THE PROFITABILITY, GROWTH AND MEAT QUALITY OF GRAIN FINISHED ENTIRE MALE AND CASTRATED *Bos indicus* CATTLE FROM A NORTH AUSTRALIAN PRODUCTION SYSTEM

Thesis submitted by Steven Wainewright B.Ag

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I, the author, wish to recognize that this thesis could not have been completed without the grateful assistance of the below mentioned individuals and organisations.

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DECLARATION

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

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DECLARATION OF ETHICS

The research presented and reported in this thesis was conducted within the guidelines for research ethics outlined in the James Cook University Statement and Guidelines on Research Practice (2001). The proposed research methods received clearance from the James Cook University Experimentation Ethics Review Committee.

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ABSTRACT

The profitability, growth, carcass and meat quality from high grade; grain fed *Bos indicus* entire male and castrated cattle that were either positively or negatively homozygous or heterozygous for the calpastatin gene from a vertically integrated north Australian production system were investigated. Preliminary analysis into the profitability of producing entire vs. castrated male cattle for the domestic market using Breedcow herd budgeting software was undertaken based on a hypothetical breeding herd of 1200 cows. Although entire males had higher gross margins compared to castrates during the finishing phase, they were unable to make up the earlier losses of $24.04/AE at weaning. There were no differences in performance between entire males and castrates prior to the onset of puberty in the on-farm experiment. Following the onset of puberty and combined with an energy dense finishing ration, entire males grew 27% faster than castrates. There were no differences in temperament between the castrates and entire males ($P > 0.05$). Entire males produced carcasses that were heavier ($P = 0.005$), had less marbling ($P = 0.001$) and were more mature ($P = 0.007$) compared to carcasses from castrates. Both entire males and castrates that were negatively homozygous or heterozygous produced carcasses that were heavier than carcasses from animals that were positively homozygous for the calpastatin gene ($P < 0.05$). All but one entire male carcass qualified as gain fed yearling beef (GFYG) under the Ausmeat selection criteria and consequently were awarded a similar price per kg compared to castrates. The price combined with the heavier carcass weights resulted in entire males being $50 more profitable per carcass compared to castrates. Entire males produced tougher samples of the *M. Longissimus dorsi* after aging for 14 days ($P = 0.001$) and 28 days ($P = 0.005$) compared to castrates. Selecting animals that were either positively or negatively homozygous or heterozygous for the calpastatin gene didn't affect *M. Longissimus dorsi* meat tenderness. In conclusion entire male cattle can be managed and produced for the domestic trade, profitably, in accordance with Ausmeat selection criteria. In addition, meat tenderness in *Bos indicus* castrated or entire male cattle was unable to be improved by selecting against the calpastatin gene.

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LIST OF ABBREVIATIONS

Abbreviations	Terms
AE	Adult Equivalents
ATP	Adenosine Triphosphate
BRD	Bovine Respiratory Disease
BF	Back Fat
$CaCl_2$	Calcium Chloride
CWT	Carcass Weight
DE	Digestible Energy
DFD	Dark Firm Dry
EMA	Eye Muscle Area
ES	Electrical Stimulation
FDA	Food and Drug Administration
GFYG	Grain Fed Yearling Beef
GnRH	Gonadotropin Releasing Hormone
HGP	Hormone Growth Promotant
HSCW	Hot Standard Carcass Weight
LWT	Live Weight
MLA	Meat and Livestock Australia
MQ4	Meat Quality 4
MSA	Meat Standards Australia
REML	Restricted Estimated Mixed Linear
RF	Rib Fat
SSB	Short Scrotum Bull
TBC	Tropical Breed Content
USMB	United States Marbling
USDA	United States Department of Agriculture
WBSF	Warner Bratzler Shear Force

LIST OF PUBLICATIONS

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CHAPTER 1
INTRODUCTION

Beef cattle production in Australia has been influenced and re-shaped by a number of external factors throughout the past century. These factors include namely: drought, government policy and global consumption (Bindon and Jones, 2001). Although these factors have been, and will continue to be, uncontrollable at the farm level the performance of any beef enterprise is driven by genetics, management and nutrition. Each of these farm level variables influences the most important production parameter that drives profit, liveweight gain. Increasing liveweight gain reduces the time taken for beef cattle to reach target slaughter weights, which in turn can improve profitability through reduced feed costs, less stocking pressure and increased stock turnover. In addition, the major benefit to the broader industry from increasing liveweight gain at the farm level is the improvement in meat quality from processing a younger animal.

Beef consumption in Australia has decreased dramatically over the past 40 years, largely due to inconsistencies in eating quality (Polkinghorne et al., 2008*a*). Beef eating quality can be affected by many predetermined, and pre and post-harvest factors including: animal age, sex, tropical breed content, level of nutrition, hormone status, handling procedures, animal temperament, aging, chilling and hanging techniques. As a result of these variables, an eating prediction model was established under Meat Standards Australia guidelines in an attempt to eliminate the inconsistencies and give the consumer more confidence when purchasing Australian beef (Polkinghorne et al., 2008*a*).

In a changing market the beef industry is under constant pressure to remain productive and to continue to satisfy consumer preferences. Examples of this are the marketing programs of major supermarket and fast food chains focusing on purchasing beef that has not been implanted with Hormone Growth Promoting agents (HGP). It has been suggested that removing HGP's will cost the industry up to $210m per year from reductions in liveweight gain and feed efficiency (Anon, 2009a). In addition, activism could further influence consumer preference for beef by targeting on-farm practices such as castration. Most castration procedures in northern Australia are surgical due to it improving the efficiency of the operation. However, the possible post-operative implications of excessive swelling, infection, haemorrhaging and poor wound healing

could provide special interest groups with evidence to target Australian beef producers (American Veterinary Medical Association, 2009). Consequently, in order for the industry to continue to satisfy consumer preferences and to remain productive, alternative management and marketing techniques must be investigated.

The concept of producing beef from entire males is poorly adopted under Australian conditions. Although there is evidence to support the model through the successful incorporation of entire males into the Australian pork industry (Australian Pork Limited, 2011), very little awareness currently exists in the beef industry. An early survey of Australian beef producers with no previous experience in the production of entire male cattle, contrary to producers with a minimum of two years experience, suggested that negative attitudes were driven by difficulties in handling, changes to management and extra fencing (Hinch and Thwaites, 1979). Although there is no recent data, given the lack of incentive to produce entire male cattle and consequently the lack of adoption, it is believed that these same inherent perceptions exist in the beef industry today.

The production advantages of entire male cattle are thought to be compromised by the inconsistencies in meat quality and difficulties in management. Although there is little growth benefit during the pre-pubertal phase (Wainewright et al., 2009a), sexually mature entire males can grow up to 17% faster and convert feed to liveweight 13% more efficiently compared to castrates (Field, 1971). Contrary to much industry belief, entire male cattle can be managed and can be produced in line with castrates provided consignments remain in the same herd. Limiting social re-mixing and allowing hierarchies to be established as early as possible is thought to improve behaviour and reduce pre-slaughter stress and potential problems with meat quality (Mounier et al., 2006).

A major limitation in the adoption of producing beef from entire males is the inconsistencies in meat quality. There is evidence to suggest that beef from entire males is darker in appearance, has less intramuscular fat and is less tender than beef from castrates (Seideman et al., 1982). In contrast, however, it has been shown that although there are objective differences in meat quality, these differences can go undetectable at the consumer level (Morgan et al., 1993a). These differences in meat quality, namely in meat tenderness, between entire and castrated males is thought to be strongly influenced

in the post-mortem period by calpastatin activity (Morgan et al., 1993a). Further investigation is needed to determine if entire male cattle can be selected against calpastatin in an attempt to improve meat tenderness.

Although there is contradicting evidence surrounding the quality of meat produced by entire males, the perception within the Australian industry is driven by the knowledge that most entire males that are processed are from animals that no longer have value as a sire. The historical pricing grid also discourages the production of beef from entire males, however, if sold over the hooks and graded using Ausmeat selection criteria, carcasses from entire males can qualify to receive an equivocal price per kilogram compared to castrates provided they achieve the acceptable standard.

Given the poor adoption rate of producing beef from entire males, there is currently no information into the profitability of such a production system under Australian conditions. The superior advantages in growth, efficiency and consequently carcass yields of entire male cattle would potentially improve the profitability of a beef productions system. Moreover, the production of beef from entire males would remove the need for HGP use and eliminate any concern that special interest groups may raise concerning the practise of castration. Wainewright et al., (2011) attempted to quantify the differences in profitability of an enterprise specialising in the production of beef from entire males compared to castrates. These authors suggested that under the traditional Australian pricing grid entire males could be sold profitability if they were marketed without the discount relative to castrates. Further investigation is required to determine if the variability in meat quality between entire and castrated males justifies such a price difference under the traditional pricing model, or whether the Ausmeat criteria is accurately measuring and awarding the true value of a carcass from an entire male.

This thesis reviews the importance of meat quality and the advantages and disadvantages of producing beef from entire males. This thesis also includes the design, results and discussion of an experiment investigating the profitability, growth and meat quality of grain finished entire male and castrated *Bos indicus* cattle from a north Australian production system.

CHAPTER 2
LITERATURE REVIEW

2.1 Development Of The Australian Meat Grading Model

2.1.1 History Of The Australian Beef Industry

The beef industry in Australia has been shaped by many external influences throughout the past century. Wars, economic depressions, droughts, transport technologies, cattle breeding, trade barriers, global consumption, livestock disease eradication, human health risks, Government policy, consumerism and beef quality have all contributed to the structure of the industry today (Bindon and Jones, 2001). Australia remains a small beef producer (2.8% of world cattle inventory) however, it exports 65% of total production or 4% of world beef supplied worth approximately $4.4B to the Australian economy (Meat and Livestock Australia, 2008). The domestic market accounts for the remaining 35% of total beef produced, with consumption per capita currently at 35.6kg (Meat and Livestock Australia, 2008).

2.1.2 Consumption Of Beef In Australia

The consumption of beef in Australia has gone through many changes as a result of changing consumer preference. This has been driven by inconsistencies in beef quality, cultural influences, pricing and demand relative to other foods, marketing and developing health considerations (Australian Bureau of Statistics, 2005). The introduction of new breeds into the Australian industry from the 1930's to the 1960's resulted in the dramatic growth of the national herd (Anon, 2009b). This was influenced primarily due to the development of *Bos indicus* cattle in northern Australia and the productivity efficiency of this genotype in tropical and sub-tropical environments added to its accelerated growth. Such is the popularity, approximately 40% of the national herd is now derived from this genotype (Bindon and Jones, 2001). With cattle numbers peaking in the mid 1970's and the global supply of beef at record levels, world beef prices collapsed. Consumption of beef and veal in Australia peaked during this period, capitalising on oversupply and the subsequent low prices, reaching 70kg per person in 1976-77 (Australian Bureau of Statistics, 2005). The years

succeeding the collapse revealed a sharp decline in consumption in Australia on the back of severe drought and changing consumer preferences for alternate protein sources (Garfield, 2006). These trends are illustrated in Figure 2.1 and Figure 2.2

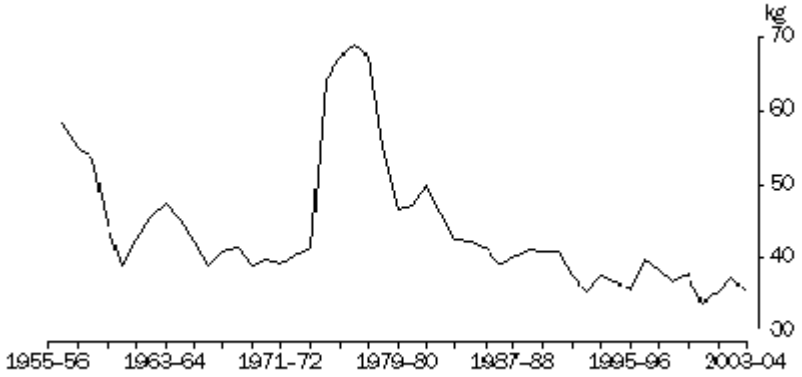

Figure 2.1. The history of beef consumption per capita in Australia
Source: (Anon, 2009b)

Figure 2.2. The history of beef price ($) / head in Australia
Source: (Anon, 2009b)

2.1.3 The Need For An Australian Meat Grading System

The mid 1980's saw the reformation of the Australian Meat and Livestock Corporation, which identified an industry wide 'production-driven' culture. Through initial market research of consumer preferences in Australia, Korea and Japan, the newly reformed corporation set about changing the industry's thinking to become 'consumer-driven' (Bindon and Jones, 2001). During the early 1990's the Australian beef industry faced some major challenges. The sector's export markets were experiencing major expansion for grain-fed beef into Korea and Japan while live cattle shipped to south-east Asia had grown over 400% from 1988-1995 (Bindon, 2001). Contrary to the growth in these markets, consumers were voicing concerns over inconsistent eating quality of ungraded Australian beef. A fall in consumer knowledge, lack of cooking skills and an apparent lack of convenience were all identified as major problems (Polkinghorne et al., 2008*a*).

The declining consumption of beef was recognised and acted upon during this period. The Meat Research Corporation of Australia developed a consumer testing project in 1994 looking at beef eating quality. The project aimed to answer two questions; i) Did consumers agree on beef eating quality? ii) If they did agree, could an accurate grading prediction model be employed by the industry to determine eating quality of retail cuts (Polkinghorne et al., 2008*b*). The project soon became known as the Meat Standards Australia (MSA) research program and eventually was developed into a commercial grading tool.

