7kg across the range of BREED (

Table 18). Based on these means, the European and European cross breeds had the highest growth, followed by the British breeds and crosses, with Bos indicus breeds and crosses having the lowest. At the same HSCW, the overall analysis showed HP8 to be the greatest in Bos indicus cattle (24.1±0.71mm), but the difference was only ca. 3mm with the lowest breeds (Bos Indicus cross and European breeds).

Table 18. Hot standard carcass weight, marble score and hot P8 fat depth categorised by breed type. Adjustments were made for induction weight, days on feed, HGP status/implant, induction frame, breed, induction dentition, illness, exit date and producer. Marble score and hot P8 fat depth were also adjusted for HSCW.

Breed type	60-100	101-140	141-175	176-220	Overall
HSCW/kg					
Bos indicus cross	358.9 ± 14.2	347.1 ± 6.6	389.8 ± 11.6		354.0 ± 4.2
Bos indicus	354.8 ± 13.0	352.6 ± 5.1	376.7 ± 12.3		355.1 ± 2.9
Crossbred		350.0 ± 7.5	383.2 ± 9.8		365.4 ± 4.9
British	346.9 ± 10.3	356.0 ± 4.6	381.4 ± 5.5	389.3 ± 4.9	367.6 ± 2.0
British cross	347.3 ± 10.7	355.9 ± 4.7	381.9 ± 5.7	387.3 ± 6.8	367.7 ± 2.1
European	352.5 ± 12.5	360.5 ± 5.5	383.8 ± 6.8		370.6 ± 3.0
European cross	359.0 ± 11.5	360.2 ± 5.2	379.0 ± 7.0		371.2 ± 2.8
Marble score					
Bos indicus cross	0.6 ± 0.2	0.7 ± 0.2	0.8 ± 0.3		0.9 ± 0.1
Bos indicus	0.4 ± 0.2	0.7 ± 0.1	0.8 ± 0.4		0.8 ± 0.1
Crossbred		0.8 ± 0.2	0.5 ± 0.3		0.8 ± 0.1
British	0.5 ± 0.1	0.7 ± 0.1	0.9 ± 0.2	1.4 ± 0.1	0.9 ± 0.1
British cross	0.5 ± 0.2	0.7 ± 0.1	0.8 ± 0.2	1.3 ± 0.2	0.8 ± 0.1
European	0.5 ± 0.2	0.6 ± 0.1	0.7 ± 0.2		0.8 ± 0.1
European cross	0.5 ± 0.2	0.6 ± 0.1	0.9 ± 0.2		0.8 ± 0.1
Breed type	**60-100**	**101-140**	**141-175**	**176-220**	**Overall**
Hot P8 fat depth/mm					
Bos indicus cross	8.9 ± 2.7	19.2 ± 1.6	23.4 ± 3.0		20.7 ± 1.0
Bos indicus	13.3 ± 2.5	22.2 ± 1.2	29.2 ± 3.2		24.1 ± 0.7

Crossbred		21.8 ± 1.8	24.7 ± 2.5		23.2 ± 1.2
British	14.0 ± 1.9	21.2 ± 1.1	24.4 ± 1.4	24.5 ± 1	23.1 ± 0.5
British cross	14.4 ± 2.0	21.2 ± 1.1	23.8 ± 1.5	22.6 ± 2	22.9 ± 0.5
European	10.6 ± 2.4	18.4 ± 1.3	23.6 ± 1.7		20.8 ± 0.7
European cross	13.7 ± 2.2	18.5 ± 1.2	23.2 ± 1.8		21.1 ± 0.7

The effect of induction dentition (INDEN) on growth, marbling and external fat depth within market group and overall

Cattle with the lower INDEN had larger growth rates at exit in market group 176-220 (P<0.001) and in the overall analysis (P<0.01) as shown in Table 15. The difference between INDEN for growth tended to decrease at the INDEN classes. Within the overall analysis there was a difference of ca. 1kg between INDEN. There was an increase in growth between market groups 101-140, 141-175 and 176-220 of ca. 30 and 8kg HSCW.

The effects of INDEN on AusMB and HP8 while statistically significant (P<0.0001), had very small biological implication, ca. 0.1 AusMB and between 1 and 2mm of HP8 (Table 19), however AusMB was ca. 0.6 higher in market group 176-220 than in the other groups (Table 19) and HP8 increased ca. 8.0, 4.0 and 0.0mm between consecutive market groups (60-100 up to 176-220).

Table 19. Hot standard carcass weight, marble score and hot P8 fat depth categorised by induction dentition. Adjustments were made for induction weight, days on feed, HGP status/implant, induction frame, breed, illness, exit date and producer. Marble score and hot P8 fat depth were also adjusted for HSCW.

Induction dentition class	60-100	101-140	141-175	176-220	Overall
HSCW/kg					
0	352.8 ± 11.4	356.6 ± 4.8	384.1 ± 5.9	393.7 ± 5.3	369.1 ± 2.3
2	350.3 ± 11.2	356.0 ± 4.8	383.2 ± 5.9	390.2 ± 5.3	368.3 ± 2.3
4	354.3 ± 11.1	355.1 ± 4.8	382.4 ± 5.9	389.6 ± 5.4	367.5 ± 2.3
6	353.6 ± 11.1	354.1 ± 4.9	381.6 ± 6.0	379.7 ± 7.3	366.5 ± 2.4
8	355.3 ± 11.4	351.4 ± 5.0	380.1 ± 6.3		365.5 ± 2.6

Marble score					
0	0.4 ± 0.2	0.6 ± 0.1	0.7 ± 0.2	1.3 ± 0.2	0.7 ± 0.1
2	0.5 ± 0.2	0.7 ± 0.1	0.8 ± 0.2	1.4 ± 0.2	0.8 ± 0.1
4	0.5 ± 0.2	0.7 ± 0.1	0.8 ± 0.2	1.5 ± 0.2	0.9 ± 0.1
6	0.5 ± 0.2	0.8 ± 0.1	0.8 ± 0.2	1.4 ± 0.2	0.9 ± 0.1
8	0.5 ± 0.2	0.7 ± 0.1	0.8 ± 0.2		0.9 ± 0.1
Hot P8 fat depth/mm					
0	12.1 ± 2.1	20.0 ± 1.1	23.8 ± 1.5	23.1 ± 1.5	21.5 ± 0.6
2	12.5 ± 2.1	19.9 ± 1.1	24.5 ± 1.5	23.4 ± 1.5	21.9 ± 0.6
4	11.9 ± 2.1	20.0 ± 1.1	24.6 ± 1.5	24.4 ± 1.5	22.1 ± 0.6
6	13.3 ± 2.1	20.9 ± 1.2	25.1 ± 1.5	23.5 ± 2.0	22.9 ± 0.6
8	12.7 ± 2.2	21.0 ± 1.2	25.0 ± 1.6		22.8 ± 0.6

The effect of illness (ILLNESS) on growth, marbling and external fat depth within market group and overall

Frequencies of the most common illnesses reported from the case study are shown in Figure 28. When analyses were performed within market groups there were several incidences where the standard errors were high. These were due to low numbers of illness type and the distribution of illness type within market groups. The ILLNESS category referred to as *other* includes a collection of illnesses which had low frequencies individually such as jaw, foot and leg swelling.

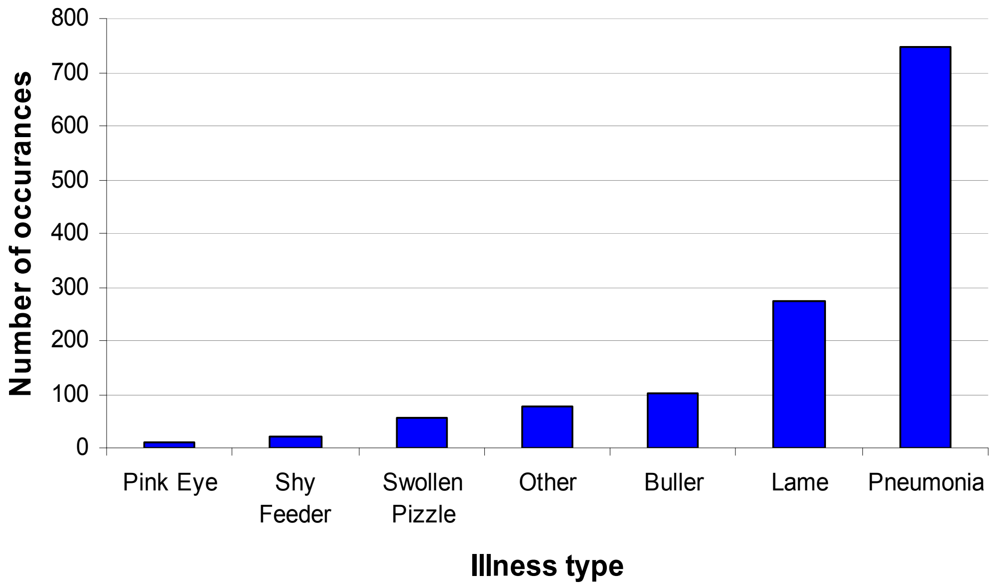

Figure 28. Distribution of illness by illness type for the case study feedlot subset (n=32,453). *Other*, includes a collection of illnesses with low frequencies.

There was a significant effect of ILLNESS on growth (P<0.0001, Table 15). Within the four market groups, pneumonia decreased growth by up to 15.0kg, when compared to animals with no illness (Table 20). Lameness also reduced growth considerably within market group. The overall analysis showed losses in growth from ca.3 to 17.5kg due to ILLNESS. ILLNESS reduced AusMB however there is low confidence (high standard errors) for some illness classes within market groups given the small number of animals (low frequencies). The effect of pneumonia and lameness (Table 20) was small causing a decrease of 0.1 units in marble score. HP8 showed small differences (Table 20).

Table 20. Hot standard carcass weight, marble score and hot P8 fat depth categorised by illness type. Adjustments were made for induction weight, days on feed, HGP status/implant, induction frame, breed, induction dentition, exit date and producer. Marble score and hot P8 fat depth were also adjusted for HSCW.

Illness type	60-100	101-140	141-175	176-220	Overall
HSCW/kg					

None	366.7 ± 8.9	371.7 ± 2.6	388.8 ± 4.3	392.2 ± 3.7	377.5 ± 1.6
Swollen Pizzle	393.8 ± 14.2	366.4 ± 5.6	385.2 ± 10.6	375.1 ± 12.1	374.8 ± 4.0
Buller		361.7 ± 4.7	387.3 ± 5.8		369.7 ± 3.1
Lame	343.8 ± 23.7	355.2 ± 4.0	381.5 ± 4.8	387.7 ± 6.8	366.9 ± 2.3
Pneumonia	347.3 ± 11.8	355.9 ± 3.3	379.1 ± 4.5	378.5 ± 4.8	365.4 ± 1.9
Shy Feeder		298.8 ± 28.0	409.3 ± 27.0	384.2 ± 7.5	362.8 ± 6.9
Pink eye		370.1 ± 11.9	358.0 ± 14.5		362.7 ± 9.0
Other	314.5 ± 22.8	357.0 ± 6.3	369.0 ± 5.8	412.0 ± 19.0	359.1 ± 3.5
Marble score					
None	0.5 ± 0.1	0.7 ± 0.1	0.8 ± 0.1	1.4 ± 0.1	0.9 ± 0.0
Swollen Pizzle	0.3 ± 0.2	0.6 ± 0.1	0.9 ± 0.3	1.5 ± 0.3	0.8 ± 0.1
Buller		0.7 ± 0.1	0.7 ± 0.2		0.9 ± 0.1
Lame	0.7 ± 0.3	0.6 ± 0.1	0.7 ± 0.1	1.5 ± 0.2	0.8 ± 0.1
Pneumonia	0.4 ± 0.2	0.6 ± 0.1	0.7 ± 0.1	1.3 ± 0.1	0.7 ± 0.1
Shy Feeder		1.0 ± 0.7	1.1 ± 0.8	1.4 ± 0.2	0.9 ± 0.2
Pink eye		0.8 ± 0.3	0.3 ± 0.4		0.8 ± 0.2
Other	0.5 ± 0.3	0.8 ± 0.2	0.9 ± 0.2	1.2 ± 0.5	0.9 ± 0.1
Hot P8 fat depth/mm					
None	15.1 ± 1.7	21.5 ± 0.6	25.3 ± 1.1	25.0 ± 1.0	23.3 ± 0.4
Swollen Pizzle	11.0 ± 2.7	21.1 ± 1.3	28.4 ± 2.7	20.4 ± 3.3	22.6 ± 1.0
Buller		21.1 ± 1.1	25.9 ± 1.5		23.9 ± 0.8
Lame	5.7 ± 4.6	19.3 ± 1.0	24.3 ± 1.2	24.9 ± 1.9	22.3 ± 0.6
Pneumonia	12.6 ± 2.2	20.9 ± 0.8	24.6 ± 1.2	23.7 ± 1.3	22.8 ± 0.5
Shy Feeder		18.7 ± 6.6	22.4 ± 6.9	22.2 ± 2.1	20.9 ± 1.7
Pink eye		20.5 ± 2.8	19.8 ± 3.7		20.6 ± 2.2
Other	18.0 ± 4.4	19.8 ± 1.5	26.1 ± 1.5	25.4 ± 5.2	23.6 ± 0.9

The effect of induction weight (INWGT) on growth, marble score and external fat depth within market group and overall

HSCW increased as INWGT increased (P<0.0001) within all market groups (Table 21), with the rate of increase being higher in successive market groups. The overall analysis showed that there was little difference in the HSCW of cattle inducted up to ca. 280kg INWGT; but from 280kg upwards the effect was marginally curvilinear (Figure 29) where an increase in INWGT of 20kg resulted in an increase of 10kg in HSCW. This effect was evident whether or not adjusted for DOF.

INWGT had no effect on AusMB and a very small effect on HP8 in one only of the market groups (Table 21), market group 141-175.