There was strong support for the development of the grading system as represented in the strategic plan by the Australian Meat Industry in 1996. The plan stated in three key points the importance of reducing the inconsistency of beef eating quality and developing a model to accurately describe palatability (Polkinghorne et al., 2008*b*). Research undertaken by Hernshaw et al., (1995) also supported the concept of developing an effective grading system to predict eating quality. This study concluded that predicting tenderness under a proposed grading model by the NSW Meat Industry Authority using solely carcass attributes such as age, weight, fatness, colour, texture, marbling and pH was undesirable. This model could not accurately group steaks into distinct tenderness sets.

In developing the grading model researchers showed that the striploin (*M. Longissimus dorsi*), which now comprises approximately 68% of all grilled muscles tested (Watson et al., 2008*a*), did not accurately represent the quality of the entire carcass. Variation between cuts of the same carcass were found to be influenced by breed type, if the animal had been weaned, Hormonal Growth Promotants (HGP), ossification, marbling and carcase weight, processing, pH and temperature decline, aging and cooking method (Polkinghorne et al., 2008*a*). In recognising the variation between cuts there was still doubt as to whether a complex system, developed at significant cost, could be justified by the industry. The proposed Australian system was in contrast to the USDA (United States Department Agriculture, 1997), Canadian Beef Grading Agency (Anon (a), 2007) and the Japanese Meat Grading Association (Japan Meat Grading Association, 1988), which all assign a single grade to a carcass.

2.1.4 Development Of The Grading Model

Allocating a grade to 40 separate cuts of a carcass required a sound protocol and extensive testing over a period of time. Untrained taste panels were used to carry out the testing in an endeavour to gain credibility within both the beef industry and consumer sectors (Watson et al., 2008*b*). It has been reported that untrained taste panels can accurately and repeatedly detect differences in meat tenderness (Wheeler et al., 2004) to a similar standard to trained panels (Wheeler et al., 2002). Following the circulation of a major questionnaire to interested sensory organisations to further refine the testing protocol in 1997, a series of consumer experiments were undertaken.

The first experiment asked consumers to analyse 120 striploin samples that had been aged for 14 days. A chart with 13 sensory scoring attributes was then completed by each consumer. The 13 attributes included dryness, ease of first bite, tenderness, liking of taste, liking of texture, liking of cooked appearance, overall liking, typical beef flavour, fatty taste, juiciness, hardness and ease of chew (Watson et al., 2008*b*). The following experiments narrowed the scoring process down to four variables after moderate to strong correlations were identified between parameters from results derived from the first trial. The four predominant variables included tenderness, juiciness, flavour and overall likability. Correlations between the tenderness variables ranged from 0.7-0.8, overall likability was 0.6, juiciness was 0.4-0.6 yet there was only a weak relationship between the flavour variable (0-0.3) (Watson et al., 2008*b*). In

experiments two and three, consumers were also asked the question 'Overall how do you rate this sample?' The choices of 'unsatisfactory', 'good everyday', 'better than everyday' or 'premium quality' now form the basis of the 3-star, 4-star and 5-star rating of the overall MSA grading system (Watson et al., 2008*b*).

Converting the scores of the 4 sensory traits into an accurate numerical grade that would categorise the cut of meat into overall score proved to be a difficult process (Watson et al., 2008*b*). A linear discriminant analysis was carried out in creating the Meat Quality 4 (MQ4) equation:

MQ4 = 0.4 x tenderness + 0.1 x juiciness + 0.2 x flavour + 0.3 x overall likability

The modelled equation allocates a final grade between 0-100 for each cut of meat with 4 sub-categories representing the 3-star, 4-star and 5-star rating. A cut that scores below 46 points is 'ungraded' and can not be marketed with a MSA brand. A cut that has a score between 47-63 grading points will be classed as 3-star or 'good everyday'. 'Better than everyday' is considered a 4-star cut of meat and will score between 64-76 points. Cuts that score 76 or above will be classified as a 5-star product and will be recognised as 'premium quality' (Smith et al., 2008).

Further developments using a similar consumer based evaluation program was undertaken for alternate cooking methods that were later added to the grading system. Initial consumer testing sampled grilled steaks, however the system has since broadened the prediction model by including roasting, stir fry, slow cooking and more recently a number of thin slice cooking techniques (Watson et al., 2008*b*). The prediction model will continue to be developed as new knowledge and processes become available. Meat Standards Australia has used over 70,000 consumers, 520,000 beef samples and 52,000 individual meat cuts to develop the model to date (Meat and Livestock Australia, 2009a). Anecdotally it is argued that the system has been developed for the benefit of retailers with little economic return for producers or independent processors. It is this point that is restricting the industry wide adoption.

2.2 The Use Of Entire Males In Australian Production Systems

The use of entire males in Australian beef cattle production systems is not a widely adopted practice. Beef from entire males has been traditionally accepted as a by-product of a cow / calf breeding operation. This is despite the growing body of international evidence suggesting that beef enterprises can benefit from the highly efficient fast growing characteristics of entire male cattle that achieve target weights earlier (Seideman et al., 1982, Field, 1971, Bailey et al., 1966, Nichols et al., 1963).

Contrary to the production benefits, there is conflicting evidence suggesting their meat from entire males has less marbling, is of coarser texture, is darker in colour and is less tender than meat from castrates (Arthuad et al., 1977). Larger carcasses and difficultly in removing the hide have contributed to the negative perceptions in the processing sector while changes to traditional management have lowered the popularity of producing entire males at the farm level (Hinch and Thwaites, 1979, Seideman et al., 1982). Consumer acceptance of beef from entire males is also a major issue due to the negative association with a darker and less tender product. This perception may be attributed to the knowledge that the majority of beef produced from entire males in Australia is a product from cast for age animals. Subsequently, historical values of carcasses from entire males in the Australian domestic market have been heavily discounted. Although there has been little research undertaken focusing on the production of beef from entire males over the past 30 years, there has previously been a significant amount of literature published that discusses the advantages and disadvantages of using entire males with specific reference to growth, efficiency, behaviour and carcass characteristics (Seideman et al., 1982, Field, 1971).

2.2.1 New Zealand Beef Production From Entire Males

Unlike the Australian beef industry, the New Zealand beef industry has a vertically integrated structure that relies heavily on the supply of dairy calves. Cows and calves of dairy origin make up approximately 65% of the beef industry. Of this 65% approximately 20% are left entire and marketed at 14-18 months or 400-420kg liveweight (Doyle et al., 1989). The majority of this beef is sold into the north American manufacturing market for the hamburger trade (Dooley et al., ND). The ground

appearance of manufacturing beef eliminates any negative perceptions consumers may potentially have with eating beef from entire males.

The New Zealand grass finishing system could not be replicated in many parts of Australia due to environmental limitations. The density of the dairy industry in parts of southern Australia could however, present a significant opportunity to produce beef from entire males. Historically, dairy calves that are left entire under an Australian system are processed at 3 – 4 days of age and are marketed as veal. Under the broad array of Australian production systems, further opportunity may exist in producing beef from entire males from both dairy and beef breeds and under grass or grain fed operations. In addition, similar to the New Zealand model, beef from entire males could potentially be marketed into Australia's existing 280kt north American manufacturing beef market (Australian Bureau of Statistics, 2009).

2.2.2 Average Daily Gain

The importance of growth and daily gain in a breeding, backgrounding or finishing operation is imperative to its success. Historically male calves are castrated at an early age in Australia to comply with market demand and decrease management stress. This practice essentially reduces the potential liveweight gain of the animal and reduces the rate of carcass maturation (Arthuad et al., 1977). In 14 studies referenced in the review completed by Field (1971), it was found that entire males had an average daily gain of 17% higher than castrates. It was also concluded in this review that entire males were 13% more efficient as measured by the conversion of feed consumed to liveweight gained. These trends were in accordance with an earlier review completed by Cahill (1964) that found entire males grew faster and converted more efficiently than a combination of early and late castrates in five separate trials.

Research undertaken by Bidart et al., (1970) looking at energy use comparisons in bulls and steers found bulls to be highly efficient. The study consisted of 218 *Bos taurus* males and showed that entire males use 6 Mcal of digestible energy (DE) per kilogram (Kg) gained compared to 20.3 Mcal of DE per Kg for castrates. Champagne et al., (1969) reported similar findings, with entire males gaining at 1.23kg / day on a feedlot ration compared to 1.04kg / day for castrates castrated at birth. Feed conversion also

favoured entire males, with efficiency ratios 14% higher compared to males castrated at birth and 18% higher for males castrated at 7-9 months.

The period of growth prior to puberty has been reported to be similar in both entire and castrated males (Wainewright et al., 2009a, Hinch and Thwaites, 1984). It is the period following puberty, which is defined as when an entire is first able to produce an ejaculate of 50 million sperm cells of which 10% are motile or begin to display secondary muscling around the neck and shoulders (Blezinger, 2002), that entire males exhibit superior growth traits. Un-weaned *Bos taurus* entire male calves slaughtered at 10 months-of-age gained 38kg more than castrates after the onset of puberty during a three month feeding period (Watson, 1969). These findings were supported by Kellaway (1971) and Bailey et al., (1966) who suggested that growth rates between intact and castrated *Bos taurus* calves didn't differ prior to seven months of age.

Conclusions made by Wainewright et al., (2009a) that suggest pre-pubertal growth rates didn't differ between *Bos indicus* bulls and steers at 7-12 months-of-age are supported by Silva-Mena (1997) who suggested animals of this genotype don't reach puberty until 16-17 months-of-age. Puberty in either genotype is, however, dependent on body weight and growth patterns rather than a specific point in time (Mukasa-Mugerwa. C, 1989). As with previous studies, post-pubertal daily gain was higher for entire males compared to castrates. Experiments examining growth of entire males under grazing conditions have also been reviewed in an attempt to replicate the Australian and New Zealand grass finishing industries.

The use of Friesian entire males as a by-product of the dairy industry is a common practice in many European countries (Mickan et al., 1981). This is also driven by the developing consumer preference for a leaner 'healthier' product. In a study undertaken by Mickan et al., (1981) Friesian entire males gained more liveweight over the two year study period compared to castrates and it was suggested that differences in growth rates were further pronounced with higher nutrition. Maximum production peaked at 0.63kg / day during the spring periods. There is, however, contradicting data that suggests under a grass finishing system entire males gain liveweight at a similar rate to castrates (Mickan et al., 1976). Higher maintenance requirements and extra energy expenditure

whilst grazing may explain some of the differences in these results. Given these experiments were conducted in a temperate climate, the lower fat levels of entire males may have increased energy expenditure in retaining body heat compared to castrates.

2.2.3 The Effect Of Castration Method On Performance

The practice of castrating male cattle has been an accepted farming protocol in Australian production systems for generations. Castration involves the removal, irreversible damage or destruction of the testes or spermatic cord of the animal (Anon (b), 2007). There is a number of castration techniques employed in cattle production, although animal welfare policies often limit the methods available as the animal ages to decrease stress imposed by specific techniques. Physical methods of castration include elastrator bands, surgical and burdizzo while methods administered by injection include chemical or immunocastration. Research has been undertaken to evaluate the affect of different methods of castration on animal welfare and animal performance (Knight et al., 2000, Jago et al., 1996, Chase Jr et al., 1995).

Surgical and banding methods of castration are considered the most popular in Australian production systems. There is ongoing debate as to which method induces the greatest production setback in calves. A study using both *Bos indicus* and *Bos taurus* genotypes concluded that there was no statistical differences in daily gain when comparing surgical and banding castration methods (Chase Jr et al., 1995). Fell et al., (1986) revealed similar findings when castrating 7-11 week old mixed breed male calves. Calves in both surgical and elastrator ring treatment groups had comparable final weights at the completion of the experiment. Stress levels as measured by salivary cortisol, however, were higher in the surgically castrated group immediately following the procedure.

Historically, surgical castration has been the preferred technique in northern Australia given the rapid and inexpensive nature of the operation. Animal welfare concerns have led to the development of the Australian policy to eliminate surgical castration after the animal is 6.0 months-of-age (Anon (b), 2007). This policy is supported by the argument that surgical castration imposes a high acute stress response in the calf (Chase Jr et al.,

1995). A comprehensive review of castration techniques and its affect on performance and stress was completed by Bretschneider (2005). This review states surgical castration post-puberty has a detrimental affect on performance extending beyond 30 days following surgery.

Post-pubertal castration is a method of obtaining the higher growth rates that entire males can achieve following sexual maturity. A finishing phase following castration intends to yield a similar carcass to that of a castrate after previously capitalising on the superior growth of an entire male (Knight et al., 2000). The viability of this practise may be questioned given the severity of the growth check post-pubertal cattle may experience. Conflicting evidence surrounding post pubertal castration and its affect on animal performance is described in recent literature (Lents et al., 2001, Knight et al., 2000, Chase Jr et al., 1995, ZoBell et al., 1993).

Contrary to previous findings, Knight et al., (2000) concluded that there were no differences in the final liveweight of sexually mature 14 month old entire males using surgical or banding castration methods. Upon further investigation it was discovered that bulls which were castrated by elastrator band had slower daily gains for the initial 35 days post operation. These results may be explained by Chase Jr et al., (1995) who observed complete scrotal loss in up to 20% of cattle didn't occur until 30 days post operation. A further study supporting the above findings has been documented by Fisher et al., (2001). Initial daily gains of 14 month old post-pubertal males castrated using elastrator rings were lower compared to castrates that were surgically treated. Alternate methods of castration have been reviewed in literature with reference to the affect of performance and animal welfare.