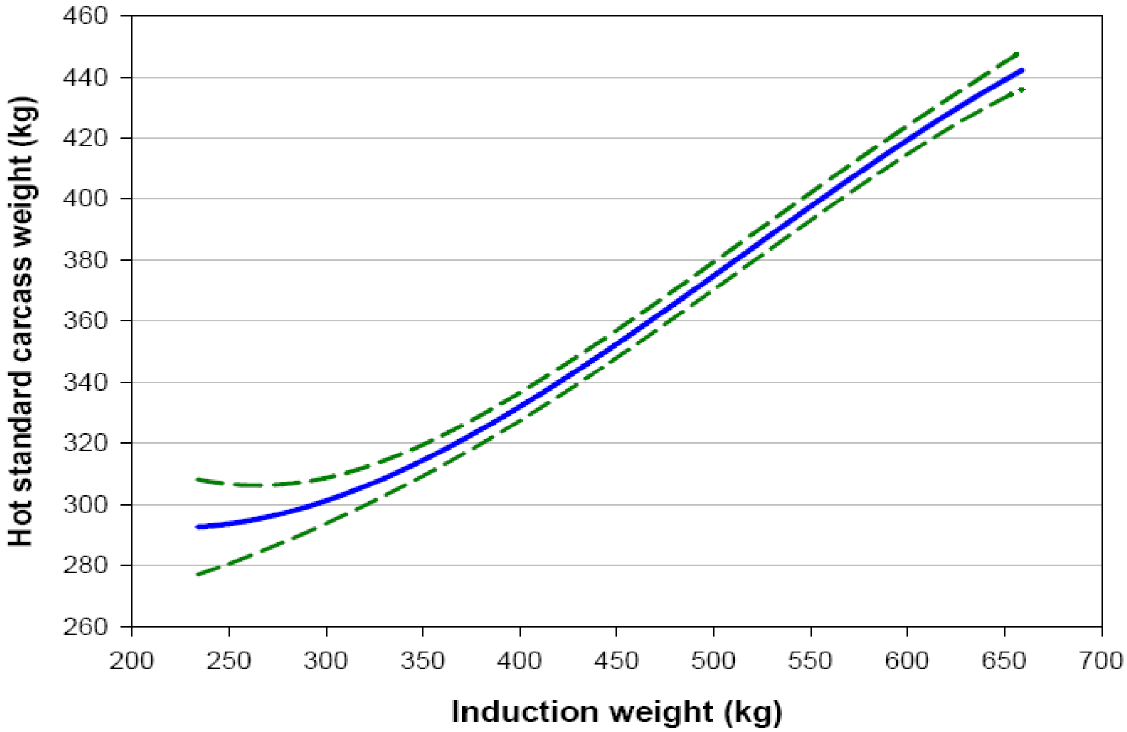

Figure 29. Hot standard carcass weight as affected by induction weight (mean and the 95 percent confidence interval). Adjustment were made for days on feed, induction weight, HGP implant status, induction frame score, breed, induction dentition, illness, exit date and producer.

The effect of hot carcass weight (HSCW) on marble score and external fat depth within market group and overall

AusMB increased significantly with HSCW (Table 15) both within market group and overall. The regression coefficients (Table 21), within market group, showed that as HSCW increased 100kg marble score increased ca. 0.1 to 0.2 for each of the market groups. The overall analysis showed a curvilinear response in AusMB as HSCW increased (Figure 30), AusMB increased as HSCW increased and effectively plateaued at greater than ca. 440kg HSCW.

HP8 depth increased ca 5.00 mm for each 100kg increase in HSCW for all market groups (Table 15). In the overall analysis the response was curvilinear (Figure 31), with a small decline in the rate of HP8 accumulation when HSCW reached ca. 350kg.

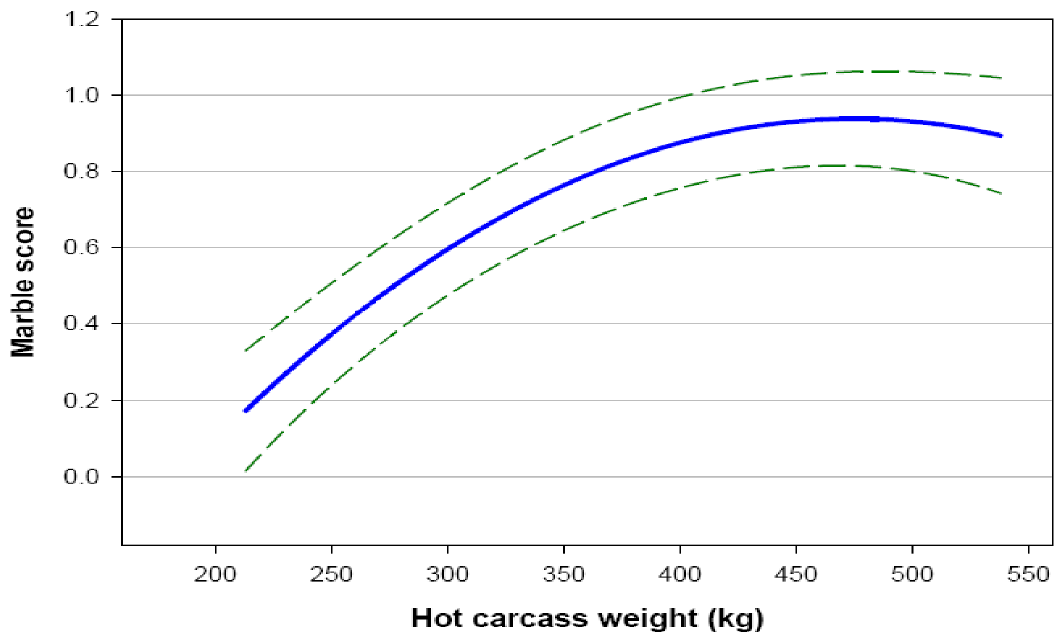

Figure 30. Marble score as affected by hot carcass weight (mean and the 95 percent confidence interval) from the overall analysis. Adjustments were made for hot standard carcass weight (kg), days on feed, induction weight, HGP implant status, induction frame score, breed, induction dentition, illness, exit date and producer.

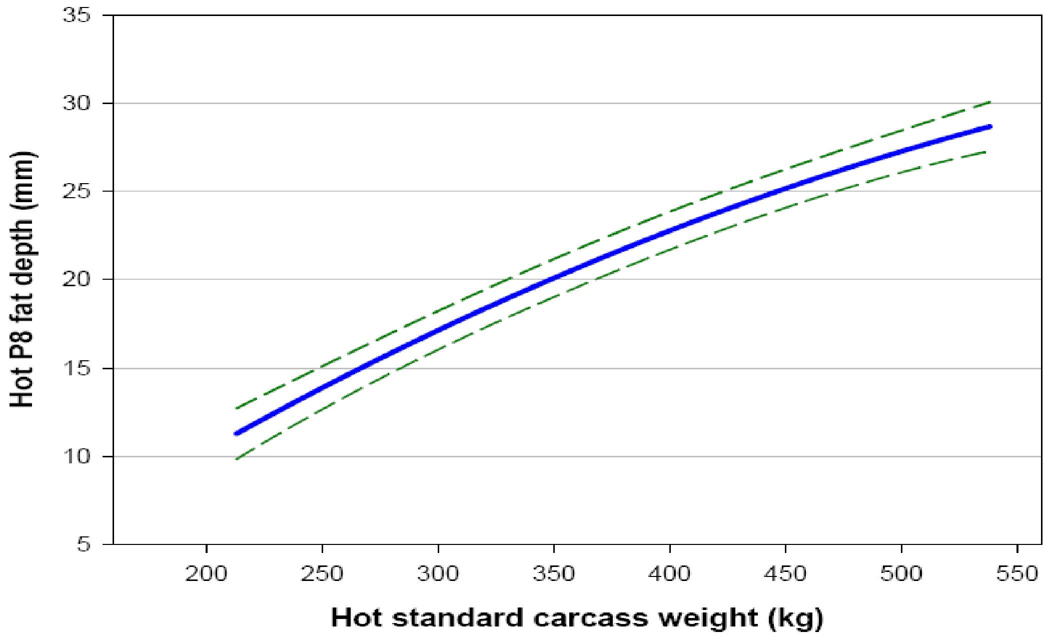

Figure 31. Hot P8 fat depth (mm) as affected by hot carcass weight (mean and the 95 percent confidence interval) from the overall analysis. Adjustments were made for hot standard carcass weight (kg), days on feed, induction weight, HGP implant status, induction frame score, breed, induction dentition, illness, exit date and producer.

Table 21. Regression coefficients and standard errors (SE) for the effect of animal and management factors in the case study feedlot data subset categorised by market group and as an overall analysis.

	Market group 60-100		Market group 101-140		Market group 141-175		Market group 176-220		Market group Overall	
Source	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
HSCW/kg										
Induction weight (kg)	0.4000	± 0.0300	0.4290	± 0.0080	0.4600	± 0.0420	0.4690	± 0.0150	-0.9353	± 0.3361
Induction weight (kg)^2									0.0027	± 0.0007
Induction weight (kg)^3									0.0000	± 0.0000
Days on feed	1.0700	± 0.2700	0.7410	± 0.0450	0.4330	± 0.0060	0.3930	± 0.0710	3.1780	± 0.6000
Days on feed^2									-0.0160	± 0.0004
Days on feed^3									0.0003	± 0.0000
Exit date	-0.0200	± 0.0200	-0.0020	± 0.0010	-0.0050	± 0.0010	-0.0110	± 0.0010	-0.1259	± 0.0644
Exit date^2									0.0000	± 0.0000
Marble score										
Days on feed			0.0100	± 0.0011	0.0041	± 0.0012			0.0700	± 0.0200
Days on feed^2									-0.0005	± 0.0010
Days on feed^3									0.0000	± 0.0000
Hot standard carcass weight (kg)	0.0009	± 0.0004	0.0019	± 0.0002	0.0023	± 0.0002	0.0013	± 0.0004	0.0100	± 0.0010
Hot standard carcass weight (kg)^2									0.0000	± 0.0000
Exit date	-0.0006	± 0.0003	0.0000	± 0.0000	-0.0001	± 0.0000	-0.0003	± 0.0000	-0.0150	± 0.0020
Exit date^2									0.0000009	± 0.00000
Hot P8 fat/mm										
Entry weight (kg)					0.0040	± 0.0020				
Days on feed			0.0824	± 0.0107					0.0420	± 0.0030
Hot standard carcass weight (kg)	0.0500	± 0.0050	0.0496	± 0.0020	0.0540	± 0.0020	0.0540	± 0.0040	0.1000	± 0.0100
Hot standard carcass weight (kg)^2									-0.0001	± 0.0000
Exit date	0.0100	± 0.0040	0.0001	± 0.0004	-0.0020	± 0.0000	-0.0020	± 0.0000	0.0500	± 0.0100
Exit date^2									-0.0000001	± 0.00000

The effect of Producer (PIC) on HSCW, marbling and external fat depth within market group and overall

Producer (PIC) effects for HSCW, marbling and external fatness overall

From the overall analysis, PIC that delivered small numbers of cattle had greater variability (standard error being a function numbers delivered), and has been illustrated for adjusted means, for HSCW, AusMB and HP8 (Table 22). A group of PIC can be identified that deliver sufficient numbers to allow them to be ranked for optimum output. Figure 32 to Figure 34 show the adjusted PIC means (adjusted to the same DOF, INWGT, IMPLANT, INFRAME, BREED, INDEN and ILLNESS) for HSCW, AusMB and HP8 plotted with their interactions. These graphs indicate how producers may be selected for high HSCW and high AusMB (Figure 32), high HSCW and low HP8 (Figure 33) and high AusMB and low HP8 (Figure 34).

Relationships between producers adjusted mean HSCW, mean AusMB and mean HP8 were only significant for HSCW and HP8 (P<0.000). Correlations between the PIC adjusted mean HSCW rate and HP8 (P>0.09) indicated that as PIC means for HSCW increased there was a marginal increase in HP8.

Table 22. Adjusted means and standard errors for hot standard carcass weight (kg), marble score and hot P8 fat depth for a subset of producers. Adjustments were made for induction weight, days on feed, induction frame and dentition score, illness, breed and producer (n=32,453).

Producer	Deliveries	Growth (mean HSCW/kg) ± se	Adjusted mean marble score ± se	Adjusted mean hot P8 depth (mm) ± se
Producer A	2	372 ± 18	1.0 ± 0.5	20 ± 4.5
Producer B	20	364 ± 6	0.8 ± 0.2	24 ± 1.5
Producer C	235	359 ± 3	0.9 ± 0.1	24 ± 0.7
Producer D	674	367 ± 3	0.9 ± 0.1	22 ± 0.6

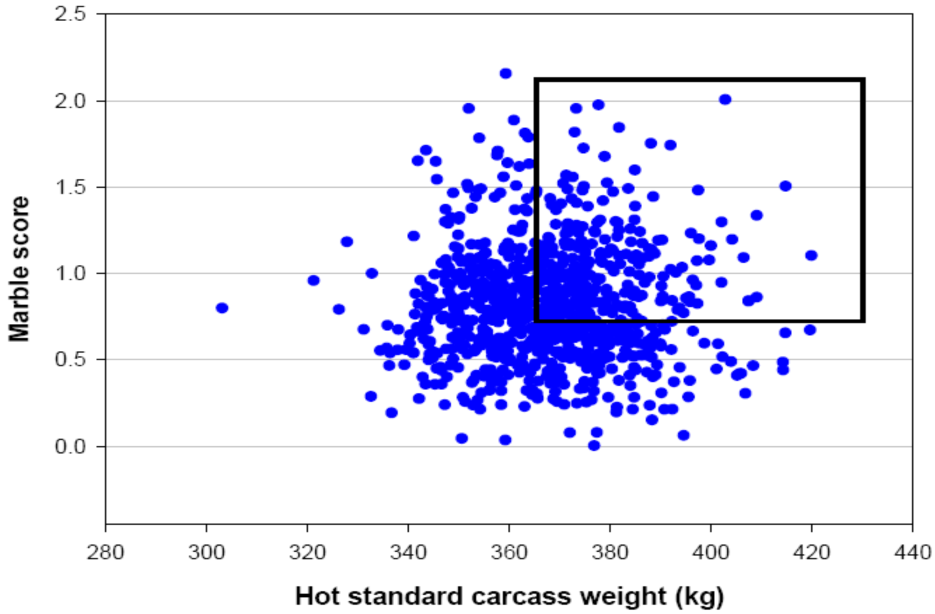

Figure 32. Adjusted producer means for hot standard carcass weight against producer means for marble score for producers who delivered more than twenty animals to the case study feedlot. Adjustments have been made for days on feed, induction weight, HGP implant status, induction frame score, breed, induction dentition, illness and HGP implant, n=32,453. The square indicates those producers producing high marble score combined with higher HSCW.