The burdizzo and chemical methods of castration are considered less common and are recognised as bloodless practises. The burdizzo method crushes the spermatic cord and destroys surrounding nerves and vessels (Anon (b), 2007). Pang et al., (2006) compared banding and burdizzo castration techniques on 5.5 month old Friesian calves. The results of the study revealed no differences in performance or stress response, as measured by plasma cortisol. Chemical castration has been examined in recent literature with limited practical success. This technique involves the injection of a toxic

agent into the testicular parenchyma to cause damage and loss of function (Anon (b), 2007). Fordyce et al., (1989) concluded that the time taken to perform the operation, healing time and success rate of chemical castration would limit the acceptance of the procedure in Australian production systems.

The final castration method involves the injection of immunocontraceptives that inhibit the production of gonadotropin-releasing hormone (GnRH) (Anon (b), 2007). The frequency of administration and failure to eliminate secondary muscular characteristics of the carcass may limit any further development as a commercial castration method. Price et al., (2003) suggested, however, that reduced sexual and fighting behaviour may benefit the management of an entire male production system using immunocastration.

2.2.4 Behaviour And Management Of Entire Males

The aggressive and sexual behaviour that pubertal and post-pubertal entire male cattle can display is a major management issue limiting the acceptance at the farm level and subsequent damage to pastures, feeders, fencing and handling equipment as a result of this behaviour can affect the profitability of an operation (Seideman et al., 1982). Farmer apprehension to a production system using entire male cattle may also be attributed to the incidence of injury to both handler and animal. Poor economic returns associated with dark cutting and bruising has also been reported as a result of poor pre-slaughter behaviour (Price et al., 2003). Implementing alternative management strategies using young entire males has been suggested in the literature with a focus on enhancing management ease and improving profitability.

It is well recognised that cattle are gregarious animals and develop social rankings within groups. Aggressive behaviour in establishing these hierarchies is a common observation that can reduce intake, increase stress and ultimately downgrade carcass quality. Re-grouping cattle based on size and liveweight prior to fattening is a standard practice and can predispose animals to unwarranted stress. Mounier et al., (2006) suggested that reducing stress and aggressive behaviour in entire male cattle was achievable. This study compared mixing entire males at the beginning of the finishing period compared to mixing during the fattening phase reduced aggressive behaviour.

Entire males that had already established a social hierarchy displayed less fear when separated and were less stressed prior to slaughter. In addition, Meridy et al., (2006) suggested social behaviour can be improved by selecting animals on individual temperament based on the highly repeatable flight score procedure. Moreover it has been stated that temperament can have a significant affect on meat tenderness and consequently farm profitability (Reverter et al., 2003).

It has been reported that entire males display higher levels of aggressive behaviour during lairage prior to slaughter (Jago et al., 1996). Social re-mixing in an unfamiliar environment can increase stress levels and aggressive behaviour that can lead to injury, bruising and dark cutting meat. Outcomes of a study carried out by Mohan Raj et al., (1992) supported past findings of mixing prior to slaughter. Re-mixing in an unfamiliar environment increased homosexual behaviour as measured by mounting and teasing. Results from this study also suggested that mounting behaviour prior to slaughter was directly related to ultimate pH, glycolytic metabolites and muscle colour. Observations also revealed aggressive behaviour as measured by the frequency of butts and pushes was initiated as an act of retaliation to homosexual behaviour. A further study concluded that aggressive and sexual behaviour was dependent on individual animal temperament (Mohan Raj et al., 1991). These findings were in accordance with Mohan Raj et al., (1992) who demonstrated aggressive behaviour occurred in retaliation of homosexual acts. The production of entire male cattle is often overlooked by producers, noting management difficulties as a primary concern.

In an early survey of Australian beef producers conducted by Hinch and Thwaites (1979) it was found that management difficulties were a common reason for poor acceptance of producing entire male cattle. In listing the reasons for the difficulties, farmers nominated fence damage, early separation of sexes and difficulties in yard handling. The low adoption rate of producers who specialise in the production of entire male cattle in today's industry suggests that these inherent perceptions still exist. This negative feedback, however, was in contrast to producers who had a minimum of two years experience farming entire male cattle. These farmers did not nominate handling difficulties as a major problem and had fewer herd injuries (4% *vs.* 8%).

Immunocastration has been shown to improve the sexual and social behaviour of entire males. Price et al., (2003) reported that entire males actively immunised against gonadotropin-releasing hormone (GnRH) were less likely to initiate aggressive behaviour, with reduced butts and sparring were notable observations from the immunised animals. A decrease in service attempts of an oestrous cow and lower leg wear scores as a measurement of male-male mounting behaviour have also been shown to be results of subdued behaviour of immunised male cattle (Jago et al., 1997). Further advantages of immunizing against GnRH include the carcass quality benefits. Cook et al., (2000) showed that there was no difference in carcass yields between entire males that were immunised or untreated against GnRH. Tenderness of the *M. Longissimus dorsi* as measured by shear force values was also less or more desirable for entire males immunised against GnRH.

2.2.5 Meat Quality From Entire Males

There is evidence that meat from entire males is of lower quality grade, is less tender and has a darker appearance than meat from castrated animals that haven't received a HGP implant (Seideman et al., 1982). Schoonmaker *et al*., (2002) demonstrated that implanted castrates had similar quality grades, however, were less tender (shear force) compared to entire males after spending 163 – 221 days in a feedlot. There is, however, contradicting evidence that suggests that on sensory evaluation using both trained and untrained panels, the difference in meat quality is often undetectable (Woodward et al., (2000); Morgan et al., (1993a)). A higher proportion of edible lean meat is often associated with carcasses from entire males (Purchas et al., 2002, Glimp, 1971, Tanner et al., 1970, Arthaud et al., 1969, Field et al., 1966). However, it is inaccurate to predict total lean meat yield based on eye muscle area (EMA). Eye muscle area only accounts for approximately 3.5% of the total carcass. In addition much of the secondary muscling following puberty in entire males is displayed in the shoulder and hindquarter cuts (Johnson et al., 1986, Brackerbusch et al., 1991). The extra muscling from the shoulder and hindquarter cuts that post-pubertal entire male cattle develop results in heavier carcass yields and potentially, given the economic penalty imposed on carcasses from entire males, similar carcass retail values to castrates. An extensive amount of research

has been undertaken in evaluating the objective and subjective quality parameters of meat from entire males compared to castrates as outlined in review of Field (1971).

Variability in the quality of meat from entire male's maybe a limiting factor to the adoption of bull beef in Australia. Statistics from the production of beef from entire males in Spain identified 17% of carcasses from Holstein entire males as having an ultimate pH of >5.8 (Mach et al., 2009). Meat with a high pH is associated with reduced glycolysis, a subsequent darker colour and lower level of tenderness. Field (1971) carried out an extensive review and showed in seven references that Warner Bratzler Shear Force (WBSF) and sensory tenderness favoured meat from castrates compared to entire males. Due to the small differences in both sensory and objective (WBSF) testing between entire males and castrates in the review of Field (1971) in which two of the studies were not statistically significant, it is debatable that a carcass from an entire male should incur such a severe economic penalty under the Australian domestic pricing model. Purchas et al., (2002) concluded that the difference in tenderness between entire males and castrates could be explained predominately by background toughness. These variables included; higher amounts of connective tissue, lower levels of intramuscular fat, and higher pH, however, the study also recognised the importance of proteolytic activity in meat tenderness. Watson (1969) documented comparable findings to Field (1971) with entire males recording less fat and lower sensory tenderness ratings in two separate experiments. Results from Watson (1969) show however that there were no differences in juiciness or flavour sensory scores between bulls and steers when slaughtered at 10 months-of-age.

Past research has shown entire males can produce heavier carcases (276kg *vs.* 272kg), produce less carcass fat percentages (19.3% *vs.* 28.9%) and be of lower quality grade (USDA) when slaughtered at a similar liveweight to castrates (Bailey et al., 1966). In an early review completed by Cahill (1964) entire male cattle were reported as having a higher percentage of edible product yet a lower USDA grading score in five separate studies. The review also concluded that sensory tenderness scores were higher for castrates compared to entire males yet differences were less pronounced after 15d compared to 3d of aging. Other studies agree that aging meat for longer periods of time

post-slaughter can offset much of the castration effect that influences tenderness (O'Connor et al., 1997, Cahill, 1964, Cahill et al., 1956).

Several supportive studies agree with the concept that beef from entire males was slightly tougher than that of castrates yet still of an acceptable eating standard. Rib cuts from entire male cattle slaughtered at chronological ages of 12, 15, 18 and 24 months were of a satisfactory eating standard based on sensory assessment (Arthuad et al., 1977). Klosterman et al., (1954) found similar findings noting that tenderness was slightly more favourable for samples from castrates, however samples from entire males was of a satisfactory eating standard. Field et al., (1966) suggested that the chronological age of an entire male strongly influenced objective and sensory meat quality traits. The study found entire male cattle slaughtered between 300-399 days of age had lower WBSF (2.80kg *vs.* 3.12kg) and a higher or more desirable sensory tenderness score compared to castrates. Entire males that were slaughtered from 500-699 days of age recorded higher WBSF values and less desirable sensory tenderness scores. These results support the theory that as animals age the properties of connective tissue changes; decreasing the solubility and increasing overall toughness of the meat (Aberle et al., 2001).

Post-mortem tenderisation of meat is believed to be the work of the calcium dependent calpain enzymatic system, which consists of two enzymes and an inhibitor. The responsible enzymes are μ-calpain and m-calpain and actively work by degrading myofibrillar proteins in post-mortem storage (Koohmaraie, 1990). The activity of these enzymes is defined by differing levels of calcium required for activation. It has been suggested the range for μ-calpain activation is 5 - 50μmol/L and 400 - 1000μmol/L for m-calpain (Ferguson et al., 2001). The system also has of an endogenous inhibitor known as calpastatin. These enzymes and their inhibitor are known to reduce in concentration after 48 hours post slaughter (Sinclair et al., 2001). Calpastatin has the specific role of binding and inhibiting the activity of calpains in post-mortem tenderization (Koohmaraie and Geesink, 2006). There is evidence suggesting the differences in production of calpastatin between entire males and castrates may be the driving force behind variations in meat tenderness (Woodward et al., 2000, Morgan et al., 1993a).

It has been hypothesised that intracellular concentrations of calcium are high enough to activate μ-calpain but not m-calpain in the post-mortem phase. Thus indicating that μ-calpain in combination with the activity of calpastatin is primarily responsible for myofibrillar degradation (Morgan et al., 1993a). There is evidence that demonstrates there are small but consistent differences between μ-calpain in entire male and castrated cattle measured at 24h post slaughter. It has also been shown that calpastatin has higher activity levels in the *M. Longissimus dorsi* muscle in proportion to the remainder of the carcass yet it has also been suggested that activity of calpastatin in this muscle in entire males is 80% higher compared to castrates (2.41units/g of muscle *vs.* 1.33units/g of muscle). The effect of the increased calpastatin activity is decreased post-mortem proteolysis in the initial seven days post slaughter and subsequently lowered tenderness in meat from entire males. Calpastatin has, therefore, been concluded to be largely responsible for differences in tenderness, when measured in the early stages of post-mortem, between sex treatments (Morgan et al., 1993a).

Further evidence supporting the above notion has been documented in past literature by Woodward et al., (2000) and Morgan et al., (1993b). Both studies concluded that the inhibitory effect of increased calpastatin activity on proteolysis was the major contributor to decreased muscle tenderness in entire males. Knowledge currently exists regarding the activity of calpastatin at varying stages post-mortem, yet limited data is available on calpastatin activity in the live muscle in genders over time. Although Koohmaraie and Geesink (2006) showed that calpastatin activity decreased with age when measured at slaughter in lambs, a significant gap in knowledge still exists in the activity of calpastatin throughout growth.

Carcasses from entire males have historically been heavily discounted in the domestic market based on the evidence that the majority of beef from entire males processed is from cast for age animals. In addition, there is a body of evidence that suggests meat quality from young entire male cattle is of lower tenderness, as measured by shear force and sensory evaluation, yet may not be of commercial significance (Morgan et al., 1993a). It is believed the difference between entire male and castrated cattle is driven primarily by the calpain enzymatic system in the post-mortem phase. Given that some studies have shown aging time removes much of the difference in meat tenderness

between genders, further investigation is required looking into the qualification of young entire male carcasses to the MSA model.

2.2.6 Growth Implants In Entire Males

Fattening entire male cattle in preparation for slaughter to comply with market specifications, has been recognised as a limitation to producing beef from entire males under Australian conditions. A number of studies (Johnson et al., 1988, Seideman et al., 1982, Martin and Stob, 1978, Glimp, 1971, Bailey et al., 1966, Cahill, 1964) suggest entire males produce a carcass characterised by higher proportions of edible product and low levels of subcutaneous and intramuscular fat compared to castrates, thus indicating longer periods on feed may be required in order to supply a carcass that will comply with market specifications. Developing consumer trends that emphasise the importance of selecting a leaner 'healthier' product may present an opportunity for the production of beef from entire male cattle in Australia (Johnson et al., 1988). Achieving a level of fatness that improves palatability, tenderness and appearance of the meat, however, may be needed to successfully market cuts from entire males.

The use of hormone implants as growth promoting agents is an accepted practice in both the grass and grain fed industries in Australia and is thought to increase the average carcass value by $50 (Hunter, 2010). This is undertaken in many systems in an attempt to accelerate growth rates in marketing cattle at a younger age. Oestrogen containing implants have been reported to increase growth rate of castrates by 10-20%, lean meat yield by 1-3% and feed efficiency by 5-8% (Kahn, 2008). It has been suggested that carcass values are potentially compromised by the use of growth promoting agents. Watson et al., (2008*b*) and Thompson et al., (2008a) have shown in separate studies using *Bos indicus* cattle, that implanting reduces carcass quality and sensory assessment scores. Reduced sensory tenderness, lower marbling scores and higher ossification were all characteristics of carcasses of implanted cattle. Attempts to increase carcass fatness and the rate of fat deposition in entire males using synthetic oestrogen implants have been reported in early literature.

The use of stilbestrol as an oestrogen implant was an accepted management strategy prior to being banned by the Food Drug Administration (FDA) due to human health concerns in 1979 (Ensmingen and Konlande, 1993). Prior to the banning, Bailey et al., (1966) reported that entire male cattle implanted with 60mg of stilbestrol gained more weight and produced a carcass with more fat. Cahill et al., (1956) agreed with these findings documenting an increase in fatness of implanted entire males. Wierbicki et al., (1955) suggested that implanting entire males with stilbestrol had no detrimental affect on tenderness and overall eating quality.

Zeranol implantation is a more recent method used in cattle production that is employed in the commercial industry today. Zeranol is the anabolic agent and acts by stimulating the pituitary gland to produce higher levels of natural growth hormones. Entire male cattle implanted with zeranol have been found to be fatter and have higher skeletal maturity scores compared to un-implanted entire males of similar chronological ages (Greathouse et al., 1983). As with other HGP's, zeranol implants reduce tenderness scores and increase detectable connective tissue scores. It is reported that flavour intensity is unaffected. Staigmiller et al., (1985) reported similar findings with carcasses from zeranol implanted entire males exhibiting more signs of intramuscular fat compared to unimplanted entire males. This study concluded that for maximum benefit implanting should be undertaken earlier in the animals' life as the affect is less pronounced after 18 months of age.

The use of HGP's in cattle production is widely accepted under Australian conditions. The accelerated growth response in implanted castrates is often offset by a decrease in carcass quality. The literature does suggest that implanting entire male cattle increases fat deposition, however, the negative affect of implantation on meat tenderness would further limit the acceptance of beef from entire males.

2.2.7 Production Of Short Scrotum Males

Artificial cryptorchidism as a method of castration is not a common practice in Australian beef production systems. The method involves pushing the testes up into the abdominal cavity and placing a rubber band around the upper portion of the scrotum.

This causes aspermatogenesis due to the removal of the thermo-regulated environment needed to produce spermatozoa (Bass et al., 1976). Male cattle castrated by this process are referred to as short scrotum bulls (SSB) or cryptorchids. Short scrotum bulls will continue to produce male hormones resulting in similar secondary sex characteristics and mating behaviour as observed in entire male cattle. Studies have been conducted under various conditions using different species in evaluating the viability of cryptorchadism as a method of castration (Albaugh et al., 1975).

The benefit of producing SSB's is the ease of management when being used in conjunction with a cow / calf breeding operation. Short scrotum bulls are infertile while still attaining similar superior growth traits that have been observed in entire males compared to castrates. Cryptorchidism in cattle varies when compared to the same practise in sheep. Glimp (1971) reported that short scrotum rams had similar growth data to rams, however, more desirable carcass characteristics similar to castrated rams (wethers). In contrast, with measurements taken in cattle, Albaugh et al., (1975) indicated SSB's had similar growth rates, carcass data and sensory scores to entire males. The lower sensory tenderness scores that were observed in this study were still considered of an acceptable eating standard.

Growth and carcass data has been compared in the literature with specific reference to castrates, cryptorchids and entire males produced under similar conditions. Wilson et al., (1974) suggested that pre-pubertal growth rates did not differ between the three sex types. Growth rates from day 190 – 402 of this study revealed superior results for both entire males and SSB's compared to castrates. Carcass data from this experiment showed castrates to have higher fat percentages, lower carcass weights and comparable sensory scores to the other sex types. Berry et al., (1978) reported similar findings with cryptorchids having larger carcasses, higher yields and lower back fat thickness compared to castrates (0.99cm vs. 1.24cm). Furthermore, entire males had lower USDA grading scores, lower sensory tenderness and a darker less desirable appearance when compared with meat from castrates.

The production benefits of short scrotum bulls are well documented; however, some literature has questioned the success of using such a technique as a method of castration.

Kellaway (1971) revealed that in four of ten later induced cryptorchids (at 10 months-of-age) spermatozoa were observed in semen samples taken prior to slaughter at 16 months. Growth and meat quality of the SSB's was similar to previously reviewed studies, yet the inability to induce complete infertility deemed the process ineffective. These conclusions did not indicate if there were any viable spermatozoa in these samples. Although spermatozoa were observed, it is suggested the probability of the SSB conceiving a calf would be low given the low semen motility and concentration. Pre-pubertal induced cryptorchidism (at 16 weeks) was shown to have a higher success rate with no spermatozoa identified in semen samples. Mean testes temperature was also higher for cattle in this treatment group (Kellaway, 1971).

There is an ever growing body of international evidence that supports the concept of producing lean beef from entire males. Animal welfare benefits are also considered with the elimination of castration from a production system. As illustrated within the literature, the drawbacks of producing beef from entire males, namely controlling aggressive behaviour and variation in meat quality, can be handled under specific management conditions. The lack of data in the production of entire male cattle in Australia, notably in northern Australia, represents an opportunity for commercial based research to determine the viability and sustainability of such an operation.

2.3 Meat Quality

2.3.1 Meat Tenderness

Meat tenderness was described in the development of Meat Standards Australia's (MSA) prediction model by consumer evaluation as ease of first bite, hardiness and ease of chew (Watson et al., 2008*b*). Tenderness is measured by laboratory based instrumental methods and sensory evaluation using trained and untrained panels. There are many variables from on-farm production, slaughter and processing of the carcass through to the cooking method that can ultimately influence the eating experience of beef. A failure of one or more links in this supply chain can have a negative effect on the overall eating experience for the consumer (Thompson, 2002). Meat tenderness has been, however, identified as the most highly ranked quality concern in the meat industry (Koohmaraie and Geesink, 2006).

Findings from a US report compiled by Morgan et al., (1991) titled the National beef Tenderness Survey stated that meat tenderness was the single most important factor affecting meat eating quality. This theory was supported by the National Retail beef Study (Savell et al., 1989, Savell et al., 1987). Such studies have used differing grades to determine if customers can identify variations in quality. Assessing cuts of varying quality with a corresponding price tag was also reviewed to understand if consumers were willing to pay for a product that was of superior quality. The data generated from these US reports supported the consumer knowledge within Australia from findings of initial Meat Standards Australia (MSA) research. Results suggested that on sampling, 41% of consumers were able to identify tender beef (Polkinghorne et al., 1999), however, they were not confident at the time of purchase that each cut would be of acceptable eating quality (Smith et al., 2008).

2.3.2 Breed / Genotype Effect On Meat Tenderness

The adaptability of the *Bos indicus* genotype to the tropics or sub-tropics of northern Australia has reshaped the Australian cattle industry. Despite the many advantages of using cattle of this genotype, it is widely accepted that *Bos indicus* cattle have the potential to produce tougher meat. These cattle survive in harsh environmental conditions that are characterized by extreme heat and humidity, low quality forage and often large distances between watering points. As explained later in this chapter these variables are detrimental in the production of tender meat. The breed / genotypic effect have been researched extensively and have been found to contribute to the variation in meat tenderness. Research has proven that there is little difference between breeds of *Bos taurus* origin, however, there is increasing evidence to suggest that as *Bos indicus* content increases, tenderness decreases (Thrift et al., 2002, Tatum, 1993).

Hereford / Angus steers of 100% *Bos taurus* content have been shown to have carcasses considered ‘acceptable tender’ compared to 86% of Brahman carcasses (Koch et al., 1982). This result may be partially explained by the frequency of the calpastatin gene within a population of *Bos indicus* animals. In unpublished work, Wainewright et al., (2009b) states that up to 37% of *Bos indicus* male cattle are positively homozygous or, as displayed in the commercially available gene star tenderness rating system (Pfizer®),

have zero favorable alleles for the calpastatin gene. Recent work completed by Cafe et al., (2010) supported these unpublished data suggesting that the low frequency of animals with two favorable alleles for the calpastatin gene in *Bos indicus* populations may be a limiting factor in meat tenderness in the northern industry. In addition, Casas et al., (2006) suggested that combined with the low frequency of animals with two favorable alleles for the calpastatin gene that little confidence could be used when employing the current marker system given the model is targeting non-functional alleles in *Bos indicus* populations.

Crouse et al., (1989) studied the affects of breed type in an experiment that represented cattle from 0:100 *Bos indicus* to *Bos taurus* inheritance. The outcome of the study showed as *Bos indicus* genotype increased, the variation (standard deviation) in meat tenderness also increased. Research undertaken by O'Connor et al., (1997) and Sherbeck et al., (1996) also support the work of Crouse *et al.* (1989). Objective tenderness as measured by WBSF was higher for cattle with increasing level of *Bos indicus* content. In each of these studies cattle were sourced from their respective points of origin before being lot fed. In Australian production systems cattle of different genotypes would have to be sourced from vastly different environments to complete such a study. The background of these animals would differ in relation to nutrition, temperature, humidity and management. The *Bos taurus* genotype is bred for production whereas the *Bos indicus* genotype is bred for survival. These confounding factors may be questioned if these studies were completed under Australian conditions.

2.3.3 Differences In Calpain And Calpastatin Activity Between Genotypes

The genotype affect is believed to be driven by the calcium dependent proteolytic system which is responsible for post-mortem degradation of myofibrillar proteins (Aberle et al., 2001). The breed affect is due to *Bos indicus* cattle having higher levels of calpastatin compared to *Bos taurus* cattle (O'Connor et al., 1997, Tatum, 1993). It has also been reported that as an adaptive trait to a hotter tropical environment, enzyme activity in *Bos indicus* cattle has also changed. It is thought that such a change in the activity of calpains can potentially produce tougher meat (Dransfield, 1994). More

research is required in this field to explain the possible differences between calpain and calpastatin activity at various temperatures between genotypes.

A study undertaken by Wheeler et al., (1990) found differences in muscle tenderness between Hereford and Brahman steers to be due to the activity of the natural inhibitor calpastatin. O'Conner et al., (1997) reported that cattle with 3/8 *Bos indicus* content had higher levels of calpastatin compared to *Bos taurus* cattle measured at 24h post mortem. Warner Bratzler Shear Force measurements were as a result higher for cuts of meat from *Bos indicus* cattle aged for 1, 4, 7, 14, 21 and 35 days. There is, however, published research to suggest that low levels of *Bos indicus* content may not have any detectable differences in meat tenderness to the everyday customer, as 25% *Bos indicus* content of cattle has been found to not adversely affect tenderness and to be of an acceptable eating quality (Sherbeck et al., 1995).

2.3.4 Heritability Of Calpastatin

Calpastatin heritability has been reported in recent literature as having a possible role in the selection process. Wulf et al., (1996) found calpastatin to have a heritability estimate of 0.49 in *Bos taurus* cattle. Other studies have reported similar findings with heritability estimates of 0.65 (Shackelford et al., 1994). These results also suggested that *Bos taurus* cattle could be selected for less calpastatin without compromising growth rate. Contradicting evidence suggests that due to a low heritability estimate (0.15) for calpastatin activity in *Bos indicus* / *Bos Taurus* composites, cattle of this origin should not be selected for, or against, calpastatin (O'Connor et al., 1997). Sensory panel tenderness for meat aged up to 14 days was shown to be moderately heritable (0.27 – 0.47).

Within the Australian beef industry, technologies are commercially available to identify cattle with genes for calpastatin. The data suggests that calpastatin is moderately heritable and it is advertised that producers can select for animals that will produce a highly desirable end product without compromising growth rate. If the cost of obtaining genetic data is sustainable and the price for supplying cattle that will produce

'guaranteed tender' beef is justified, then there is potential that this knowledge can benefit the industry. Future research efforts may be directed at calpastatin selection indices in *Bos indicus* cattle in a tropical or sub-tropical environment in northern Australia to remove some of the variation in meat tenderness within this genotype.

The current MSA meat grading model in Australia discounts tropically bred cattle based on farmer declaration and phenotypic evidence of the carcass. Measurable phenotypic characteristics of *Bos indicus* cattle include hump height, length and shape of ear, amount of sheath and shape of head. Data from a study conducted by Sherbeck et al., (1996) suggested that Brahman cross steers of varying concentrations of *Bos indicus* genotype had weak negative correlations (-0.16) between hump height and tenderness as assessed by a taste panel. The results found that correlations between hump height and shear force were also weak (0.16). Given the nature of these correlations, there is a case in further refining the MSA model to select each carcass from a tropically bred animal on due merit rather than discounts based on poor evidence associated with hump height. Other measurable phenotypic and genotypic traits that possibly interact with tenderness may be in need of investigation. The traits include shape and length of ear, shape and placement of eye, shape of head, size of sheath, size of hump and the presence of the calpastatin gene.

2.3.5 Growth Path And Its Effect On Eating Quality

Controlling pre-slaughter growth rates to influence meat quality is a farm controlled factor that invariably stimulates debate. The effect growth path has on palatability remains unclear. However, the following definitions has been stated; Calkins et al., (1987) defines growth rate as; "is the net difference between synthesis and degradation" and states that hyperplasia ends at birth, while Koohmaraie et al., (2002) describes muscle growth as being determined by hyperplasia and hypertrophy and the affect of the calpain proteolytic system as regulator of muscle protein degradation.

Cattle with faster growth rates pre-slaughter generally obtain target market live weights sooner than their slower growing counterparts. Growth rate has been shown in a number of studies to be a major pre-slaughter factor affecting meat tenderness

(Shackelford et al., 1994, Fishell et al., 1985). Decreased concentrations of collagen and increased collagen solubility have been identified in cattle with higher growth rates in the finishing phase (Aberle et al., 1981). Fishell et al., (1985) reported that castrates with a faster growth pattern were more tender when examined by a taste panel. These results were in contrast to Calkins et al., (1987) who found no significant affect of feeding regimen on meat quality. That study did, however, hypothesize that a relationship may exist between enzyme measurements and meat tenderness. Tomkins et al., (2006) suggested that a growth check at weaning would not affect meat quality provided it was followed by a period of adequate nutrition.