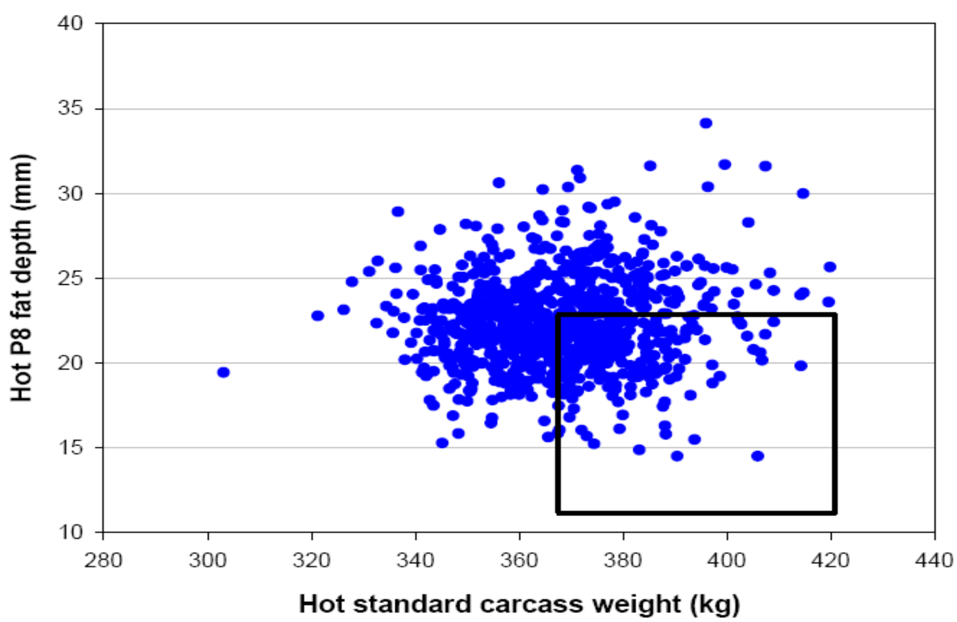

Figure 33. Adjusted producer means for HSCW against producer means for hot P8 fat depth/mm for producers who delivered more than ten animals to the case study feedlot. Adjustments have been made for days on feed, induction weight, HGP implant status, induction frame score, breed, induction dentition, illness and HGP implant, n=32,453. The square indicates those Producers producing lower hot P8 fat depth combined with higher growth.

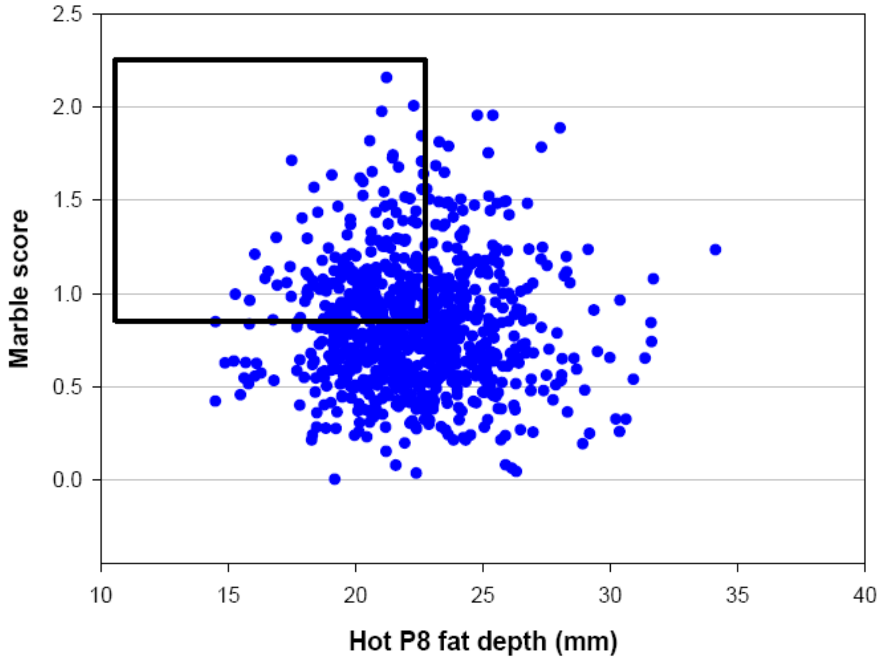

Figure 34. Adjusted producer means for hot P8 fat depth/mm against producer means for marble score for producers who delivered more than ten animals to the case study feedlot. Adjustments have been made for days on feed, hot carcass weight/kg, HGP implant status, induction frame score, breed, induction dentition, illness and exit date, n=32,453. The square indicates those Producers producing lower hot P8 fat depth combined with higher marble score.

The overall analysis showed that there was a large amount of variation between producers for measures in production traits. An illustration of the size of the variation is shown in Figure 35. As shown by the quality loss functions (chapter 3, page 63, *The costs associated with non compliance in Australian beef carcasses*) there are large costs associated with carcass traits that are out of specification. The variation in HSCW between two producers identified as Producer A (n=120) and Producer B (n=146), after adjusting for induction weight, days on feed, frame score, breed and illness shows that the mean HSCW for Producer A and B were very similar 381kg (± 15) and 379kg (± 28) respectively. However the range in HSCW for producer A was 76kg and for producer B was 112kg. Furthermore producer A had carcass weights that were highly concentrated between 380 – 410 kg (more than 80% of deliveries) whereas producer B delivered carcasses between 350 – 430kg. The results indicate that some producers within the case study feedlot's suppliers are delivering animals that do not have the ability to meet the case study feedlot's customer requirements and therefore result in large costs to the feedlot.

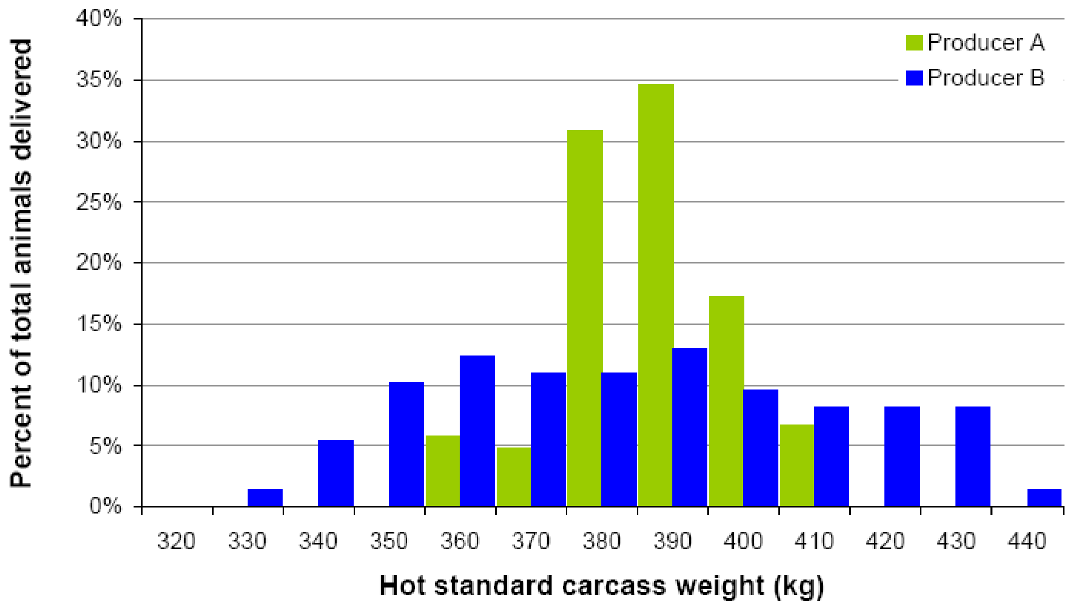

Figure 35. Variation in hot standard carcass weight for two producers nominated as Producer A (n=146) and Producer B (n=120) in the case study feedlot's dataset. Hot standard carcass weight (kg) has been adjusted for induction weigh, days on feed, frame score, breed and illness.

Correlations of producer (PIC) effects between market groups

Producers had a significant positive correlation for HSCW between market groups 60-100 and 101-140 (0.62, P<0.000), Table 23. This indicated those producers that delivered into both 60-100 and 101-140 day market groups would have similar ranking on HSCW after adjusting for factors included in the HSCW statistical model. PIC correlations between the 101-140 and 141-175 market groups and 141-175 and 176-220 market groups were significant (P<0.005 and P<0.01, Table 24). There was a significant PIC correlation (Table 24) between PIC from market groups 101-140 and 141-175. This indicated that there was a trend for Producers of low/high marble score to have a low/high marble score in both market groups. PIC correlations for HP8 fat depth were positive but small between the 101-140 and 141-175 market groups (Table 25).

Table 23. Correlation, significance and number for hot standard carcass weight adjusted for induction weight and days on feed between producer adjusted means within market groups. Adjustments were made for induction weight, days on feed, HGP implant status, induction frame score, breed, induction dentition, illness, exit date and producer.

Market groups (days on feed)	60-100	101-140	141-175	176-220
60-100	1.00	0.62 (P<0.000) n=38	0.31 (P=0.207) n=18	0.64 (P=0.248) n=5
101-140		1.00	0.20 (P<0.005) n=197	0.04 (P=0.760) N=61
141-175			1.00	0.26 (P<0.014) n=89
176-220				1.00

Table 24. Correlation, significance and number for marble score (adjusted for carcass weight) between producer adjusted means within market groups. Adjustments were made for hot standard carcass weight (kg), days on feed, HGP implant status, induction frame score, breed, induction dentition, illness, exit date and producer.

Market groups (days on feed)	60-100	101-140	141-175	176-220
60-100	1.00	0.28 (P=0.090) n=39	0.24 (P=0.326) n=19	0.19 (P=0.758) n=5
101-140		1.00	0.38 (P<0.000) n=197	0.05 (P=0.702) n=61
141-175			1.00	0.10 (P=0.370) n=89
176-220				1.00

Producer adjusted means were highly positively correlated between the induction groups and the overall analysis in for HSCW, marbling and fatness, with the exception of HP8 for market group 141-175 and the overall analysis (Table 25).

Table 25. Correlation, significance and number for hot P8 fat depth/mm (adjusted for carcass weight) between producer adjusted means within market groups. Adjustments were made for hot standard carcass weight (kg), days on feed, HGP implant status, induction frame score, breed, induction dentition, illness, exit date and producer.

Market groups (days on feed)	60-100	101-140	141-175	176-220
60-100	1.00	0.03 (P=0.877) n=39	0.10 (P=0.683) n=19	-0.56 (P=0.337) n=5
101-140		1.00	0.22 (P<0.002) n=197	0.08 (P=0.548) n=61
141-175			1.00	0.16 (P=0.133) n=89
176-220				1.00

5.5. Discussion

HSCW

Animal growth results from feed intake over time, and, the efficiency with which this is partitioned between maintenance and growth (Parks 1982). The growth curve for live weight as a function of age is not linear, with younger animals growing faster than more mature animals (Brody 1945; Berg and Butterfield 1976; Berg and Walters 1983). It is therefore expected that overall growth rates for animals under long feeding regimes would be slower than those on short term feed, as the latter's growth will be measured only during their younger, faster growth period. Results from the case study feedlot dataset suggest the highest growth rates were within induction group 60-100 (1.07kg/day HSCW).

Finishing beef cattle for slaughter, deposition of fat increases while muscle deposition slows, resulting in slower and less efficient gain (Cook *et al.* 2001). HGP implants are known to improve growth rate (Perry *et al.* 1991; Raun and Preston 2001), feed conversion (Andrews *et al.* 1954; Buttery and Dawson 1990; Perry *et al.* 1991; Johnson *et al.* 1996), and protein deposition in cattle (Montgomery *et al.* 2001). HGP implants are widely used in the beef industry and include implants that contain an androgen (trenbolone acetate; TBA) and an estrogen (estradiol; E2). The manufacturer's recommendation for the HGP implants used in the case study feedlot is that the growth response is maintained for 100 - 120 days, and then further implants are required to extend the growth response.

The case study feedlot data show that when implants include a combination TBA/E2 such as Revalor, further implants were not required given that their effect on growth was maintained through to 220 days on feed. Combination implants in the case study feedlot data resulted in similar weight increases to those of Johnson *et al.* (1996) who fed large framed crossbred steers an ad libitum diet and administered a TBA/E2 implant. Johnson *et al.* (1996) found implanted cattle were consistently heavier than the controls at days 115 and 143 by 20 and 25kg respectively. Frame score 5, Charolais crossbred cattle were fed for 80 days by Hayden *et al.* (1992). The use of TBA/E2 implants increased weight by 18kg above the non implanted controls. A number of modes of action have been reported which include the promoting of muscle protein synthesis (Hayden *et al.* 1992), a decline in the catabolic action of cortisol and an increase in synthesis of muscle proteins (Cook *et al.* 2001), higher percentages of fast-twitch glycolytic muscle fibers and a concomitant increase in fibre area due to hypertrophy (Fritsche *et al.* 2000), furthermore it has been shown that aggressive implants result in an increase in the level of calpastatin (Gerken *et al.* 1995) which may result in decreased protein degradation.

This sustained treatment response did not occur for Syn-S since both treated and untreated animals were similar in growth beyond 140 days on feed. These decreasing weight differences between control and E2 implanted animals were similar to Bartle *et al.* (1992) who fed steers for 140 to 168 days, commenting that no effect on growth rate between the control group and E2 implanted steers was evident at extended days on feed. Moreover it has been shown by Hayden *et al.* (1992) that the largest weight differences between control and E2 implanted steers occurred at 40 days post implant. The use of Synovex increased oxidative muscle fibres but unlike TBA/E2 implants did not cause hypertrophy (Fritsche *et al.* 2000). The difference between Syn-S and a combination TBA/E2 in long fed animals suggested that protein synthesis and degradation reverted to pre-implantation levels when Syn-S was used and therefore the growth advantage was eroded. This result was contrary to others who observed an increase in mature body size after treatment with Syn-S (Loy *et al*. 1988: Rumsey *et al.* 1992), however the results of (Loy *et al.* 1988: Rumsey *et al.* 1992), do not account for differences at extended liveweight. This analysis has shown that the use of HGP implants will increase growth when either E2 or TBA/E2 are used however dual implants have been shown to maintain their advantage beyond that of the E2 only implant and could be used in longer (more than 120 days) fed animals.

Growth was affected by frame score as well as dentition. Animals with larger frame sizes grew faster in all market categories. This has been shown consistently in studies (e.g. Block *et al.* 2001; Camfield *et al.* 1997; Dolezal *et al*. 1993 and Tatum 1982). Tatum *et al.* (1986) indicated the effect of frame score (small, medium and large) on carcass weight was 528, 451 and 407 kg, respectively, while these differences were larger in magnitude than the case study feedlot analysis. Tatum *et al.* (1986) included only yearling steers that included beef and dairy breeds. The breed effect on carcass weight in the case study feedlot analysis was considerably lower than those reported by Kempster and Southgate (1984) who showed carcass weight differences between breed of 5%. Block *et al.* (2001) showed that breed effects may be in the order of 40kg carcass weight (Charolais 40 kg heavier than Hereford). There was an expectation that breed and frame score would be highly related (Arango *et al.* 2002), but in this analysis the dependency was only of the order of 2% as indicated by a sequential (Type I), sums of squares analysis. It is therefore likely that the breed category was based largely on coat colour and physical appearance, whilst frame score was based on skeletal development (i.e. hip height). It has been commented by Dolezal *et al.* (1993) that diversity and crossbreeding in cattle populations has lead to a decline in precise breed identification, therefore interpretation of the breed effect in this analysis should be treated with caution.