An elevated level of nutrition following a period of growth restriction has been shown to have an affect on growth rate and carcass quality. This period has been defined as a period of 'compensatory gain' and as Hornick et al., (2000) suggests, re-feeding following a period of growth restriction combined with a pubertal affect can have a synergistic affect on growth. That study also suggests that immediately following growth restriction, compensatory gain is identified by the fast deposition of lean tissue. However, as protein synthesis decreases and provided feed intake remains high, fat deposition will begin to increase.

The role of the calpain enzymatic system remains unclear in periods of high growth (Therkildsen et al., 2002). There is, however, evidence to suggest periods of feed restriction for two weeks prior to slaughter can increase the activity of calpastatin and thus affect meat tenderness (Thompson et al., 1992). Australia's meat grading system attempts to quantify this growth path effect by classifying carcasses on physiological age.

2.3.6 Animal Age Effects On Meat Quality

The MSA prediction model measures the physiological age of a carcass from ossification scores developed from the USDA system (Smith et al., 2008). Ossification is the calcification of cartilage measured in the sacral, lumber and thoracic vertebral regions of the carcass (Smith et al., 2001). It is an estimate of maturity that is influenced by breed type and environmental stressors. Previous research has reported

that there is a negative relationship between skeletal maturity (ossification) and muscle tenderness. A study by Hilton et al., (1998) found that as skeletal maturity increased so to did the amount of connective tissue. Sensory and objective data for tenderness, juiciness and flavor intensity favored the carcasses with less ossification. Hall and Hunt (1982) reported similar findings, that animals with higher proportions of collagen, associated with maturation after feed restriction, had a higher objective or a less desirable score for muscle tenderness. These variables affecting tenderness as a result of carcass maturation may help explain results from previous studies (Seideman et al., 1989, Seideman et al., 1982, Glimp, 1971) that state entire male cattle have higher ossifications scores and consequently less tender meat samples compared to castrates.

Actual age and dentition in relation to carcass weight were also reviewed when developing the MSA model as a predictor of palatability. Actual age of the cattle was found to be difficult to measure and monitor in a commercial farming operation and was subsequently eliminated. Dentition was also removed as a predictor of meat palatability due to poor correlations between actual age, ossification and carcass weight (Polkinghorne et al., 2008*b*). Age, genetics, diet and environment all contribute to the variation in dentition that could not be quantified in the grading model. This was supported by previous research that suggested that dental classification was not related to meat tenderness (Wythes and Shorthose, (1991); Lawrence et al., (2001)).

A significant component of beef cattle production in southern Australia includes the sale of young un-weaned cattle (10 months or less). When slaughtered, this class of cattle has lower ossification and higher eating quality than a weaned animal of the same chronological age (Watson et al., 2008*a*). Such cattle are referred to as 'milk fed vealers'. Farmers are required to nominate on a declaration statement if calves fit this category, which is worth between 0-6 MQ4 grading points under the current system (Polkinghorne et al., 2008*b*). With a limited understanding of the mechanism behind the effect, further research is needed in this area.

2.3.7 Pre-Slaughter Handling Effects On Meat Quality

Animal handling techniques during the period before slaughter can play a major role in beef eating quality. This pre-slaughter phase from mustering through to the animal being loaded into the knockout box at the abattoir can expose the animal to many stressors (Ferguson and Warner, 2008). Such stimuli include increased human contact, food and water restriction, transport, unfamiliar environment, a change in social structure and exposure to variable climatic conditions (Ferguson et al., 2001). The affect of these stimuli can lead to a series of physiological processes that can have detrimental affects on meat quality.

2.3.8 Physiological Responses To Pre-Slaughter Stressors

Physiological responses are driven by the animals attempt to restore order and remain in homeostasis. Adjustments in metabolism during this period are influenced by four biological responses 1) behavior 2) autonomic nervous system 3) neuroendocrine 4) immune (Moberg, 2001). A change in respiration rate, elevated body temperature, greater alertness and redistribution of visceral blood to the brain and skeletal muscles are responses often seen from a stress stimulus (Ferguson and Warner, 2008). The magnitude of the stress related response is primarily due to the intensity, nature and duration of the stimulus (Ferguson and Warner, 2008). Stress is believed to be a combination of intrinsic and learned behavior based on past experiences by the animal (Moberg, 2001).

2.3.9 Pre-Slaughter Stressors In Northern Australian Cattle Production

Fear induced by human contact from mustering, drafting and transport is an unavoidable component of cattle production. Infrequent human contact in combination with varying levels of temperament is reported to affect meat quality. Due to the practical limitations of the large property sizes and the use of *Bos indicus* genotypes in northern Australia, annual or biannual contact is a common practice. Over 80% of the north Australian cattle herd is of *Bos indicus* origin (Burrow and Dillon, 1997) and it is recognized through producer surveys that this genotype is less docile than cattle of *Bos taurus*

decent (Elder et al., 1980). Petherick et al., (2002) suggested that *Bos indicus* steers with poor temperament, based on flight speed, were more likely to have lower initial meat pH levels. This result shows that some glycogen depletion may have occurred pre-slaughter due to higher levels of stress.

Glycogen depletion as a response to pre-slaughter stress has been recognized as the major cause of dark cutting meat or a condition called 'dark, firm, dry' (DFD) beef (Gardner et al., 2001). Reduced muscle glycogen at the time of slaughter reduces the potential post-mortem production of lactic acid. This in turn results in a decrease in the rate of pH decline. It is widely accepted that darker colored meat with a higher ultimate pH (>5.7) is poorly accepted by the consumer due to tenderness, color and palatability issues (Gardner et al., 2001).

The extensive geographical boundaries of the northern Australia cattle industry results in cattle being transported considerable distances and experiencing long periods without access to feed and water. Weight loss is an unavoidable expense and has been reported as being greatest in the initial 12 hrs of fasting (Wythes and Shorthose, 1984). This is primarily due to the excretion of the gastrointestinal tract (Ferguson and Warner, 2008). Muscle catabolism and dehydration is expected to negatively affect carcass quality if fasting exceeds 48 hrs. In a study completed by Smith et al., (1982) cattle were deprived of feed and water for 52 hrs. The results supported the hypothesis stated by Wythes and Shorthose (1984) as cattle had a weight loss of 2.57 kg/hr for the first 5.3 hrs before decreasing for the remainder of the fasting period.

2.3.10 Transportation

Transportation of animals to market or slaughter can have a negative effect on meat quality from bruising and yield losses. Although there is little data available reporting recent losses, historical data suggests that bruising alone costs the Australian industry $A42 million per year (Eldridge and Winfield, 1988). Results from a study completed by Eldridge and Winfield (1988) comparing bruising and carcass weights highlighted the affects of different pen spacing. Cattle with low space allowance had bruising scores two times higher and carcass yields of 10kg less than cattle in medium spaced

pens. Eldridge et al., (1988) also reported cattle with a smaller pen allowance had higher heart rates and movement scores up to 260% higher than control animals. Social interaction between animals during transport or lairage prior to slaughter can also influence animal well-being and meat quality.

2.3.11 Social Remixing

Disruption to the social hierarchy through regrouping is almost unavoidable in the pre-slaughter phase. The social remixing of 15 month old bulls during transport has been shown to induce several stress related responses. They included more frequent urination, elevated heart rate, higher blood cortisol concentration and an increased frequency of sexual behaviour and mock fighting (Kenny and Tarrant, 1987). Sexual behaviour as measured by male-male mounting following social mixing is thought to significantly contribute ($r = 0.76$) to dark cutting meat in entire males (Franc et al., 1988). Similar observations were made by Warriss et al., (1984) who reported lower concentrations of liver glycogen from animals slaughtered the day and day after mixing. Although unlikely to be of commercial significance, cattle with lower levels of liver glycogen had darker coloured meat. The affect of lairage and method of marketing has also been studied as a pre-slaughter factor influencing meat quality.

2.3.12 Lairage

Pre-slaughter stress can be raised significantly in the confinement to yards or facilities in the hours prior to slaughter. This area is referred to as lairage (Ferguson and Warner, 2008). Glycogen depletion was measured in *M. Semitendinosus* and *M. Semimembranosus* of lambs over three separate lairage periods by Jacob et al. (2005). In eight of 13 consignments of lambs, muscle glycogen was lowest on arrival before slowly increasing as animals adjusted during longer lairage time. Animals processed in Australian abattoirs must be rested for a minimum of two hours post transport. Research supporting this concept compared cattle allocated to different lairage times following a 150 day finishing period. The study found no differences between carcass weight, muscle glycogen, ultimate pH or shear force for the three hour or 18 hour lairage periods (Ferguson et al., 2007a).

2.3.13 Marketing Method

Sale yard marketing of cattle can also predispose animals to higher levels of stress through an increased number of stimuli. Extended fasting, social regrouping, more transport, unfamiliar environments, noise and extra handling can all contribute to the effect. Ferguson et al., (2007b) compared carcass quality and sensory characteristics of sale yard and direct consignment cattle. Cattle sold through the sale yards were found to have higher levels of glycogen depletion in five of the nine consignments. Sensory data also indicated that there was a trend towards lower MQ4 scores for cattle marketed through the sale yards, although not always of statistical significance ($P>0.05$). The MSA grading model accommodates for sale yard exposure with a small deduction in MQ4 scores for cattle marketed using this method. The regrouping that is associated with sale yard or direct consignment marketing has also been found to affect cattle physiology and meat quality. Colditz et al., (2007) found that cattle slaughtered a week after being regrouped had higher peak force values than cattle with a four week adjustment period. Plasma glucose was also higher ($P>0.01$) in Hereford cattle that had a four week adjustment period after regrouping.

In developing the MSA prediction model, attention was given to the importance of animal handling and it's affect on eating quality. Given the body of research that supports this concept, a number of key points are listed for producers to abide by in order to supply MSA accredited beef. The key points for registered producers include; supplying information regarding *Bos indicus* content, if the cattle are milk fed and time of loading (Thompson, 2002). Producers must also ensure cattle have had adequate nutrition for at least a month prior to dispatch, cattle must be handled quietly when mustered, drafted and loaded (minimum use of electric prodders), cattle must have access to water and feed until dispatch (dependent on curfew), farmers must avoid mixing mobs and avoid consigning sick or infected cattle for MSA accreditation (Meat and Livestock Australia, 2004).

2.3.14 Post-Slaughter Affects On Meat Quality

Following immobilization and exsanguination or loss of blood during the processing phase, a series of biophysical events are instigated within the muscle (Ferguson et al., 2001). The biophysical events relate to the process of rigor mortis and the degree of myofibrillar fragmentation during the period following slaughter. The rate and degree of these events can influence tenderness and overall palatability of beef. Other processing practices that have be shown to influence meat quality include degree of aging, hanging method, electrical stimulation, controlled chilling and calcium chloride muscle infusion.

Meat tenderness is determined by the amount and solubility of connective tissue, sarcomere shortening during rigor mortis and the activity of the endogenous calpain proteolytic enzyme system (Koohmaraie and Geesink, 2006). The amount and solubility of connective tissue is often referred to as background toughness and is predetermined by age, genotype and sex of the animal. Although Nishimura et al., (1998) provided evidence to suggest connective tissue decreased in toughness after 10 days of aging, it is widely accepted that sarcomere shortening and proteolysis have a much larger affect on meat tenderness in the post-mortem aging period (Ferguson et al., 2001).

2.3.15 Aging

Post-mortem aging or cool storage of meat has been known to improve meat tenderness for almost a century (Koohmaraie and Geesink, 2006). The weakening of myofibers under cooler conditions in the period following slaughter is well recognised as the work of endogenous enzymes. Three endogenous enzymatic systems involved in proteolysis have been identified in past literature including; i) the calcium dependent (this system consists of an inhibitor calpastatin and enzymes μ-calpain, m-calpain and more recently calpain 3 (Koohmaraie et al., 2002)) ii) lysosomal cathepsins (cathepsin B, D, H and L) and iii) proteosomes (Ferguson et al., 2001). Strong evidence suggests that the post-mortem myofibrillar degradation is primarily the work of the calpain system (Koohmaraie, 1990).

The calpain enzymes target major regulatory proteins tropomyosin and troponin and cytoskeletal proteins titin and nebulin (Aberle et al., 2001). Activation and deactivation of the calpain enzymes is highly dependent on both pH and temperature (Ferguson et al., 2001). The pH of a carcass will decrease in accordance with the muscle trying to produce energy anaerobically to remain functional during the post-mortem phase. Adenosine triphosphate (ATP) is used as an energy source by the muscle and is produced when glycogen is converted to lactic acid. This process ultimately decreases the muscle pH (Ferguson et al., 2001). Dransfield (1994) reported that the ultimate pH (5.3-5.7) of a beef carcass would take between 15-36h.

The tenderization curve that represents the degree and duration of aging is uniquely different for each individual carcass. A sharp rise in objective shear force (kg) for the initial 24h post slaughter explains the 'toughening' phase where sarcomere shortening is thought to be solely responsible during rigor mortis (Koohmaraie, 1996). Although sarcomere shortening during rigor is thought to be primarily responsible for this toughening, it does not have an effect on the degree of proteolysis (Wheeler and Koohmaraie, 1999). Therefore, these conclusions suggest sarcomere shortening under normal conditions doesn't limit tenderisation. The interaction between sarcomere length, proteolysis and resulting meat tenderness remains unclear amid contradicting findings that suggest shorter sarcomeres (2.57μm *vs.* 1.43μm) result in less degradation of troponin in the initial seven days post-mortem and higher WBSF values (Weaver et al., 2008).