Morbidity in feedlot cattle due to high metabolic diets and diseases causes a two fold problem; firstly the loss of production due to decreased growth rates and secondly the cost of treatment and/or removal (Galyean *et al.* 1999). Disease has the potential to affect carcass weight by changes in the quantity, location, and ratio of muscle, fat, and water (Larson 2005). In the case study feedlot analysis disease incidence was highest for pneumonia, lameness and *bullers*. They had a similar adverse impact on growth between successive market groups by (ca. 23, 15, 6, 4kg respectively) and in the overall analysis (ca. 7kg). Smith (1998) showed HSCW decreased between ca. 16 - 30kg due to respiratory disease whereas Gardner *et al*. (1999) found differences of between ca. 5 and 15kg in HSCW in cattle with or without respiratory disease. The case study feedlot dataset showed cattle identified as suffering pneumonia were 10-17kg lighter in HSCW than healthy cattle. The largest effect of pneumonia on HSCW (ca. 17kg) was for group 101-140. These results were higher than Thompson *et al.* (2006b) who estimated an 11kg reduction in HSCW. Classifications of diseases were made by feedlot staff based on observations of physical characteristics. Diagnoses of illness however can be presumptive where agents are not cultured or identified by immunohistochemistry Haines *et al.* (2004). Fulton *et al.* (2002) and Booker *et al.* (2008) have indicated that a large number of feedlot deaths attributable to pneumonia are dually influenced by pneumonia and Bovine viral diarrhea virus indicating the true identification of diseases may differ from those nominated by feedlot staff. Incidences of *Bullers* in the case study feedlot were 0.3%, considerably lower than those of Brower and Kiracofe (1978) who showed the rate of *Bullers* in Kansas feedlots were 2.2%.

Marble score

Fat is late maturing relative to other tissues (Brody 1945; Berg and Butterfield 1968) and on a high plane of nutrition can result in the surplus energy going to fat deposition after meeting all other requirements (Owens *et al.* 1995). The reduction in the rate of intramuscular fat accumulation between days ca. 120 to 190 were similar to those shown by Van Koevering *et al.* (1995). In the trials conducted by Van Koevering *et al.* (1995) there was no deposition of intramuscular fat after 133 days on feed, however in Van Koevering *et al.* (1995) the maximum time on feed was 147 days. In this analysis there was a decline at ca. 120 days on feed followed by an increase in the rate of marbling at ca. 190 days on feed. Marble scores increased as hot carcass weight increased up to ca. 450kg HSCW then plateaued after 450 kg carcass weight. This plateau was consistent with the observation that relative feed intakes began to decrease in long fed animals at carcass weights greater than 450 kg (G. Bond, pers. Comm., 15 November 2007).

The concomitant effect of HGP implants meant that while there was increased protein deposition there was also a decrease in marbling associated with the dilution of intramuscular fat in larger muscles (Milton *et al.* 1996; Ducket *et al.* 1999). HGP implants reduced the marble score within the case study feedlot dataset by ca. half a marble score within market groups and in the overall analysis, an effect consistent with the characteristics of HGP implants and their inclination to increase growth rather than fatness. E2 and/or TBA+E2 combinations were not significantly different in their effect on marbling within market or in the overall analysis. Results from this analysis were similar to those of Ducket *et al.* (1999) and Rumsey *et al.* (1992).

In the case study feedlot data there appeared to be a small effect of INFRAME on AusMB, similar to that shown by Tatum (1982), who found AusMB was marginally different across INFRAME, adjusted to the same DOF. Dolezal *et al.* (1993) and Camfield *et al.* (1997), however, showed larger framed animals consistently had smaller amounts of fat overall. Camfield *et al.* (1997), using British cross steers, found that large frame steers consistently had less marbling (ca 10%) than medium frame steers.

BREED did not affect marble score in the case study feedlot analysis, but has been recognised by Kerth *et al.* (1995) as an important factor contributing to the explanation of marble scores. Kerth *et al.* (1995) found that continental European breed types had less marbling compared to British and British cross breed types. However Dolezal *et al.* (1993), commenting on the US feeder cattle population, remarked the population has become diverse, has experienced intensified use of crossbreeding and large changes in size, body type, and growth, and that precision in breed identification has become essentially impossible for a large portion of the feeder cattle population. This may well also explain the lack of breed distinction within the case study feedlot dataset.

Older cattle partitioned energy more towards fat than muscle. The trend for marbling as a function of INDEN was similar to that of Lawrence *et al.* (2001) who found marble scores generally increased with dentition but marginally declined at 8 teeth although the 8 teeth cattle had large standard errors.

The effect of illness on the immune system may cause depressed feed intake and growth (Thompson *et al.* 2006b). However there was only a small effect of illness on marble score (pneumonia and lameness ca. 0.1 - 0.2 marble scores) in the case study feedlot data. Gardner *et al.* (1999) also found little effect of a single incidence of respiratory disease on marble scores for animals 150 days on feed.

External fat depth

Most weight related traits, including external fat thickness, increase linearly over days on feed (May *et al.* 1992). Owens *et al.* (1993) commented that weight gain beyond maximum lean body mass indicated an increase in fat. In the case study feedlot analysis HP8 increased ca. 9mm/100 DOF, a similar rate to that found by May *et al*. (1992). Mature body size can be defined as the point at which protein accumulation reaches a plateau (Berg and Butterfield 1976). Beyond this point a feedlot animal consuming ad libitum feed, deposits fat and gains weight with minimal muscle growth (Berg and Butterfield 1976).

The effect of HGP implants on HP8 in the case study feedlot analysis was small, ca. 2mm difference between the TBA/E2 and E2 implant, similar in magnitude reported by Montgomery *et al.* (2003). However others (Gerken *et al.* 1995; Samber *et al.* 1996; Roeber *et al.* 2000) found little or no effect of HGP implant on fat thickness (ca. 0.4, 0.3 and 0.1 rib fat 12/13 rib respectively).

Earlier maturing or small framed cattle exhibit enhanced fattening and reduced slaughter weight (Owens *et al.* 1993). Block *et al.* (2001) showed frame size was a characteristic related to mature size with the implication that large-framed cattle will reach a specified level of fatness at heavier weights than small framed cattle. There was an overall decrease in HP8 fat of ca. 4mm attributable to increased frame score within market groups 101-141 and 141-175. In contrast, Dolezal *et al.* (1993) found that large framed steers had ca. 0.4mm more external fat than small framed steers however these steers were slaughtered at different carcass weights.

At the same carcass weight, there was a higher amount of rib fat on Bos indicus, British and crossbred animals compared to continental breeds, which had about 4 mm less than the other breed categories. This was similar to findings of Marshall (1994) and Urick *et al.* (1991). Changes in INDEN resulted in a negligible increase of ca. 1mm from 0 – 8 tooth and indicated age was not a significant contributor to rib fat. Similarly Dolezal (1993) showed age effects in the order of 13.1, 13.3 and 14.3 mm rib fat respectively for calf, yearling and long fed yearlings (8, 12 and 18 months of age) at the same carcass weight. Illness also caused a small reduction in external fat depth, which was consistent to the results presented by Gardner *et al.* (1999).

Producer (PIC) as suppliers effect between markets and overall

Suppliers are increasingly important for the success of companies (Wagner and Boutellier 2002). The majority of problems and costs associated with firm's production quality caused by the quality and variability of incoming materials (Feng *et al.* 2001). In order to maintain product quality the management of supplier's capability is increasing (Wu and Pearn 2008). Multiple criteria such as quantity, price, quality and capability over time (Hong *et al.* 2005) are monitored since poor supplier performance impacts on the whole supply chain (Sarkar and Mohapatra 2006). Supplier selection is a multicriteria problem (Ghodsypour and O'Brien

1998) involving purchase decisions (de Boer *et al.* 2000) which include qualitative and quantitative factors (Houshyar and Lyth 1992; Demirtas and Üstün 2008; Ha and Krishnan 2008; Sanayei *et al.* 2008). The suppliers (Producers) in the case study feedlot dataset were evaluated across multiple performance categories (HSCW, AusMB and HP8). It has been shown by Ha and Krishnan (2008) that a system of supplier selection (similar to the results shown in figures 46-48) could be used to partition suppliers into market end points. These partitions can then provide common quantitative measures on manufacturing capability and production quality (Wu and Pearn 2008). Furthermore it is argued by Saen (2007) and Araz and Ozkarahan (2007) that supplier selection significantly reduces costs and improves competitiveness (Florez-Lopez 2007) since suppliers may not produce common outputs. It is argued by Lee (2008) that a good buyer - supplier relationship can guarantee quality, technology diffusion and entry into new markets. Interaction with suppliers through a supply chain alliance has the potential to help the case study feedlot's suppliers to increase their capacity to meet carcass specification thereby improve the feedlots competitiveness and reduce costs due to carcass traits that are out of specification.

Commercial producers choose genetics, experience environmental fluctuations and illness and make herd management decisions that impact on feedlot growth, AusMB and HP8. A positive correlation for a PIC between market groups for a trait indicated a similar ranking by his cattle in both market groups. Where PIC correlations are high there was greater predictability as to this performance across market groups. PIC effects were positively correlated for growth across market groups, although the correlation weakened when market groups became more dissociated.

The overall analysis allowed all Producers to be compared when adjusted to a common reference i.e. DOF, INWGT. These comparisons showed that there are some producers who currently deliver high HSCW and high AusMB therefore have greater potential to satisfy the market requirements of the case study feedlot. Furthermore it allows producers to be identified that the case study feedlot can encourage changes in factors such as management and/or genetics, so that animals better suited to feedlot requirements are delivered.

5.6. Conclusion

These analyses suggests that a number of practical management decisions significantly affect carcass production in the case study feedlot and that the factors affecting the variability in growth, marbling and external fat depth can be partly managed by purchase and induction decisions. Furthermore decisions can be made that minimise non-conforming or underperforming animals that visually measured traits of feedlot cattle do not address. These analyses showed a combination TBA/E2 HGP implants increased HSCW overall by ca. 25kg, but reduced marble score by 0.5 of a marble score. Higher INFRAME scores resulted in ca. 7kg increase in HSCW per frame score however higher frame scores marginally reduced AusMB.

The largest incidence of illness was pneumonia and lameness which impacted on growth (ca. 15kg HSCW) with a marginal effect on AusMB (ca. 0.1 AusMB). As HSCW increased beyond 450 kg there was little increase in AusMB. Heavier animals had greater external fat, increasing at a rate of 6mm every 100kg. The data showed breed or dentition classes had little impact on HSCW and AusMB (British breeds consistently contributed only small increases to AusMB).

Producer effects can impact on HSCW, AusMB AND HP8. Before producer effects are used to allocate premiums and discounts more information is required on the partitioning between genetics and management effects. The results from this analysis showed no large or unanticipated deviations from current literature and biological knowledge, however, marble scores and external fat depth were expected to increase more as carcass weight increased. The decrease in marble score and declining trend in HP8 as HSCW increased was possibly explained by reduced relative (HSCW) feed intake.

6. Purchase and management optimisation of feedlot animals.

This chapter explores value based pricing of individual animals and the opportunity to add value through selection and sorting strategies. The economic value beef feedlot animals could be determined at procurement based on the sum of an animals' economic component values. In addition growth and composition models can be used to sort cattle into homogeneous groups thereby increasing uniformity and profitability.

6.1. Abstract

The procurement of livestock for feedlots has been traditionally conducted in open auction systems involving spot prices, dead weight sales and forward contracts (Hobbs 1997). However a criticism of these markets is that there are large fluctuations in prices (Todd and Cowell 1981). Open market purchases have involved price inefficiencies and price variation as a result of issues to do with valuation of liveweight (Hall and Shorthose 1982; Capps *et al.* 1999), sex, breed (Geay 1984) and lot size (Sosnick 1963). It is argued by (Barker 1984) that a system of price differentiation based on consistent and meaningful criteria could improve pricing efficiency. Furthermore an increase in pricing efficiency could result from improved methods of linking quality attributes and price (Johnson 1994).

Quality and production requirements constrain an enterprise's ability to allocate its resources (Tsiakisa and Papageorgiou 2007). Difficulty arises in feedlot production when animals are required to be allocated to days on feed so that they attain optimal carcass composition for the feedlots' customers while maintaining profitability. It has been argued by Feuz (1999) that the risks associated with a system of carcass transactions where cattle are traded based on averages will not send effective price signals that reveal consumer preferences. Minimising

the risk of not achieving task objectives is best overcome by strategic allocation of resources (Cooper *et al.* 2005; Schwindt 2005) which results in the ability to attract and retain customers (Gorchels 2000). The ability to predict carcass growth and composition in cattle allows feedlots to sort animals at induction to optimal days on feed and helps to achieve the best economic outcome (Aiken 2004) while satisfying customer requirements. Sorting cattle to their optimal days on feed is an opportunity to increase the value of animals while in the feedlot (Gresham 2005; Vasconcelos 2007).

A formal analysis of carcass value provides indicators of the component value of animals. These values can be used by feedlots such as the case study feedlot in the procurement of animals through a pricing structure (premiums and discounts) that either rewards or penalises animals based on a true value grid. Furthermore the use of growth and composition models allows animals to be allocated to their optimal days on feed and fulfills the value requirements of the case study feedlots' customers without the need to vary the current intake specifications.

6.2. Introduction

Some biological antagonists are quickly seen to also be economic antagonists. For example increased days on feed potentially increases carcass value due to greater carcass weight but potentially decreases carcass value due to increased external fat depth. It is argued by Boardman and Sauser (2008) and Jackson (2003) that any systems antagonisms must be reviewed as a coexistence of events thereby helping to understand the relationships between its components (Sherwood 2002). This allows more efficient allocation and pricing of resources (Haines *et al.* 2005) and lowers costs (Daellenbach and McNickle 2005). Table 15, page 105 has provided an analysis of carcass traits (HSCW, AusMB and HP8) in order to review *technical efficiency* (the possible level of output achieved for a set of inputs or resources) (Daellenbach and McNickle 2005). The analysis of value extends this to include factors effecting carcass value but not including costs such as purchase cost $/kg liveweight, feed or other fixed or variable costs. The analysis of value gives retrospective insight that helps allow cost of production to be explored with regards to carcass components and the component premium or discount potential at procurement (Leach 2005). Exploring this *economic efficiency* (in terms of maximising the difference between revenue and costs) however will not mean that the system will be *effective*. The *system effectiveness* in terms of objectives (Daellenbach and McNickle 2005; Haines *et al.* 2005) post procurement was explored using a series of simulations incorporating allocation to optimal days on feed and sorting routines (Basarab 1999; Cooper 1999; Trenkle 2001) underpinned by an animal growth and composition model (Oltjen *et al.* 1986a).

It is argued by (Todd and Cowell 1981) that many livestock transaction systems provide no clear understanding of the factors that influence prices paid by buyers. Open market purchases have involved price inefficiencies and price variation as a result of purchases which include liveweight (Hall and Shorthose 1982; Capps *et al.* 1999), sex, breed (Geay 1984) and lot size (Sosnick 1963). Barker (1984) argues that a system of price differentiation based on consistent and meaningful criteria could improve pricing efficiency. Furthermore an increase in pricing efficiency could result from improved methods of linking quality attributes and price (Johnson 1994). Nah (2002) argues that within enterprises their resource planning is the key to optimising performance; however the logistics of choice, timing and cost minimising while attempting to maximise acceptance rates and performance (Cooper *et al.* 2005) are also important issues to businesses. Complexity of resource allocation arises due to interactions and dependencies; implicit such as competing resource use and explicit due to precedent requirements for the completion of an activity (Haines *et al.* 2005; Schwindt 2005). These simulations via a series of pricing structures were able to allocate resources (animals and feed) at an individual animals' optimum net value.

The hypotheses under test in these analyses were

1) An analysis of carcass value (Au$) that included feedlot induction traits and management such as time on feed would indicate the component value of carcasses and thereby facilitate more efficient procurement and management decisions.

2) Sorting routines underpinned by growth and composition models would allow more efficient allocation of individual animals at induction.

Efficient allocation of cattle at feedlot entry has the potential to improve feedlot profitability. Carcass value coupled with days on feed will influence when revenue is at an optimal point along the production curve (Coelli *et al.* 2005). Predicting the value of the compositional traits hot carcass weight, marble score and hot P8 fat depth of an animal and its feed intake over consecutive days on feed allows individual animals to be optimally allocated to different endpoints (Cooper *et al.* 1999; Bruns and Pritchard 2003; Gresham 2005), and therefore best manage resource allocation in the feedlot (Goodpasture 2004; Cooper *et al.* 2005; Schwindt 2005).

6.3. Materials and methods

Phenotype data

Two datasets were used to investigate the determinants of individual animal carcass value (Au$) in the case study feedlot. The first analysis used the dataset described earlier (Table 12 page 101 and Table 14 page 103). The traits used in this analysis were days on feed (DOF), induction frame score (InFrameS), HGP implant (HGP), induction weight (InWgt), illness (Illness), breed (Breed), induction dentition (InDen) and producer (PIC). Some 32,452 animals were included in this initial dataset.

A subset of animals were then used in a series of simulations with the UC Davis growth and composition model (**DGM**) (Oltjen *et al.* 1986a) to determine the optimal days on feed allocated to animals at feedlot induction. The subset of data was determined by availability of input information required for the DGM from the initial dataset; this reduced the initial dataset to ca. 15,000 animals. The error differences (actual carcass traits minus projected carcass traits) were determined to select for the DGM growth and composition accuracy. The final selection of animals was based on those animals that were less than or equal to one standard deviation from the mean error difference in order to asses to economic benefit of a relatively accurate growth and composition model. The final simulation subset included 4979 animals. A full description of traits is given in Table 12 page 101; the simulation subset had similar induction trait means and variances when compared to the initial dataset (Table 29).

Carcass value determination

Value was determined by pricing carcass traits measured at slaughter: hot standard carcass weight (HSCW), AUSMeat marble score (AusMB) and external fat depth (HP8). The pricing grid (Table 26) was an adaptation of the grid described in Table 5 page 70. This grid shows that optimal prices were created for carcass weights between 330 to 370 kg (Au$3.50/kg carcass weight) and that external fat depth incurred discounts beyond 20mm. Furthermore, premiums were given for marble scores 2 and above.

Table 26. Revenue structure used to value the case study feedlot cattle at slaughter for statistical models and simulations. The value grid included hot carcass weight (kg), marble score and external fat depth (mm). (D Llewelyn[A] 2007, pers. Comm., 12 February, T Suzuki[B] 2007, pers. Comm., 12 February).

Trait	Trait specification and Indicator price					
Hot carcass weight (kg)	310	330	350	370	380	390
Indicator price ($)	3.30	3.50	3.50	3.50	3.30	3.20
Hot P8 fat depth (mm)	0	10	20	25	30	40
Indicator price ($)	3.50	3.50	3.50	3.45	3.40	3.40
AUSMEAT marble score	0	1	2	3	4	5
Indicator price ($)	3.50	3.50	3.70	3.75	3.80	3.90

Four simulations were used to determine the optimal days on feed allocated to animals at feedlot induction. The four simulations were based on the cost structures outlined in Table 27 which included four scenarios covering different combinations of liveweight purchase prices per kg and feed costs per tonne. Each simulation was run twice, firstly on the actual days on feed recorded in the case study feedlot data file, and secondly on the optimal days on feed determined by sequentially iterating over days on feed and accumulating value for carcass traits and incurring costs due to feeding each day. The fixed cost of purchase was incorporated into net value for each day throughout the simulations. These simulations used no other fixed or variable costs or logistical approach that attempted to manage or allocate animals to sub groups. Costs (labour, management, transport or other costs) and income (hide, offal and other income) and the need to fill markets would therefore be required to further these simulations in order to increase their application within feedlots.

Table 27. Cost structures applied to the simulations used to determine the optimal days on feed for animals at induction in the case study feedlot simulation dataset.

Scenario	Purchase cost $/kg liveweight	Feed cost $/tonne
1	1.40	200
2	2.00	200
3	1.40	350
4	2.00	350

Analyses

The analysis of value included all of the significant terms and their interactions from the phenotype models used in Table 15 page 105. The statistical model for the analysis of value included the terms days on feed, induction frame score, HGP implant type, induction weight, illness type, breed class, Producer and induction dentition. Least square means were predicted for the induction frame score, HGP implant type, illness, breed class and producer after adjusting for terms in the model. Similarly predicted means and standard errors were predicted for days on feed and induction weight.

The simulations were performed with the DGM (Oltjen *et al.* 1986a); input parameters included induction weight (kg), induction frame score, induction body score, implant status, energy composition of feedlot rations (Mcal/kg). A quadratic equation, Equation 5, was fitted over the days on feed to obtain an unbiased maximum net carcass value.

Equation 5. Unbiased net value function used to determine the unbiased maximum net carcass value ($) over days on feed.

$$y = a + bx + cx^2$$

Y = Unbiased net carcass value

For x = 1 to 400 days on feed

6.4. Results

Analysis of carcass value

Sources of variation for the final analysis of carcass value are shown in Table 28. The final model had an R^2 of 0.64.

Table 28. F ratios, numerator (NDF) and denominator degrees of freedom (DDF), regression coefficients and standard errors for carcass value ($) as affected by days on feed, induction frame score, implant type, induction weight, illness, breed class, producer and induction dentition from the case study feedlot dataset (n= 32,452).

Source	NDF, DDF	F Value		Regression coefficient	Standard error
Days on feed	1, 32452	213	***	49.8786	3.3710
Days on feed^2	1, 32452	175	***	-0.3014	0.0227
Days on feed^3	1, 32452	160	***	0.0006	0.0000
HGP implant	3, 32452	20	***		
Days on feed and implant interaction	3, 32452	12	***		
Induction frame score	7, 32452	42	***		
Induction weight	1, 32452	9	**	-6.0784	2.0060
Induction weight^2	1, 32452	15	***	0.0156	0.0041
Induction weight^3	1, 32452	13	***	-0.0000	0.0000
Illness type	7, 32452	19	***		
Breed class	6, 32452	6	***		
Producer	2313, 32452	4	***		

*, **, *** P<0.05, <0.001, <0.0001 respectively

The effect of days on feed on carcass value

The analysis showed that there was a curvilinear response in carcass value as days on feed increased, Figure 36. Moreover there was a significant interaction with days on feed and implant type (P<0.000 Table 28). An oestrogen only implant such as Synovex was ca. $40 better than no implant at 100 days on feed however there was no significant difference after 120 days on feed. More aggressive implants that included both estrogen and trenbolone acetate (Synovex plus and Revalor) increased total carcass value by ca $110 at 100 days on feed however these were not significantly different from no implant at 160 days on feed. Animals that had no implant continued to gain value as they were kept on feed (Figure 36).

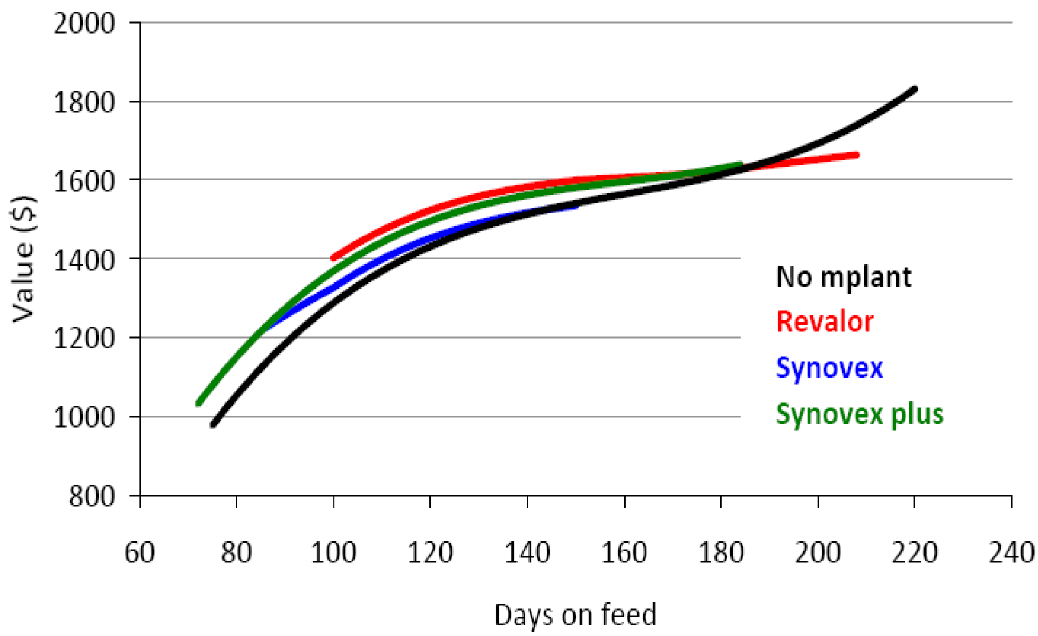

Figure 36. Plot of the interaction between implant and days on feed on carcass value ($) from the case study feedlot carcass value model. The model contained terms for days on feed, induction frame score, implant type, induction weight, illness, breed class, producer and induction dentition (n= 32,452).

The effect of induction frame score on carcass value

The predicted means and standard errors for InFrameS shown in Figure 37 indicate that value increased significantly (P<0.001, Table 28) as InFrameS increased from 1 to 6. There was a ca. $25 increase in value for each increase in InFrameS however due to small numbers within frame scores 0 and 7 the standard errors were large. The level of confidence for estimates of InFrameS 0 and 7 are low.

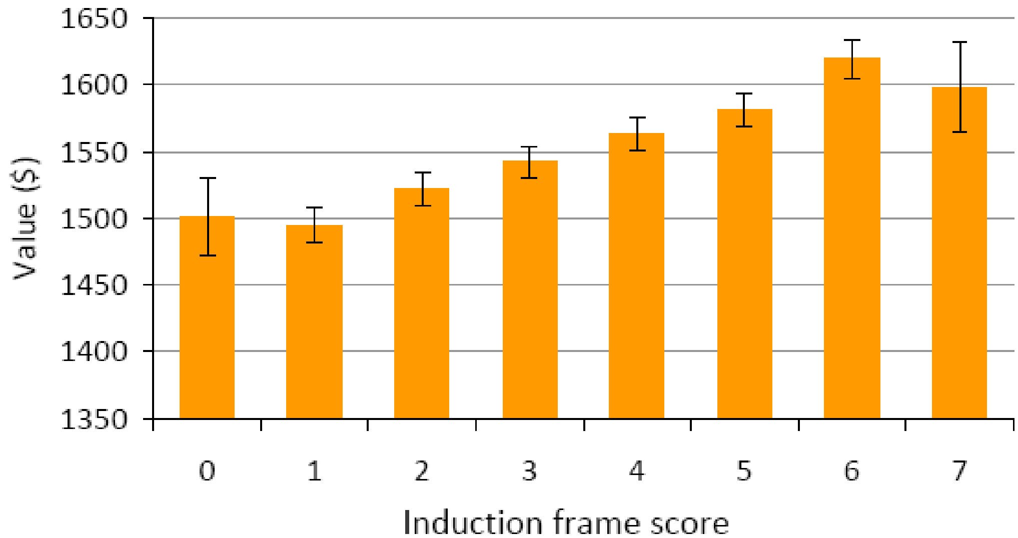

Figure 37. Plot of the predicted means and standard errors for carcass value ($) by induction frame score. The model contained terms for days on feed, induction frame score, implant type, induction weight, illness, breed class, producer and induction dentition (n= 32,452).

The effect of induction weight (kg) on carcass value

There was a significant effect of induction weight (kg) on carcass value (P<0.001, Table 28). There was a nonlinear increase in value as induction weight increased, Figure 38. This analysis showed that there was no increase in carcass value between the minimum weights and up to ca. 320kg induction weight. There was an increase in carcass value for induction weights above 320kg of ca. $40 for every 50kg increase in live weight. However there was a significant (P<0.001, Table 28) decline in value as induction weights reached an optimum of ca. 700kg.

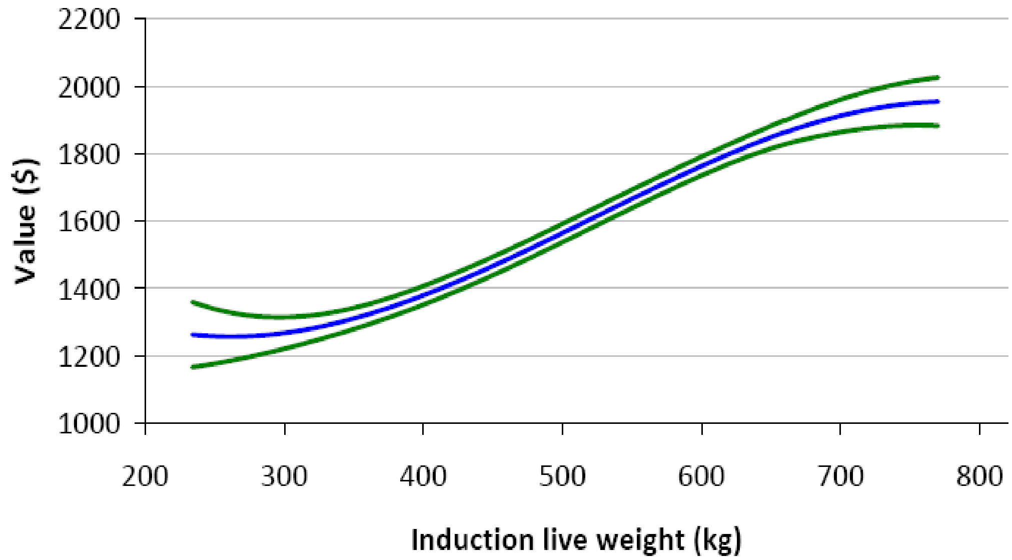

Figure 38. Plot of the predicted means and standard errors for carcass value ($) by induction live weight (kg). The model contained terms for days on feed, induction frame score, implant type, induction weight, illness, breed class, producer and induction dentition (n= 32,452).