Following the initial 'toughening' phase the tenderisation curve follows a linear downward trend due to the degradation of myofibrillar structural proteins. The majority of tenderisation occurs during this period. Variation in aging rates between muscles has been documented in past literature. It is believed that muscle aging requirements are in the order *M. Abdominis*, *M. Tricep brachii, M Semitendinosus, M. Longissimus dorsi* and the *M. Psoas major* (Jarrige and Beranger, 1992). It is thought this ordering is strongly related to muscle fibre type. Dransfield (1994) stated that the level of calpains and calpastatin was influenced by fibre type. It is reported that red or 'slow twitch' muscle fibres have lower levels of calpains and therefore take longer to age than white or 'fast twitch' muscle fibres. Results from a study completed by Seideman et al.,

(1986) comparing fibre types in entire male and castrated cattle found that entire males produced a higher number of red fibres (28.25% *vs.* 24.10%) and a lower level of white muscle fibres (44.49% *vs.* 53.17%) compared to castrates. The fibre type combined with entire males having higher levels of calpastatin activity (Morgan *et al.* 1993a), it could be hypothesised that there would be strong interactions between red muscle fibres and aging time.

2.3.16 Hormone Implantation Affecting Aging

Evidence in recent literature suggests that the use of hormonal growth promoting agents (HGP) has a negative affect on the amount of time required to age meat. It has been reported that the increase in aging time is due to the effect growth promoting agents has on the calpain proteolytic system, notably the increased activity of calpastatin. The inhibitory effect calpastatin has on μ-calpain and possibly m-calpain is believed to be largely responsible for the decrease in the degradation of structural myofibrillar proteins (Koohmaraie et al., 2002).

As documented in the review competed by Koohmaraie et al., (2002), an increase in protein accretion is associated with increased calpastatin activity and a subsequent suppression in myofibrillar degradation. In a study with castrated Brangus cattle treated with oestrogenic and androgenic implants, implanted steers had more variation in tenderness of top sirloin steaks compared to un-implanted castrates (Gerken et al., 1995). *M. Longissimus dorsi* samples from implanted castrates all had higher 24h calpastatin levels, however, no interaction between three different aging times (7, 14 and 21 days) and sensory tenderness was recorded. Sensory tenderness was however lower for steaks from implanted steers. Comparable results have been documented concluding that increased calpastatin levels from implanting failed to show any interactions with aging time and tenderness (Thompson et al., 2008b) It is suggested that by day five of aging any affect that implanting had on calpastatin activity may be exhausted.

The concept of reimplanting steers with a HGP has been investigated by several authors (Poland and Hoppe, 1999, O'Neill et al., 2002). Providing a single implant was shown to

provide the highest return per dollar invested, however, re-implantation was shown to produce heavy steers. It was concluded that re-implantation was viable given the effectiveness was reduced further into the payout period. Re-implantation was also found to have a negative affect on meat tenderness and intramuscular fat in steers. It is recommended that a clear strategy is used when producers implant steers with HGP's to maximise return without limiting marketing opportunities.

Given the body of research that supports the effect implants have on enzymatic activity, the MSA prediction model currently penalises a carcass that has been implanted by 3-6 MSA grading points. The degree of downgrading is depended on the muscle and its aging potential (Watson et al., 2008*a*), however, within the commercial industry, it may be more profitable to use implants as the benefit in weight gain and yield may outweigh the negative impact implants have on meat quality. An economic analysis may be warranted to test this hypothesis within a northern beef enterprise.

2.3.17 Controlled Chilling

Controlled chilling is a practice carried out by processors in order to comply with food safety requirements, maximise shelf life and reduce the possibility of producing tough meat (Savell et al., 2005). A series of biochemical steps including rigor mortis and pH decline in the 24-48h post slaughter are heavily influenced by chilling practices. The phenomenon of 'cold shortening' is the result of often uncontrollable temperature and carcass variables. The end result, however, is a tough, less desirable piece of meat.

The condition known as 'cold shortening' can result in decreased tenderness. Cold shortening exists when carcass temperature drops below 15ºC before the onset of rigor mortis (Aberle et al., 2001). During this period of induced cooling, the sarcoplasmic reticulum loses normal function and releases an abundance of calcium, forcing the muscle into maximum contraction. The carryover affect causes the actin and myosin filaments to slide over each other severely shortening the sarcomere (Savell et al., 2005). Savell et al., (2005) and Dransfield (1994) stated that cold shortening in beef and lamb is a possibility when pH is above 6.2 and muscle temperature drops below 10ºC. Hannula and Puolanne (2004) developed similar recommendations from an

experiment carried out at a number of processing plants. The study concluded that carcass temperatures should be kept above 7-10ºC until the onset of rigor or until a pH of 5.7 is recorded.

It has also been reported in a review completed by Savell et al., (2005) that subcutaneous fat depth of <6.3mm at the 12th rib may predispose a carcass to cold shortening. This result is explained by accelerated cooling of the carcass due to the lack of outer carcass fat. Subcutaneous fat helps maintain body heat in the live animal and controls the rate of temperature decline in the carcass post slaughter. These results are supported by the MSA prediction model that eliminates carcasses that have <3mm of fat at the 12th rib (Watson et al., 2008*a*). Bowling et al., (1977) supported this theory when studying grain and forage finished castrated cattle. Grain finished castrates with higher subcutaneous fat levels (8.9mm *vs.* 1.27mm) were more tender upon sensory evaluation. Sarcomere length was also higher (2.09µm *vs.* 1.79µm) for grain finished castrates indicating less shortening occurred during post-mortem storage. In explaining this result, carcasses from grain finished steers possibly had a slower cooling rate due to the extra outer fat acting as insulation.

It has been reported that red muscle fibre type is more susceptible to cold shortening than white muscle fibres (Savell et al., 2005). It is believed white muscle fibres have a higher level of glycogen therefore have a more severe drop in pH earlier in rigor mortis. Although muscle and breed dependent, entire males have higher levels of red muscle fibres and lower levels of white muscle fibres compared to castrates (Dreyer et al., 1977). This evidence suggests that in combination with low levels of carcass fatness, entire male cattle may be highly susceptible to cold shortening. Alternative management strategies may be in need of investigation from the farm through to the processing sector if cold shortening is to be eliminated as a potential problem in producing beef from entire males. As discussed earlier in the chapter, a method of increasing fat cover in entire males profitably may need to be reviewed.

2.3.18 Hanging Method

Alternative methods of suspending or hanging a carcass are used to i) reduce the degree of sarcomere shortening during rigor and ii) to reduce the aging potential in specific muscles. The traditional method of suspending a carcass from the Achilles tendon has been challenged over the past fifty years. Suspending a carcass by the pelvic bone or sacro-sciatic ligament has been proven to prevent shortening in the hindquarter muscles (Ferguson et al., 2001). The alterative method replicates an animal's natural relaxed state by straightening the vertebral column and is referred to as the tenderstretch method (Ahnstrom, 2008). As illustrated in Figure 2.3, the carcass is positioned to stretch the loin and hindquarter muscles to subsequently avoid sarcomere shortening and reduce aging time.

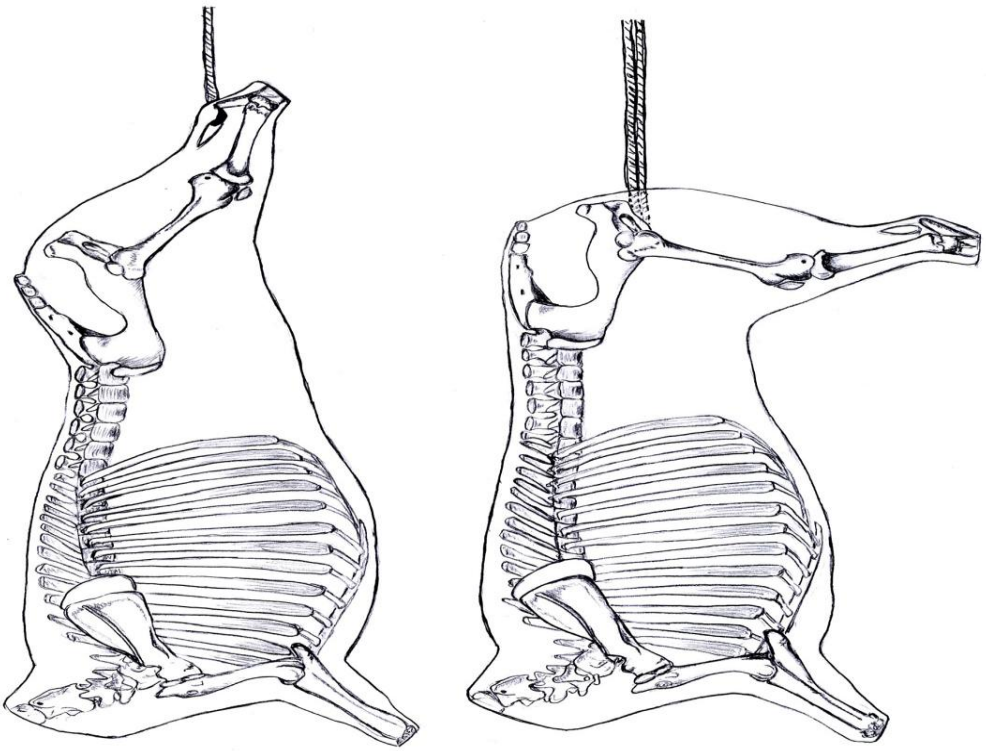

Figure 2.3. The Achilles tendon hanging method (left) compared to the sacro-sciatic or tenderstretch method (right)
Source: (Ahnstrom, 2008)

Tenderstretch carcass suspension improves shear force, sarcomere length and MQ4 values for *M. Longissimus dorsi* and *M. Semimembranosus* muscles (Park et al., 2008). Little improvement is seen in forequarter cuts under different cooking methods compared to achilles tendon suspension. Sheep carcasses also show improved sensory and shear force scores for loin and leg muscles when hung by the sacro-sciatic ligament (Thompson et al., 2005). Carcasses from entire males have also shown significant improvements in tenderness as measured by shear force when suspended using the tenderstretch technique (Ahnstrom, 2008). The recommendation that aging time of entire male carcasses could be reduced from 14 days to seven days using tenderstretch suspension would improve the viability of processing beef from entire males through reduced storage.

Tendercut™ is the final method used in carcass suspension that was developed in the early 1990's (Sorheim and Hildrum, 2002). Tendercut™ involves making specific cuts between the 12^{th} and 13^{th} rib and in the junction between the sirloin and round muscles. This results in further skeletal stretching while the carcass is hung by the Achilles tendon (Ferguson et al., 2001). As with the tenderstretch method Tendercut™ prevents specific muscles from shortening. Tendercut™ is commercially viable and doesn't require any modifications to existing facilities. The method is proven under a commercial setting to improve sensory tenderness ($P>0.05$) (Ludwig et al., 1997).

2.3.19 Electrical Stimulation

The use of post-mortem electrical stimulation (ES) has widespread acceptance in the beef processing industry. The noted benefits of providing voltage stimulation within a range of 45V – 1200V (Ferguson et al., 2001) to a carcass are well documented throughout the literature. The acceleration in glycolysis and subsequent reduction in pH has been shown to hasten the process of proteolysis. In a commercial setting this results in less aging time and increased inventory turnover. The benefits to beef palatability and meat quality have also been documented with several specific references to improvements in bull beef (Strydom et al., 2005).

The historical reasoning behind the development of ES was to eliminate the possibility of cold shortening (Ferguson et al., 2000). The abrupt reduction in pH following stimulation reduces the possibility of rigor taking place under cooler conditions. Strydom et al., (2005) outlined the benefits of delayed (45m post-mortem) high voltage ES on aging time, as carcasses had lower 24h calpastatin activity signifying an early onset of proteolysis. Improvements in tenderness were observed in meat aged for two days from bodies that were ES, however, the difference was less pronounced after 14 days of aging. Ferguson et al., (2000) revealed comparable findings when examining a breed affect on ES. The experiment came to similar conclusions with the early onset of proteolysis and a less pronounced difference between ES and non-ES carcasses after extended aging. It was also concluded that tenderness in carcasses from *Bos indicus* genotypes could be reduced by using ES.

Further evidence has been put forward in explaining the mechanisms behind improving tenderness from ES. Ho et al., (1996) suggested that ES not only accelerated the function of proteolysis but was responsible for mechanical disruption of the I-band structure at the time of voltage. It has also been suggested that ES is responsible for rupturing the Lysosomal membrane, therefore, releasing and activating lysosomal enzymes. Cathepsin's are believed to be inactive under normal post-mortem conditions (Dutson et al., 2006).

As discussed, producing beef from entire males can carry the consumer perception that the final product is tough, has a poor quality grade and is of poor appearance. The problem exists in the variability and lack of consistency that is associated with the beef from entire males. Due to fibre type and lower levels of fatness, entire male carcasses are more susceptible to cold shortening. The use of ES on entire male carcasses may be warranted to improve the consistency of an otherwise poorly accepted product (Seideman et al., 1982). A study produced by Solomon et al., (1986) used ES on a combination of *Bos indicus* and *Bos taurus* entire males. Carcasses that received ES treatment displayed improved loin tenderness scores, both sensory and objective, while improvements were also observed in lean meat colour. Improved tenderness scores of roasts from the *M. Semitendinosis* muscle and higher subjective lean muscle colour scores were observed in a report published by Klastrup et al., (1984).