The effect of illness on carcass value

Illness had a significant effect on carcass value (P<0.001, Table 28). The cost of an incidence of illness is shown in Figure 39. The largest loss to carcass value from an incident of illness was ca. $65 in the category *other* (Table 12 page 101 outlines the description of these animals and their occurrence rates).

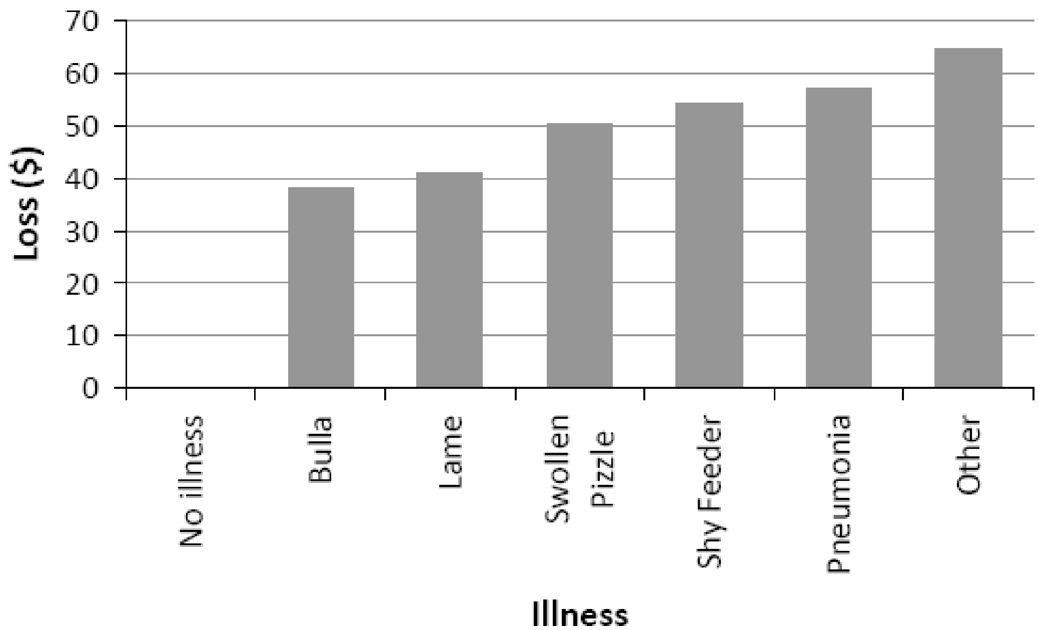

Figure 39. Plot of the predicted mean loss ($) differences from no feedlot illness. The model contained terms for days on feed, induction frame score, implant type, induction weight, illness, breed class, producer and induction dentition (n= 32,452).

The effect of breed on carcass value

The effect of breed on carcass value was significant (P<0.001, Table 28). Figure 40 shows that while the British, British cross, European and European cross cattle were similar they were ca. $50 higher in value than B*os indicus* cross, ca. $70 higher in value than B*os indicus* cattle and ca. $10 higher in value than the B*os taurus*/B*os indicus* crossbreds. Crossbreds and B*os indicus* cross had high standard errors due to low numbers of animals in the dataset.

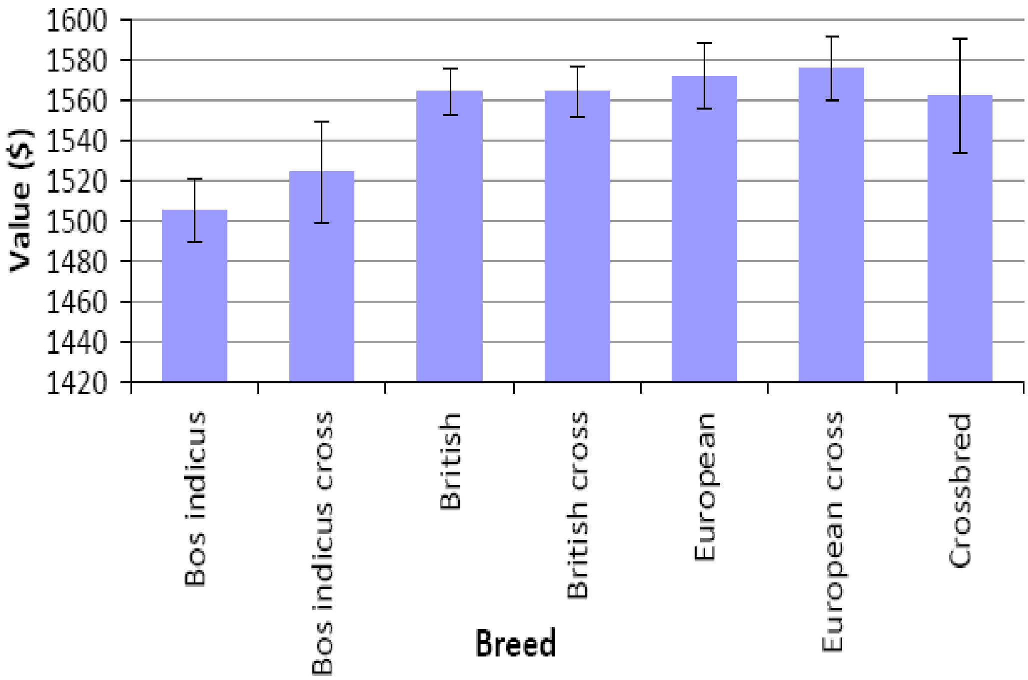

Figure 40. Plot of the predicted means and standard errors for carcass value ($) by breed. The model contained terms for days on feed, induction frame score, implant type, induction weight, illness, breed class, producer and induction dentition (n= 32,452).

The effect of producer on carcass value

There was a large amount of variation between producers for carcass value. When producer predicted means were centered (deviated from the average) it could be seen that some producers were $240 better than the average, others were $200 worse (Figure 41). Most producers were ± $68 of the mean.

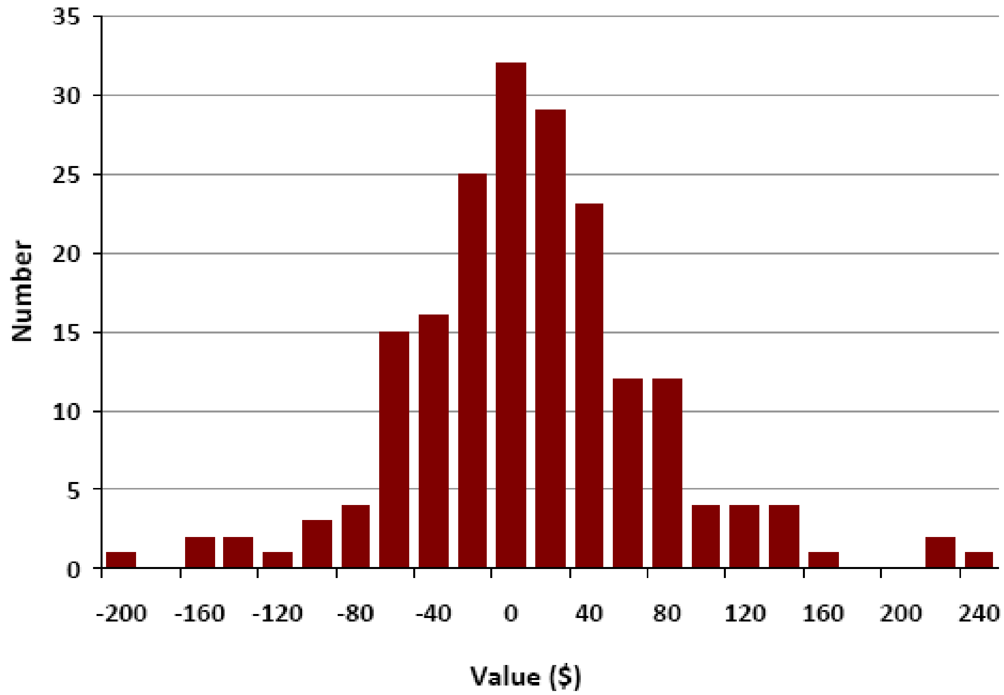

Figure 41. Histogram of the centered differences in predicted producer means for carcass value ($). The model contained terms for days on feed, induction frame score, implant type, induction weight, illness, breed class, producer and induction dentition (n= 32,452).

Simulations

Actual days on feed and actual carcass traits used in the simulations and their comparative projected carcass traits are summarised in Table 29. Actual carcass traits HSCW, HP8 and AusMB had correlations of 0.8 (P<0.000), 0.4 (P<0.000) and 1.0 (P<0.000) respectively. The distributions of actual hot P8 fat depth and projected fat depth, Table 29 indicated that projected hot P8 fat depth was ca. ±5mm greater than abattoir measurements.

Table 29. Days on feed and carcass trait means, standard deviation, minimum and maximum of data from the case study feedlot simulation dataset (n=4969). Comparisons indicate similarities of the abattoir data (actual) and projected data from the UC Davis (Oltjen *et al.* 1986a) growth model.

Trait	Mean	Std Dev	Min	Max
Actual days on feed	146	23	94	224
Actual carcass traits				
Hot standard carcass weight (kg)	379	30	267	513
AUSMeat marble score	2	0	1	2
Hot P8 fat depth (mm)	22.3	5.8	9	40
Projected carcass traits				
Hot standard carcass weight (kg)	375	28	266	496
AUSMeat marble score	2	0	1	2
Hot P8 fat depth (mm)	22.4	2.4	14	32

Days on feed changes from simulations

The simulations from scenarios 1 and 2 (Table 27) indicated the mean actual days on feed were 12 days more than the mean optimal days on feed which were 134 ±44 days, min 19 and max 295 days on feed. Simulations from scenarios 3 and 4 (Table 27) indicated the mean actual days on feed (Table 29) were 107 days more than the mean optimal days on feed which were 39±26 days, min 14 and max 146. The density distribution, Figure 42, indicated that the within the simulation dataset actual days on feed mostly occurred at ca. 150 days and to a lesser extent at 110 and 210 days on feed. Simulations from scenarios 1 and 2 indicted ca. 20 percent of the 4969 animals would be at optimal days on feed at ca. 120 days. When feed prices were considerably higher, scenarios 3 and 4 (Table 27) the optimal days on feed for a large proportion of these data was ca. 20 days on feed, Figure 42.

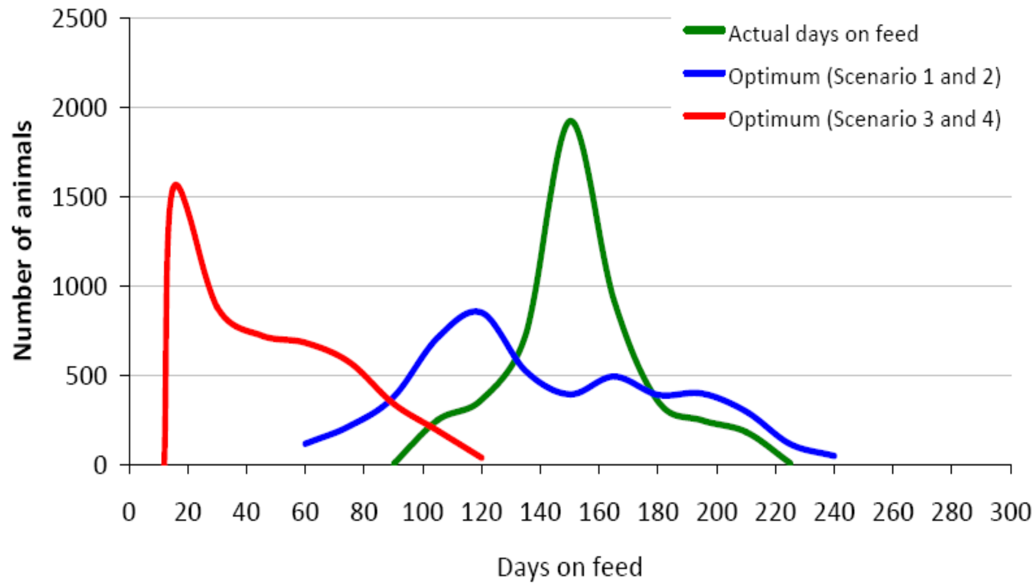

Figure 42. Density distribution of days on feed indicated by the case study feedlot simulation dataset, the predicted optimums from scenarios 1 and 2 (purchase cost \$1.40 and \$2.00/kg/liveweight respectively and feed cost \$200 tonne) and scenarios 3 and 4 (purchase cost \$1.40 and \$2.00/kg/liveweight and feed cost \$350 tonne), n=4969.

Carcass trait characteristics from simulations

Carcass trait characteristics at the optimal days on feed are outlined in Table 30. Scenarios 1 and 2 resulted in slightly lighter carcasses when compared to the actual days on feed (Table 29) by 9kg of carcass weight and but had similar HP8. Under scenarios 3 and 4 carcass traits showed that HSCW was 70kg lighter, there was a decrease of 1 marble score and HP8 was ca. half the depth at the actual days on feed.

Table 30. Carcass trait means, standard deviation, minimum and maximum from the simulations for optimal days on feed under scenarios 1 and 2 (purchase cost $1.40 and $2.00/kg/liveweight and feed cost $200 tonne) and scenarios 3 and 4 (purchase cost $1.40 and $2.00/kg/liveweight and feed cost $350 tonne), n= 4969.

Trait	Mean	Std Dev	Min	Max
Scenarios 1 and 2				
Hot carcass weight (kg)	368	29	310	532
AUSMeat marble score	2	0	1	3
Hot P8 depth (mm)	22	4	2	41
Scenarios 3 and 4				
Hot carcass weight (kg)	309	25	192	440
AUSMeat marble score	1	0	0	2
Hot P8 depth (mm)	13	6	2	21

Simulation effects on carcass value

The economic benefit obtained under scenarios 1 and 2 show that allocating animals to their optimum days on feed increased net value by ca. $50 per animal, Table 31 and Table 32. These changes were a result of a reduction in feed costs and increases in the value of carcass components.

Table 31. Means, standard deviation, minimum and maximum of the net value, cost components and carcass component values simulated to the actual days on feed and the simulated allocation in scenario 1 (purchase cost $1.40/kg liveweight and feed cost $200 tonne) n=4969.

	Actual				Optimal			
Trait	Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
Net value	342	42	194	493	390	33	276	541
Feed Cost	277	44	171	452	253	85	39	652
Purchase cost	677	58	444	917	677	58	444	917
Total cost	954	78	666	1281	930	74	754	1370
Carcass value	1269	75	0	1638	1278	78	1086	1755
Marbling value	44	39	0	99	49	37	0	133
P8 fat value	-16	7	-47	0	-8	10	-53	0

Table 32. Means, standard deviation, minimum and maximum of the net value, cost components and carcass component values simulated to the actual days on feed and the simulated allocation in scenario 2 (purchase cost $2.00/kg liveweight and feed cost $200 tonne) n=4969.

	Actual				Optimal			
Trait	**Mean**	**Std Dev**	**Min**	**Max**	**Mean**	**Std Dev**	**Min**	**Max**
Net value	52	55	-102	188	100	38	20	263
Feed Cost	277	44	171	452	253	85	39	652
Purchase cost	967	83	634	1310	967	83	634	1310
Total cost	1244	99	856	1637	1220	83	1000	1733
Carcass value	1269	75	0	1638	1278	78	1086	1755
Marbling value	44	39	0	99	49	37	0	133
P8 fat value	-16	7	-47	0	-8	10	-53	0

The economic benefit obtained under scenarios 3 and 4 (high feed costs) show that allocating animals to their optimum days on feed increased net value an average of $144 per animal, Table 33 and Table 34. These changes resulted from a decrease in feeding costs. The reduction in the average days on feed at the optimum allocations reduced feed costs and had a concomitant decrease in the value of the carcass components HSCW and AusMB; however since animals were on feed for shorter periods there was no discount for HP8 out of specification Table 33 and Table 34.

Table 33. Means, standard deviation, minimum and maximum of the net value, cost components and carcass component values simulated to the actual days on feed and the simulated allocation in scenario 3 (purchase cost $1.40/kg liveweight and feed cost $350 tonne) n=4969.

	Actual				Optimal			
Trait	**Mean**	**Std Dev**	**Min**	**Max**	**Mean**	**Std Dev**	**Min**	**Max**
Net value	135	56	-31	298	279	46	156	433
Feed Cost	485	78	299	791	126	83	34	432
Purchase cost	677	58	444	917	677	58	444	917
Total cost	1162	103	833	1621	803	87	478	1163
Carcass value	1269	75	0	1638	1071	105	635	1452
Marbling value	44	39	0	99	10	24	0	88
P8 fat value	-16	7	-47	0	0	0	0	0

Table 34. Means, standard deviation, minimum and maximum of the net value, cost components and carcass component values simulated to the actual days on feed and the simulated allocation in scenario 4 (purchase cost $2.00/kg liveweight and feed cost $350 tonne) n=4969.

	Actual				Optimal			
Trait	**Mean**	**Std Dev**	**Min**	**Max**	**Mean**	**Std Dev**	**Min**	**Max**
Net value	-155	60	-386	30	-11	27	-76	66
Feed Cost	485	78	299	791	126	83	34	432
Purchase cost	967	83	634	1310	967	83	634	1310
Total cost	1452	121	1023	1976	1093	99	668	1533
Carcass value	1269	75	0	1638	1071	105	635	1452
Marbling value	44	39	0	99	10	24	0	88
P8 fat value	-16	7	-47	0	0	0	0	0

6.5. Discussion

Analysis of carcass value

Using hormonal growth promotant (HGP) implants at feedlot induction increases the value of animals on short and medium fed programs but had an adverse effect on long feeding programs. As implanted animals remained on feed the rate at which they accumulated value declined. Estrogen (E2) only implants had lost their economic advantage after ca. 120 days on feed, however a combination implant trenbolone acetate and estrogen implants (TBA/E2) were viable up to ca. 160 DOF. Phenotype analyses, Table 15 page 105, has shown that carcass weights from E2 implanted animals was not significantly different from no implant after ca. 120 days on feed, however carcass weight from the TBA/E2 combination consistently remained ca. 25kg heavier. Across all implant types marble score was reduced significantly. Moreover there was an increase in the rate of change in marble score accretion after 180 DOF (Table 21 page 120) allowing non implanted animals to increase in carcass value. A result of the antagonism between rates of change in carcass weight and marble score from HGP implants means that animals on short fed programs (0-100 DOF) would benefit from E2 and TBA/E2 implants, mid fed animals (100-160 DOF) TBA/E2 implants and long fed animals no implant in order to maximise value. Short and medium fed programs would benefit by ca. $100 from HGP implants, in contrast no implant in the long fed animals can benefit by ca. $200 as a result of increased marble score between days 190 to 220 days on feed. Given these results feedlots would benefit from the use of HGP implants when feeding for short or medium fed markets however when feeding for long fed markets no implant should be used.

Frame score has a large impact on the value of a carcass. An increase in frame score from 1 to 6 resulted in an increase in ca. $120 carcass value or $20 a frame score; frame scores 0 and 7 had low numbers therefore the confidence in their predicted means is limited. The phenotype analyses (Table 15 page 105) has shown these value differences were a result of HSCW (increased ca. 5kg per frame score 1 to 6) and a decrease in HP8 (5mm from InFrameS 1 to 6). Trenkle (2001) has reported larger framed steers were worth ca. US$60 head more than small framed steers (US$834 and US$894 for small and large frame respectively). Larger frame steers have greater value due to less back fat (Bruns and Pritchard 2003) and heavier carcass weights (Williams and Bailey 1984; Trenkle 2001; Brethour 2000b). Grid premiums and discounts for frame scores 0 to 6 would be an opportunity that the case study feedlot could incorporate when procuring feedlot cattle. These results suggest feedlots could partition the management of animals into markets that are short, medium and long fed and use HGP implants to increase carcass value.

Induction weights between 300-650kg liveweight resulted in ca. $2/kg value per kg of InWgt. Value remained relatively constant up to 300kg InWgt as well as above 650 InWgt. Phenotype analyses (Table 15 page 105 and Figure 29 page 117) showed that light animals (up to 300kg InWgt) and heavy animals (above 650kg InWgt) were not growing; InWgt between 225 and 300kg all achieved ca. 295kg HSCW; also for all InWgt above 650kg HSCW was ca. 450kg. Therefore within these two InWgt ranges value remained constant across InWgt ranges at ca. $1250 and $1950 respectively. This analysis has indicated that animals entering the feedlot between InWgt 300 and 650kg liveweight could feasibly attract a price of up to 2$/kg liveweight (break even price). However, animals outside these InWgt ranges should be paid a constant rate, set at the lowest InWgt within each weight range due to the lack of growth potential.

Total losses due to illness were ca. $69,800, however the number of animals which incurred lameness (n=280) and pneumonia (n=750) meant that losses within these two categories totaled $12,000 and $44,000 respectively. Lame cattle were 10kg HSCW lighter (Table 15 page 105 and Table 20 page 116) than cattle with no illness and had a slight reduction in AusMB which resulted in a $40 loss in value compared to no illness. Cattle with pneumonia were ca. 13kg HSCW lighter and had a slight reduction in AusMB (Table 15 page 105 and Table 20 page 116) which resulted in a $55 loss in value compared to no illness. There are opportunities from this work to look at a cost benefit analysis (incorporating the feedlots cost structure) could be used to define the level of induction treatment such as vaccinations and "*hospital pen*" treatment of sick animals. Further statistical models should be used to indicate the significant factors that contribute to illness.

The effect of breed class on carcass value in this analysis indicated British, British cross, European, European cross and B*os indicus*/B*os Taurus* cross cattle were of similar carcass value. The analysis shows discounts are valid for both B*os indicus* and B*os indicus* cross cattle however there is a low degree of confidence in these results as these breed classes had high standard errors within the phenotype analyses (Table 15 page 105 and

Table 18 page 113) due to their low numbers. It has been shown in

Table 18 page 113 that B*os indicus* in the longer fed markets were significantly fatter when compared at the same HSCW than the remaining breed classes. It has been stated by Kerth *et* *al.* (1995) that breed is an important factor contributing to marble score however it has been recognised by Dolezal *et al.* (1993) that precision in breed detection has essentially become impossible for a large proportion of the cattle population. The analysis of carcass value indicated no purchase price discrimination should exist between British, British cross, European, European cross and crossbred cattle, however B*os indicus* cattle and their crosses require further validation to ensure the apparent discount suggested from this analysis is valid.

There was a large effect of individual producer on carcass value variation. The predicted producer means showed that while most producers were within ±$80 of the mean; there were some producers who were consistently $240 above the average and some consistently $200 below the group average. The producer effects (Table 15 page 105) indicate there was a large amount of variability between producers for HSCW, AusMB and HP8. An example of a producers predicted means, using least square means from HSCW, AusMB and HP8 (Table 15 page 105, Figure 32 page 122, Figure 33 page 122 and Figure 34 page 123) of individual producers resulted in Producer A) 400kg, 2 and 16mm; Producer B 360kg, 1 and 20mm; and Producer C) 340kg, 0 and 28mm. These large producer effects indicate that there is an opportunity to offer premiums to suppliers who are prepared to pursue genetic gains and optimise their management strategies.

Simulations

Net economic outcome from these simulations could be grouped by feed cost scenarios. Simulations that used feed costs of $200/tonne (scenarios 1 and 2) had similar economic outcomes as did those that used feed costs of $350/tonne (scenarios 3 and 4). There was ca. $48/animal economic advantage of optimal allocation when compared to the actual days on feed, at feed costs of $200/tonne or ca. $230,000 over the 4969 animals. Furthermore the economic benefit of optimal allocation over the actual days on feed when feed costs were

$350 tonne was ca. $144/animal or $712,000 over the 4969 animals. These results indicate that the annual benefits to the case study feedlot with an annual intake of ca. 14,000 animals could be between ca. $670,000 to $2,016,000 annually. Again these results have not included income or costs that may relate to individual feedlot businesses.

It is argued by Nah (2002) that within enterprises their resource planning system is the key to optimising performance; however the logistics of choice, timing and cost minimising while attempting to maximise acceptance rates and performance (Cooper *et al.* 2005) are important issues to businesses. Complexity of resource allocation arises due to interactions and dependencies; implicit such as competing resource use and explicit due to precedent requirements for the completion of an activity (Haines *et al.* 2005; Schwindt 2005). These simulations via a series of pricing structures were able to allocate resources (animals and feed) at an individual animals' optimum net value whether that was a maximising the return or minimising the loss.

More efficient management of animals at feedlot induction such as allocating individual animals to their optimal DOF within the current dataset resulted in greater profits in all scenarios. It has been commented by Ibarburu and Lawrence (2005) that feedlots are increasingly managing cattle as individual animals rather than on a pen basis to overcome allocation inefficiencies. Differences in feedlot output frontiers and inefficiencies in feedlot cattle have been shown by Fleming *et al.* (2004) to originate from genetic merit, farming and climatic background and nutritional background (Sainz *et al.* 1995). This variability at induction results in costly non uniform carcass traits and carcass quality resulting in discounts at slaughter (Sainz *et al.* 1995). The benefits of technical efficiencies and effective resource use (Daellenbach and McNickle 2005) were explored using the DGM to simulate optimal DOF and sorting strategies at feedlot induction. Managing animals as individuals allows optimal marketing and management such as allocation to DOF for each animal allowing greater technical efficiency and effective resource use. Using simulations over DOF with the DGM (Figure 43) it is possible to evaluate decisions daily in order to maximise an objective function (Amer *et al.* 1994), in these simulations this objective was revenue. Figure 43 shows that as animals remain on feed their value changes with increased HSCW and AusMB (increasing net value) and HP8 and the cost of feed consumed (decreasing net value) (Nelson and Purcell 1973). When iterated over DOF the revenue function has the potential to identify the optimal DOF for each animal at feedlot induction; given the nominated revenue (Table 26) and costs structures (Table 27). The simulations based on the current dataset indicate that greater technical efficiency and effective resource use are attainable.

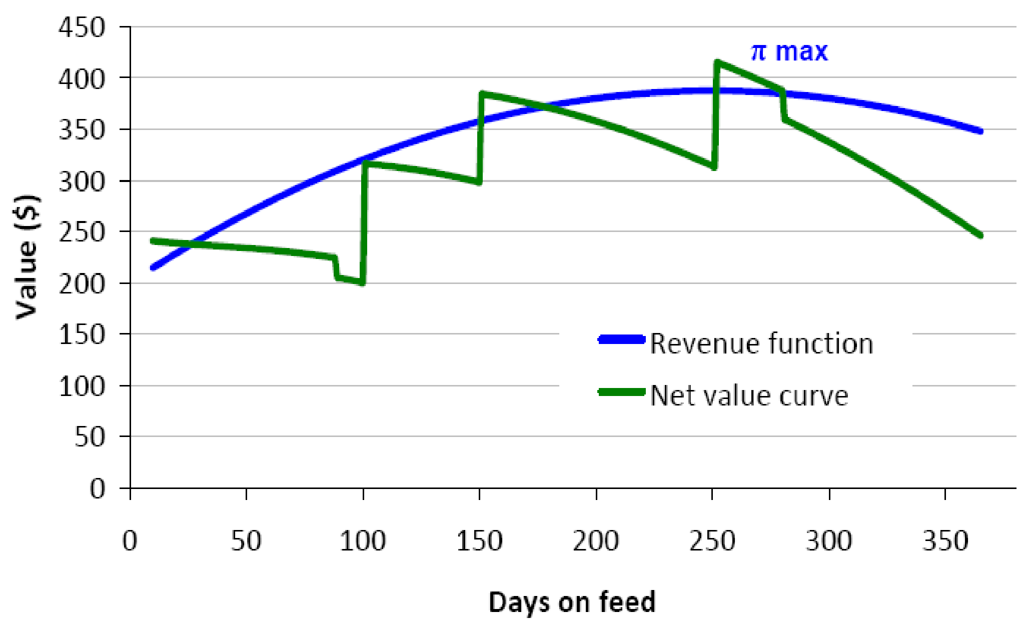

Figure 43. Single animals net value curve ($) incorporating carcass weight (kg) and marble score premiums; discounts for hot P8 fat depth, purchase price $kg liveweight and cost of feed. The curve was derived from the UC Davis growth and composition model (Oltjen *et al.* 1986a). An objective function (revenue) indicates the unbiased maximum revenue at π max.

Envelopment analyses and production functions (Fleming *et al.* 2004) of feed cost and feed intake have indicated that the number of days in the feedlot and daily feed intake were highly significant. In addition Griffith *et al.* (2004) have shown that the price of feed is a large component input that affects feedlot utilisation. Changes in feed prices and other factors held constant were shown by (McLemore and Butts 1979) to influence the optimal days in both replacement and non replacement strategies.