2.3.20 Calcium Chloride Muscle Injection

The infusion of calcium chloride ($CaCl^2$) into a carcass pre-rigor is a process that has been scientifically proven to increase the rate of post-mortem tenderisation (Ferguson et al., 2001). It is believed the influx of calcium ions initiates the early activation of calpain enzymes. Wheeler et al., (1993) demonstrated both the benefits and drawbacks of pre-rigor injection of $CaCl^2$ with improvements observed in shear force measurements of treated muscles. Retail lean colour, flavour intensity and off-flavour rating were all noteworthy drawbacks of $CaCl^2$ injection. As was also seen in the above experiment, Ferguson et al., (2001) suggests the major limitation in processor adoption is the likelihood of microbial spoilage in the injected muscles. In other studies attempting to improve tenderness of *Bos indicus* cattle (Jaturasitha et al., 2004, Wheeler et al., 1991), $CaCl^2$ injection was again successful in improving shear force values. Contrary to recommendations made by Wheeler et al., (1991) the application of $CaCl^2$ injection to beef from entire males is debatable given the impact treatment has on muscle colour and flavour.

2.3.21 Profitability Of Producing Entire Males Vs. Castrates

The profitability of producing entire males under Australian conditions is largely unknown. As previously discussed the poor acceptance of producing beef from entire males can ascend from the producer through the supply chain to the consumer and consequently, there is currently no domestic market for entire male beef given the lack of demand. Contrary to the market demand, as suggested earlier in the chapter, there is a body of literature supporting the argument that young entire male cattle aged between 12-30 months can produce a carcass of similar meat quality compared to castrates (Field, 1971, Field et al., 1966, Bailey et al., 1966, Cahill, 1964, Klosterman et al., 1954). A carcass from an entire male can qualify under Ausmeat requirements for Grain Fed Yearling Beef (GFYG), which requires the carcass to fit into selection criteria for; dentition, fat depth, meat and fat colour and days on feed (Ausmeat, 2011). However, if the carcass fails to meet these criteria then the current Australian domestic pricing grid which penalises carcasses from entire males up to 90c/kg compared to castrates, may need to be reviewed in order to ensure an accurate price is awarded to each individual carcass, based on retail value and regardless of gender (JBS Swift and Company, 2009).

The pricing grid of leading beef processor, JBS Swift, states that the window of acceptance for carcass criteria is substantially tighter when selling castrates compared to entire males. For example, if a carcass from an entire male fails to qualify under GFYG, they are subject to a selection requirement of a fat depth of 0-32 mm, dentition of 0-8 teeth and muscle shape of A-D. Whereas the requirement for a castrated animal is more specific, requiring a fat depth of 5-12 mm, dentition of 0-2 teeth and a muscle shape of A-C (JBS Swift and Company, 2009). Consequently and as stated previously, the price awarded to an entire male carcass compared to a castrate is penalised up to 90c/kg.

Although there is little understanding of the profitability of beef from an entire male production system under Australian conditions, some recent work undertaken by Wainewright et al., (2011) used economic modelling in northern Australia to forecast the gross margins of three hypothetical entire male cattle case studies. The modelling used industry based surveys by Bortolussi et al., (2005a), Bortolussi et al., (2005b), Holroyd et al., (1979) and Donaldson (1962) to develop credible input variables that were an accurate reflection of the northern beef industry. The modelling predicted under the current domestic pricing grid that castrates had greater gross margins compared to entire males when slaughtered at 24-30 months of age. Although entire male cattle had greater growth rates and were more efficient during the finishing phase of the case studies, they could not account for the earlier economic losses. Given the literature supporting the argument that entire males can produce a carcass of comparable quality to that of castrates (Field, 1971, Field et al., 1966, Bailey et al., 1966, Cahill, 1964, Klosterman et al., 1954), Wainewright et al., (2011) predicted by removing the penalty imposed on the production of entire males that don't qualify under GFYG, that entire male cattle could yield greater gross margins compared to castrates given the superior post-pubertal growth rates and heavier carcass weights.

Given the lack of evidence surrounding any comparisons in profitability between the production of entire male and castrated cattle, further work is required to support the conclusions of Wainewright et al., (2011).

2.4 Conclusion

Further to the findings of this report, a significant gap in knowledge exists surrounding the viability and sustainability of producing beef from entire males in a north Australian production system. From the reviewed literature entire males have the potential to gain more liveweight, convert feed to liveweight more efficiently and produce a lean carcass that has a higher dressing percentage. Provided aggressive behaviour can be controlled and management both pre and post-slaughter can adapt to recommended practices it is hypothesised that producing MSA graded beef from entire males under tropical and / or sub-tropical conditions can be profitable.

The ever growing body of research that supports the concept that the calpain enzymatic system is primary responsible for post-mortem tenderisation has been extensively reviewed. Evidence that suggests both entire males and *Bos indicus* genotypes have higher levels of calpastatin may result in difficulties producing consistently tender beef in such a production system. Given the moderate heritability of calpastatin, DNA selection against the gene can act as a management tool in partially offsetting the activity of the inhibitor in *Bos taurus* populations yet may need further testings in *Bos indicus* populations to validate any commercial credibility.

The findings of this report has initiated the need for two experiments to be carried out in answering i) Can entire males be produced and managed in a vertically integrated north Australian production system to profitably supply a carcass of comparable quality compared to that of a castrate? ii) Can entire male *Bos indicus* cattle be selected against the calpastatin gene in an attempt to offset meat toughness without compromising productivity? The experiments were conducted under commercial conditions in a tropical environment in north Queensland. Following selection of genotypes and allocation to treatment groups, measurements of growth, eye muscle area and fat depth, flight score measurements and profitability estimates were undertaken. Following slaughter carcass measurements such as: carcass weight, ossification, meat and fat colour, pH and temperature decline and Ausmeat grade were recorded. Meat colour, pH and objective tenderness were also measured on samples from the *M. Longissimus dorsi* after aging for 7, 14 and 28 days.

CHAPTER 3

AN ECONOMIC CASE STUDY OF ENTIRE MALE GRAIN FED BEEF FROM A NORTH WEST QUEENSLAND PRODUCTION SYSTEM

3.1 Abstract

Assessing the differences in gross margins for a North West Queensland beef production system was undertaken using herd budgeting software. The analysis reviewed the viability of producing beef for the domestic market from either an entire male or castrated cattle production system. A hypothetical herd of 1200 breeders was created for the case study evaluation. An integrated beef production system from breeding to feedlot finishing was found to be less profitable for entire male beef production compared to a beef production system from castrates at the current market prices. Although production of entire males was more profitable than the production of castrates during the feedlot phase, the production of entire male cattle in this phase failed to compensate for the earlier economic losses in the weaning phase of -$24.04/AE. During the feedlot phase the entire male production system had lower break even sale prices compared to the production of castrates. In reviewing two pricing scenarios for entire male cattle it was found that entire males marketed at the same price as castrated cattle was the most profitable production system. It is concluded that the production of beef from entire males in a north west Queensland production system can only be profitable if entire males can be sold without discount relative to castrates.

3.2 Introduction

The production gains that entire males exhibit compared to castrated cattle are well documented. Entire male cattle can grow up to 17 % faster and convert feed consumed to liveweight gain 13% more efficiently than castrates (Field, 1971, Seideman et al., 1982, Cahill, 1964). These production gains have been attributed to the androgenic affect of male hormones, promoting lean tissue growth and heavier final carcass weights. However, the production of beef from entire males remains a poorly accepted practise under north Australian conditions.

A survey of Southern Australia beef producers reported that a perception of management difficulties was a common reason for poor acceptance of entire male beef systems (Hinch and Thwaites, 1984). In listing the reasons for the difficulties, graziers nominated fence damage, the need for early separation of sexes and difficulties in yard handling as being the main reasons for the lack of adoption. This negative feedback, however, was in contrast to specialised entire male cattle producers with a minimum of two years experience. The specialised producers of beef from entire males did not nominate handling difficulties as a major problem and had fewer herd injuries than non-bull beef producers (4% *vs.* 8%). The low adoption rate of specialised producers of entire male cattle in North and South Australia suggests that these inherent perceptions still exist.

Furthermore, meat wholesalers have been reported as perceiving meat from entire male carcasses from cast for age animals as having poor meat quality for the domestic retail market (Hinch and Thwaites, 1984). The wholesalers surveyed by Hinch and Thwaites (1984) did not list meat quality, defined as toughness, as a problem in beef from young, light weight entire males producing a carcass less than 250 kg. This would indicate that beef produced from entire males for the domestic market may be acceptable to wholesalers and subsequently consumers. In support of this the Australia national meat standard for grain fed young beef allows for the inclusion of entire and castrated males providing the carcass, age and dentition specifications are achieved (Ausmeat, 2011).

Beef from entire male production systems could provide significant benefits to the beef industry today by decreasing age at slaughter and decreasing feed costs. If entire male cattle were produced to the same market specification as castrated males and marketed at the same price, I hypothesised that the advantages associated with beef from entire male production would yield greater economic returns compared to a traditional castrated male production system from North West Queensland.

Typical of the North West Queensland region, the mustering of cattle for branding and marking occurs throughout the dry season usually in two or three intensive mustering periods. The second round mustered calves are usually smaller in liveweight and age than the first calves mustered for the season, and subsequently, leave the producer with the task of carrying these animals for another wet season. The implications for this are that the marketing options are reduced for these animals often tying the producer to an industry price cycle of lower prices offered for these animals. An analysis was conducted of the economics of using entire male cattle from a second round muster as a production strategy to increase profits within this cohort of animals.

3.3 Materials and Method

Assessing the difference in gross margins of a *Bos indicus* herd where the male progeny from an annual weaning round was either left entire or castrated was analysed using formulated spreadsheets and Breedcow herd budgeting software (Holmes, 2009). A steady state herd model was used to test the profitability of the alternate management systems. The case study was based on a northern cattle operation supplying grain finished beef for the domestic market. The production system was integrated into three divisions; the breeding, the backgrounding and the feedlot phases. Upon exit of each of the three sectors cattle were valued at entire or castrated male market prices. These exit or sale values were then used as entry or purchasing prices for the subsequent sector of the production system. The breeding phase prices were sourced electronically from the Gracemere saleyards website (Central Queensland Livestock Exchange, 2009). The backgrounding phase prices were sourced from market reports published electronically from Meat and Livestock Australia (Meat and Livestock Australia, 2009b). The feedlot phase exit prices were sourced from a JBS Swift price grid and were based on dressed carcass weights (JBS Swift and Company, 2009). All sources for exit prices in the model were sourced on 11 June 2009.

Herd structure was determined using findings from a published survey conducted across North Queensland (Bortolussi et al., 2005a). The survey compared production parameters including reproduction rates, calving patterns, weaner and supplementation practises across various regions (Bortolussi et al., 2005a). The case study herd was modelled on a hypothetical 1200 cow breeder operation. The assumptions of production parameters for the case study are outlined in Table 3.1. It was assumed year round mating was typical to the region with the majority of conceptions occurring in either the early or late stages of the wet season (Holroyd et al., 1979).

Table 3.1. The Breedcow model assumptions for the breeding, backgrounding and feedlot finishing phases of the production system

Breeding Phase		
Region	Gulf of Carpentaria	
Herd genotype	*Bos indicus*	
Branding %[A]	*Castrated*	*Entire*
- 1st calf heifers	76%	76%
- 2nd calf heifers	59%	59%
- cows	67%	67%
- herd average	69%	69%
Breeder death rate	7%	7%
Weaner death rate[A]	10%	10%
Maximum male turnoff age	3	3
Cow culling age	9	9
Sale weight live – traded	170 kg	170 kg
Sale price/kg live	$1.90	$1.22
Sale price/head net	$323.30	$208.09
Backgrounding phase		
Region	North Western QLD	
Purchase weight live	170 kg	170 kg
Purchase price/kg landed (includes transport)	$2.09	$1.41
Purchase price/head landed	$355.00	$240.00
Mortality	1%	1%
Days on forage	335	335
Average Daily Gain kg/head/day	0.39	0.39
Sale weight live – traded	300 kg	300 kg
Sale price/kg live	$1.42	$1.04
Sale price/head net	$426.00	$312.00
Feedlot phase		
Region	Western Darling Downs	
Purchase weight - live	300 kg	300 kg
Purchase price/kg landed (includes transport)	$1.63	$1.25
Purchase price/head landed	$489	$375
Mortality	1%	1%
Dressing %	55%	60%
Days on Feed	70	70
Average Daily Gain kg/head/day	1.5 kg	1.75 kg
Yard fees (inc. fed costs/day)	$3.00	$3.00
Market specifications		
Weight – live	400 - 450kg	400 – 450kg
Fat cover (P8)	5 - 12 mm	0 – 32mm

A (Donaldson, 1962)

The case study herd had a carrying capacity of 2,264 head of cattle and it was assumed the system was managed as a typical operation of the region. The Breedcow model accounted for an unweaned calf by calculating an Adult Equivalent (AE) rating for a lactating cow and calf unit of 1.35. It was assumed that there would be no difference in the structure of the herd for the alternate turnoff strategies. The model predicted an annual turn off of 831 weaners with a heifer retention rate higher than the district average at 76% (Table 3.2).

Table 3.2. The breeding herd structure calculated by the Breedcow model at weaning

Total breeders mated	1200
Total cattle carried	2264
Total adult equivalents (AE)[A]	1758
Total calves weaned	831
Total cows/heifers sold	290
Total entire/castrates sold	367
Heifer retention rate	76%

[A]An adult equivalent of 1 is defined as a non-pregnant, non-lactating beast of 455kg carried for 12 months.