Feeding animals longer than required is a waste of feed resources however it is also true that cattle with too light carcass weights are not fed long enough (Garmyn *et al.* 2003). It is argued by Brethour (2000) that cattle processing has historically been a batch process in which all cattle in a pen are usually slaughtered on the same day under constant days on feed. These simulations indicate that the optimal DOF for feedlot cattle is driven by variable costs, in particular ration costs. The distribution of optimal days on feed (Figure 42) was the same for scenarios 1 and 2; and the same for scenarios 3 and 4 regardless of animal purchase prices ($1.40 or $2.00kg liveweight). The actual DOF allocation showed that ca. 75% of animals were fed between 110 and 180 days. Scenarios 1 and 2 indicated that 20% of animals were fed between 100 and 140 days and that 40% were fed between 140 and 220 days. Scenarios 3 and 4 showed that 80% of animals would be on feed for a period of no more than 60 days and the balance up to ca. 100 DOF.

6.6. Conclusion

The results from the analysis of carcass value shows there is opportunity for pricing the component value of carcasses under a management and procurement strategy (Heerkens 2002). The interaction of implant treatment at induction and days on feed indicated that E2 only implants were worth about $100/head more than unimplanted animals at 90 days on feed and the combination of TBA/E2 in Synovex Plus and Revalor were $100/head up to about 140 days on feed; however when animals were required for long fed, highly marbled export market the use of implants is detrimental and unimplanted cattle begin to be worth more after

180 days on feed. This analysis has indicated premiums of up to about $25 could be paid per frame score for frame scores 1 to 6 at induction. Induction weights between about 300kg and 650kg liveweight were worth $0.8 per kg however when buying cattle up to 300kg the amount paid should be no more than the minimum liveweight of 260kg due to poor growth potential in the feedlot. Illness categories lameness and pneumonia was a loss to carcass value of $40 and $65 per animal per incidence respectively; however these were also the largest in number there for their combined effect was a $69,800 loss to the feedlot. There was a small difference between European, British breeds and their crosses in carcass value indicating there should be no difference in the rates of payment or premium between these breed categories. Most producers were worth between ± $80 to the case study feedlot; presumably the management and genetics of the worst producers' cattle contributed to a producer difference of $440 between the best and worst producer within this analysis.

The UC Davis growth and composition model (Oltjen *et al.* 1986) is a useful tool to predict the optimal days on feed for individual animals at induction, particularly when feed costs are high. Predicting growth and composition allows individual animals to be allocated to their optimal days on feed or their optimal market. An industry grid that included premiums for desirable traits was used to simulate individual animals to their optimal days on feed within four scenarios. These involved a low and high price per kg liveweight at induction ($1.40 and $2.00) and a low and high price per tonne of feed ($200 and $350). These simulations have shown that there are allocation optimums that substantially increase profits in all scenarios. When feed costs were $200/tonne it was possible to increase the net value of animals in the feedlot of $44 compared to the actual days on feed they were allocated. When feed costs were increased to $350/tonne it was possible to increase the value of animals' net value by about $150 per animal. These results translated to between $670,000 and $2,016,000 extra value created by allocating animals to their optimal days on feed.

The analysis of carcass value shows that it is possible for the case study feedlot to customize a procurement grid that facilitates the component value of individual animals. These grids would allow the purchase price of animals to more closely represent the true value that the case study feedlot receives from its animals at slaughter. Post procurement opportunity for individual animal management has been shown to significantly increase the net revenue obtained from allocating animals to their optimal days on feed. Moreover the simulations were able to obtain profitable alternatives without changes to the case study feedlots' supply specifications or phenotypes such as weight, breed and other induction traits.

7. Overall conclusions

The majority of transactions in the Australian beef feedlot industry are based on pen averages (Johnson and Ward 2005). These transactions are considered to be highly variable (Todd and Cowell 1981) and are characterised by both poor information and poor feedback regarding customer requirements and customer satisfaction (Salin 2000). Average pricing leads to failures in the price discovery mechanism since information is not provided to producers of the component value of individual animals', or the information becomes distorted (Fausti *et al.* 1998). Value-based pricing has been identified by numerous industry participants as a key strategy for improving consumer satisfaction (Tronstad and Unterschultz 2005). Within Australian production systems variation in individual carcass value has been shown by Edmondston *et al.* (2006) to range by ca. \$210. Polkinghorne (2006) identified the variation present in carcass yield and quality resulted in \$2.50/kg of carcass weight or a net value difference of up to \$700 for individual carcasses when using both yield measurements and the Meat Standards Australia (MSA) grading model.

Consumers are developing an awareness of health (nutrition and food safety), welfare (stock handling and transport), and environmental issues (Cox *et al.* 2006; Desmarchelier *et al.* 2007; Dunne 1999). The cost of not meeting consumer requirements such as quality non-compliance is costly (Allerton 1999). Food service industry trials conducted by Cox *et al.* (2006) showed 42% of product did not meet specification despite the provision of product specifications; however, quality partnerships were able to reduce customer complaints by 96% and improve customer satisfaction by 34%. Supply chain alliances improve competitiveness (Hayes *et al.* 1998) through increased quality and customer awareness (Dunne and O'Keefe 2003), greater risk management, increased information flow and profitability (Wincel 2004). Supply chain alliances are likely to focus on marketing with a focus on the customer (Hayes *et al.* 1998) therefore more often meet specifications and reduce downgrades (Chorafas *et al.* 2001) and variability of production (Sethi *et al.* 2005). This can result in minimising production uncertainty and increase the benefits that are derived from the exchange and use of information within the alliance (Batten and Savage 2006).

The overall objective of this thesis was to review the potential for supply chain alliances within the Australian beef feedlot industry. The investigation was conducted using four questions:

1) Well-defined carcass specifications have existed for Australian cattle targeted at particular market endpoints. An analysis of a subset of Australian beef feedlot industry data could assess the cost of carcasses that are out-of-specification and secondly determine the causes for carcasses out-of-specification.

2) The Australian beef industry currently has access to both information and techniques through MSA to manage the factors that impact on eating quality. Does access to a total quality management system result in changes within the Australian beef industry?

3) Under means-end theory product attributes are weighted to obtain an overall value. The variation in growth and composition of animals during their time on feed impacts on carcass attributes, therefore, are the variations in carcass attributes able to be explained by induction traits, time on feed and origin (Producer) which would facilitate better management of animals?

4) Carcasses are a composite of economically weighted attributes. The economic weight of these attributes changes according to market allocation and attribute expression (i.e. marble score) over time on feed. At procurement is it possible to increase the efficiency of pricing; and at induction optimise the allocation of animals to times on feed using more efficient management strategies such as sorting techniques?

7.1. The cost of out-of-specification

Hypothesis 1)

Carcass specifications and grid prices can be used to determine out-of-specification costs for beef carcasses in the Australian beef industry.

Hypothesis 2)

An analysis of the dependent variable out-of-specification cost (for individual animals) against induction traits and time on feed can be used to determine whether the factors that contribute to out-of-specification costs arise due to pre-feedlot, during time on feed or both.

The economic value associated with carcasses out-of-specification were illustrated by the Taguchi Quadratic Loss Function (Patil *et al.* 2002), which fixes an economic value out-of-specification. This analysis showed that at the nominated HSCW specification (300kg - 400kg) in the short fed export market there were 28 per cent outside of specification and the long fed export market (380kg - 450kg) 29 per cent were outside specification. A HP8 specification of 10mm-26mm showed 16 per cent outside of specification. At the nominated AusMB specification (3+) 70 per cent are outside of specification.

This analysis demonstrated that there is a large amount of variation in cattle across beef production systems which have lead to a reduction in opportunities for precision management and value based marketing. Furthermore this analysis showed that contributions to out-of-specification costs were predominantly due to pre-feedlot factors. Factors driving out-of-specification costs for HSCW and HP8 were induction weight (kg/live) and producer effects in both the short and long fed export markets, AusMB was significantly affected by induction weight (kg/live) and producer effects, days on feed and HGP implant status.

Extrapolating these estimates across the whole Australian feedlot industry is not easy. Official ALFA/MLA feedlot survey data suggests that around 2.5 million cattle are turned off Australian feedlots each year, and of these approximately one-third are destined for the domestic market and two-thirds for the export market. If all of those cattle fed for the domestic market had compliance rates similar to the short-fed cattle represented in the two industry data sets analysed, the total cost of non-compliance could be around $19 million. Similarly, if all of those cattle fed for the export market had compliance rates similar to the long-fed cattle in the industry data sets, the total cost of non-compliance could be around $193 million. These are significant industry costs.

Recommendations from this analysis are to further analyse induction traits, producer effects and time on feed to asses their physiological contribution to the carcass traits HSCW, AusMB and HP8. The component value of these induction traits can then be used to more efficiently allocate cattle to management groups which would more likely to meet market specifications and therefore, decrease the cost of non-compliance.

7.2. Factors effecting temperature at pH 6 in beef carcasses.

Hypothesis 3)

Total quality management systems such as Meat Standards Australia allow information sharing within the Australian beef industry which over time increases the industries ability to offer greater customer relationship management by better management of resources.

The analysis in chapter 4 has indicated that about half of the variation in temperature at rigor in the Meat Standards Australia abattoir audit dataset could be explained by time over the three years data collection period, slaughter plant within state, carcass weight, rib fat and an interaction of percentage B*os indicus* and season. This analysis showed that from the years 2003 to 2005 inclusive $Temp_{pH6}$ decreased by $1^{o}C$ per year during the three years.

Under optimal slaughter conditions the $Temp_{pH6}$ of carcass muscles will pass through the MSA pH/Temperature between $19.5^{o}C$ and $37.5^{o}C$ (Thompson 2002) to ensure optimal eating quality. During the years 2003 to 2005 there has been a decrease in the percentage of carcasses that were above $37.5^{o}C$ at a pH of 6 from 9.5%, 5.5% to 1% (years 2003, 2004 and 2005 respectively). It is concluded that information sharing in the Australian beef industry has aided value-based marketing systems through facilitating clear specifications for market targets (Tzokas and Saren 1999) and helped the process of information transfer along the production chain (Edmondston *et al.* 2006; Cross and Savell 1994). The MSA grading system has been adopted and has led to a better understanding by suppliers of their customer requirements thereby promoted a more customer driven organisation.

Furthermore, the initial MSA audit dataset included a large number of uncollated files and errors within files. The collection of data should be done in a system that has checks and prompts built in so that information integrity is maintained. These errors meant that the size of dataset analysed was ca. 5% of the original data collected. Moreover it is apparent that the variety of information collected had reduced over time despite available data fields. Therefore significant effects such as those examined by other researchers i.e. Daly (2005) were not able to be pursued. Recommendations from this analysis are firstly to upgrade the existing data capture system so that errors can be minimised and secondly to analyse data more regularly in order to disseminate information to both slaughter facilities and MSA.

7.3. Sources of variation in beef feedlot carcass growth and composition

Hypothesis 4)

The component value of induction traits and time on feed to the carcass traits hot carcass weight, marble score and external fat depth can be quantified by an analysis of carcass traits using induction traits, producer and time on feed as independent variables.

Hypothesis 5)

The component value of induction traits can be used to increase the efficiency of sourcing and management of animals at feedlot induction to slaughter endpoints resulting in a greater percentage of carcasses meeting market specifications.

The analyses in chapter 5 were performed to identify the significant factors effecting hot carcass weight, marble score and external fat depth in a commercial feedlot. These were used as indicators of quantity and quality; since part of the production system within the data was the long fed market and waste from fat trim or factors that decrease yield. These analyses aimed to identify and quantifying the sources of variation in growth and composition using induction traits and events during an animals' time on feed in order to manage this variation.

These results provide a framework to manage animals. Anecdotal evidence suggests managers of feedlots are not familiar with the component value of animals at feedlot induction. Results from this analysis allow more efficient allocation and management of animals within both current markets as well as providing a framework that allows exploration of future potential markets. Examples of this include the use of hormonal growth promotants where short fed markets could be administered estrogen only implants, medium fed markets estrogen and trenbolone acetate and long fed markets no implant.

Due to the diversity in management and genetics in commercial production systems producer means varied by as much as 100kg hot carcass weight, 2 marble scores and 15mm of external fat. These results indicate that there is opportunity for feedlots to integrate the size of producer effects into their feedlot management system. Furthermore by providing feedback to producers with regards their animals potential for growth, marbling and external fat depth would help to increase the producers' ability to purchase genetics and manage market specifications and to make changes that increase the proportion of animals that meet market specifications.

There is strong evidence to suggest that, within these data, breed has little effect on growth and composition, contrary to traditional thinking. Dolezal *et al.* (1993) have commented that diversity and crossbreeding in cattle populations has lead to a decline in precise breed identification, therefore interpretation of the breed effect in this analysis should be treated with caution. It is therefore recommended that decisions to allocate animals to market groups should have less emphasis on breed. There are producers within the dataset that posses the capacity to deliver animals into all market groups that would result in minimal variation. However there are opportunities to interact with individual producers to negotiate their management and genetic selection to reduce their impact on carcass variation.

Pneumonia and lameness made up about 75% of the incidences of illness. It is recommended that an analysis of the term illness be undertaken to identify the specific factors that cause health problems in the feedlot.

These data had been collected for about 15 years however four of the early years were removed from the dataset due to missing data. The first recommendation is to increase the frequency of analyses and refine collection parameters thereby increasing the level of information on factors that effect growth and composition which would help to improve carcass consistency and remove variation within markets.

7.4. Procurement and management optimisation of feedlot animals

Hypothesis 6)

An analysis of the economic value of carcasses allows a more efficient purchase price schedule by quantifying the economic component value of induction traits and time on feed.

Hypothesis 7)

An increase in individual animal profitability over traditional transaction cost payments systems could be achieved by incorporating accurate growth and composition models in the Australian beef feedlot industry.

The analyses in chapter 6 estimated the effect of induction traits with regards to their impact on carcasses economic value, and, the economic value of using sorting routines at induction to allocate animals to optimal days on feed.

The analysis of carcass value indicates upper limits of the component economic weight of animals for valuing animals at procurement. This allows more efficient pricing of animals for feedlots and also sends clearer market signals to producers. Moreover the economic value of the component weight can be used to make up a grid payments system which prices animals efficiently. Furthermore carcass costs due to illnesses can be used to determine induction treatments (vaccinations) or weighted against treatment costs allowing cost/benefit decisions for levels of health treatments.

This analysis used a single grid to calculate the value of carcass, however many grids would exist each representing their respective markets or sub markets i.e. more than one purchaser of long fed cattle. It is therefore recommended that the analysis of carcass value be run across a range of these market opportunities to expand a procurement grid.

These simulations indicated there were optimal days on feed that animals could be allocated that were significantly profitable for feedlots. These simulations indicate a feedlot with throughput of about 10,000 head per year has the potential to increase its net revenue between $670,000 to $2,016,000 per year.

While these simulations showed significant profits it remains difficult to fit all animals to growth and composition models. Therefore it is recommended firstly that the current model continue to be refined through statistical growth modeling and secondly that terms from the phenotype analysis (chapter 3) be added to help explain variation in carcass traits. It is further recommended that simulations be run using various market and sub market payment grids to replicate market opportunities and incorporate cost structures and logistics that may provide more customised outcomes.

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