3.3.1 Breeding Phase

The breeding herd was based on a property within the Gulf of Carpentaria region in far North West Queensland. There are two distinct spikes in the incidence of cow conception patterns in northern breeding herds that occur during the start and end of the wet season (Holroyd et al., 1979). This case study seeks to evaluate the viability of sourcing entire and castrated male calves from a second round muster. It was assumed that the second round muster took place in September-October where calves were to receive a clostridial and botulism vaccine, identification and NLIS tag, a property brand and be dehorned if required. The case study investigated the profitability of leaving male calves entire or to surgically castrate at this point. Following branding, calves were to be 'mothered up' and be managed in the breeding unit until weaning. Weaning occurred during the subsequent muster or between March-April where the calf is expected to obtain a liveweight of 170 kg (Bortolussi et al., 2005a). Typical of the

region, once weaned, calves were transported by road and grown out on more fertile country. Calves entered the backgrounding phase at this point.

3.3.2 Backgrounding Phase

It was assumed calves would be grown out on the Mitchell grass downs of north western Queensland to a target weight of 300 kg at two years of age. With expected growth rates of 0.15 kg/day during the dry season and 0.60 kg/day during the wet season, the backgrounding phase was likely to take 334 days to achieve desired weights (McDonald. A, 2010). Daily liveweight gains were expected to be similar between groups due to no pre-pubertal differences in growth (Wainewright et al., 2009a). In addition, the liveweight gains used in the model were supported by the data published by Bortolussi *et al.* (2005b).

3.3.3 Feedlot Phase

The analysis of time spent on feed was undertaken using formulated spreadsheets that accounted for input expenses, a fixed starting price and variable end prices. Following backgrounding it was assumed calves were transported 1500 km by road to enter the feedlot phase. The extensive distance travelled between backgrounding and finishing was justified by the feedlot's close proximity to the processing facility. In accordance with domestic carcass specifications, the feedlot model was run assuming both entire and castrated male cattle would be fed for 70 days. Based on evidence suggesting entire males gain faster and convert feed more efficiently than castrates (Field, 1971), the case study accounted for entire males cattle to gain an extra 0.25 kg/day compared to castrates for the same amount of feed consumed. It was therefore assumed that feed costs remained constant for the entire feeding period for both groups.

3.4 Results

Producing entire males marketed at the same price grid as castrates was the most profitable production system. However, when entire males were marketed at the discounted grid price normally awarded to carcasses from an entire male, total enterprise gross margin was less than a system producing castrated male cattle (Table 3.3). The breeding herd analysis at weaning demonstrates that an enterprise producing castrated male calves under the current pricing model will yield a greater herd gross margin and gross margin per AE compared to a system producing entire male calves valued at the market price for entire males (Table 3.3).

Table 3.3. The economic status of the herd at the breeding, backgrounding and feedlot finishing phases of the production system when entire male progeny are valued at the entire male market price (i) or at the castrated male market prices (ii) and castrates are valued at the castrated male market price

	Castrate	Entire (i)	Entire (ii)
Weaning phase			
Net cattle sales	$232,765	$188,673	$232,765
Contribution of bull/steer sales	$118,614	$76,369	$118,614
Gross margin (GM) for herd	$166,006	$123,751	$166,006
GM after interest	$92,560	$54,310	$92,560
GM per AE	$94.44	$70.40	$94.44
Backgrounding phase			
Gross margin/hd	$66.44	$69.18	$66.44
Gross margin/AE/yr	$140.58	$146.84	$140.58
GM for bull/steer backgrounding phase	$24,117	$25,112	$24,117
Feedlot phase			
Gross margin/hd	-$124.38	-$53.86	-$41.36
GM for castrate/entire finishing phase	-$44,652	-$19,335	-$14,848
Combined gross margins			
Total GM	$145,471	$129,528	$175,275

The gross margin/hd and gross margin/AE was greater for an entire male production system in the backgrounding phase compared to a castrate production system when valued at current market prices. Under the same induction and feeding regime entire male cattle marketed at entire male grid prices and castrated male grid prices had lower break even prices ($/kg cwt) compared to castrated animals. The lower break even prices of entire males compared to castrates were driven by higher carcass yields and lower starting values per head (Table 3.4).

Table 3.4 . A break even analysis upon feedlot exit assuming entire males are (i) marketed at entire male grid prices and (ii) marketed at castrate grid values and castrates valued at castrates grid value[A]

	Castrate		Entire (i)		Entire (ii)	
Yards fees	$/hd	$/cwt	$/hd	$/cwt	$/hd	$/cwt
$2.50	$688.78	$3.10	$573.46	$2.27	$689.46	$2.72
$3.00	$723.78	$3.26	$610.46	$2.41	$724.46	$2.86
$3.50	$758.78	$3.42	$645.46	$2.55	$759.46	$3.00
$4.00	$797.43	$3.59	$685.08	$2.70	$799.08	$3.15
$4.50	$832.43	$3.75	$723.08	$2.85	$834.08	$3.29

[A]Assume feedlot entry prices were $375 for an entire (i) and $489 for an entire (ii) and $489 for castrates. Assume induction costs $7/hd (no HGP) and transport from the feedlot is valued at $17.78/hd for castrates and $18.46/hd for entire males. End values are assuming a castrates produces a 222kg carcass and an entire male produces a 253kg carcass after the 70d feeding period.

3.5 Discussion

Entire males produced to a domestic carcass specification and paid under the same price grid as castrated males yield greater combined gross margins compared to a traditional production system supplying castrates. However, when entire male cattle were valued at entire male market prices throughout the growing and backgrounding phases of the operation they were less profitable than a traditional system producing castrated male calves. Profitability for all phases of the production system was driven largely by higher end market values per head. The key variables that impact upon this profitability were starting and finishing values per head. A contributing factor to the profitability of the entire male enterprise when marketed under the castrated or entire male price grid was the higher dressing percentages. Entire male cattle produce a carcass that has approximately 5% greater carcass weight compared to castrates (Field et al., 1966, Arthaud et al., 1969, Purchas et al., 2002). The benefits of entire male cattle on growth rate may be reduced if the comparison was made with a castrated animal subjected to an aggressive hormonal growth promotant implant regime. However, the current domestic market push for hormonal growth promotant free beef would suggest that the carcass gain from an entire male cattle finishing system will become an important strategy for Northern beef production systems.

The current pricing grid that is offered to producers by the meat processing industry requires the carcass to fit a number of categories, if it does not qualify for GFYG under Ausmeat selection criteria. These categories include carcass weight, dentition, fat depth, muscle shape and a quality grade. The window of acceptance for these parameters is substantially tighter when selling castrated compared to entire male cattle. For example, a price grid for entire males includes a fat depth of 0-32 mm, dentition of 0-8 teeth and muscle shape of A-D. Whereas the price grid for castrates is more specific, requiring a fat depth of 5-12 mm, dentition of 0-2 teeth and a muscle shape of A-C (JBS Swift and Company, 2009). The resulting difference is a significantly higher price paid per kg for castrated animals. With the fat depth requirement of 0-32 mm for bulls (Table 3.1), I suggest once the desired liveweight is achieved entire males can be turned off, regardless of the level of finish or fatness if manufacturing beef is the targeted market. However, time on feed constraints such as the 70 day requirement for the domestic grain fed young beef market may negate an earlier turn-off from the feedlot (Ausmeat, 2011). In the current case study entire males achieved the same

target weight 10 days earlier than castrated cattle. This is supported by others who demonstrated that superior gains from entire males resulted in target weights being reached sooner than castrates (Nichols et al., 1963). Although still recording a loss during the feedlot phase, entire males outperformed castrates males in both production and gross margin indices. The feedlot gross margins for the entire male production systems were -$19,335 and -$14,848 when valued at the entire and castrated price grids respectively (Table 3.3). Although entire males received lower end market values in this model, the higher margins and lower break even prices were influenced by superior daily gains and lower entry values to the feedlot compared to castrated males (Table 3.4). The superior daily gains in the feedlot by entire males compared to the pasture based phases of the model is supported by the fact that as the plane of nutrition increases the androgen activity within the animal also increases resulting in attributes such as increased growth rates and increased muscle accretion (Mickan et al., 1981). The profitability of the feedlot phase is further enhanced through a rapid turnover of animals. However, within the steady state models used for this analysis, the degree of profitability due to increased livestock turn-over is unknown.

The case study merges the breeding, backgrounding and finishing sectors into one enterprise. Therefore, the opportunity cost of selling and buying animals at market value between sectors is absorbed by the business. In assessing the performance of the sectors individually, it was clear that a system producing castrated males had higher gross margins throughout the breeding phase, yet were outperformed by the entire male enterprise in both the backgrounding and feedlot phases under the current pricing model. The superior value of castrated cattle compared to entire males and the assumption that there was no difference in mortality rate in the backgrounding sector led to entire males having greater gross margins using current prices. The data suggest that producers could achieve improved gross margins when buying entire male cattle opportunistically to be backgrounded and finished in accordance with domestic market requirements compared to castrates. However, the value of castrated males as yearlings or trade cattle is greater than entire male cattle and subsequently a shortage in supply of entire male cattle may be encountered in the store cattle market. It is possible that a supply of trade animals may come from young uncastrated males from the pastoral regions of northern Australia. In addition, a further opportunity exists for the establishment of a supply chain arrangement for feedlots and meat processors where

prices for entire male cattle could be pitched to equal the profitability of system producing castrated cattle.

3.6 Conclusion

The future acceptance of beef from grain fed entire male cattle under Australian conditions is largely unknown. The percentage of beef produced from entire males in European and New Zealand industries and the influence of animal welfare groups suggest that the sustainability of entire male grain fed beef will be closely reviewed again in the future. In addition it is concluded that the production of beef from entire male cattle in a north Australian production system is profitable if entire males can be sold without discount relative to castrates.

CHAPTER 4

THE ON-FARM PERFORMANCE OF ENTIRE MALE AND CASTRATED *BOS INDICUS* CATTLE IN A NORTH AUSTRALIAN PRODUCTION SYSTEM

4.1 Abstract

The on-farm performance of entire male and castrated *Bos indicus* cattle was investigated in a north Australian production system. The experiment tested the liveweight performance, live carcass traits and temperament of entire and castrated male cattle that were either negatively or positively homozygous or heterozygous for the calpastatin gene. There was no difference in liveweight between entire or castrated males prior to the onset of puberty, however, entire males grew 27% faster than castrates in the post-pubertal phase ($P < 0.05$). Coinciding with the marked growth response in entire males, castrated males had a significantly higher rib fat percentage ($P < 0.05$). Both entire and castrated males that were negatively homozygous or heterozygous were significantly heavier ($P < 0.05$) than animals that were positively homozygous for the calpastatin gene. Contrary to industry belief, there was no difference in flight score between entire or castrated male cattle. In conclusion entire male cattle can be successfully managed and can grow faster than castrates in the post-pubertal phase in a north Australian production system. Furthermore selecting animals that are negatively homozygous for the calpastatin gene in an attempt to improve meat tenderness can potentially improve the profitability of a north Australian beef enterprise.

4.2 Introduction

The performance of any commercial beef enterprise is driven by a number of variables including genetics, management and nutrition. Although the science and understanding of each of these variables is complex, they each influence liveweight gain. Liveweight gain is the most important production parameter of any beef enterprise. Reducing the age of cattle at the point of sale but maintaining liveweight and hence carcass weight is a strategic priority for the industry's peak body Meat and Livestock Australia (Meat and Livestock Australia, 2010b).

Livestock industries have struggled to compete with other industries in terms of productivity improvement rates in recent years (Meat and Livestock Australia, 2010b). This fact combined with a declining terms of trade, extreme seasonal conditions and rising input costs has led to livestock producers needing to increase on farm efficiency in order to remain sustainable. Thus highlighting the need for producers to understand, adopt and engage in new and more efficient technologies and practises to sustain on farm profitability.

The use of HGP's to increase the liveweight of beef cattle is an accepted practise within the Australian beef industry that yields an additional AUD $50 per domestic carcass (Hunter, 2010). However, the current stance by the two major food retailers to the Australian domestic market for hormone free beef will result in a loss of the use of this technology to producers catering to the domestic market. This will reduce the opportunistic income previously received from the use of HGP's. In addition, the age of cattle at slaughter will increase and the system will impose penalties to beef producers for increased ossification and age specifications. However, the anabolic affect of naturally produced hormones that sexually mature entire males' exhibit would produce faster growth rates and a resulting heavier carcass at the point of sale. Moreover, beef producers would save on the cost of HGP's and be able to meet domestic market specifications.

The following chapter investigates the liveweight, live carcass traits, temperament and genotypic interactions between entire and castrated male cattle over time. The experiment was conducted over a 512 day period to determine if entire males of various genotypes compared to castrates could be managed and successfully incorporated into a

beef production system in northern Australia. It was hypothesised that the anabolic affect of naturally produced hormones in sexually mature entire male cattle would result in higher liveweight gains compared to castrated males from the same commercial herd.

4.3 Materials and Methods

The experiment was conducted across two sites in Queensland, Australia. The experimental cattle were sourced and grown out on Fletcherview research station (20°04.603´ S / 146°15.802´ E) before being relocated to be grain fed at the Wallumba feedlot (26°39.747´ S / 150°9.906´ E). Fletcherview research station is located 27 km NW of Charters Towers where the region is defined as having a tropical environment with an annual rainfall of 668 mm (Bureau of Meteorology, 2009). Wallumba feedlot is located south of Miles in the western downs of south east Queensland. The climate is considered tropical with an annual rainfall of 653 mm (Bureau of Meteorology, 2009). The project protocol was approved by the James Cook University Ethics Committee, approval number A1424.

4.3.1 Animals and treatments

Male progeny (n = 80) were sourced from the Fletcherview Brahman herd in March 2009. All calves had a hair follicle sample taken and were tested for commercially available gene markers for beef tenderness at a laboratory in Brisbane (Pfizer Animal Health, 2009). The analysis identified animals that were either negatively or positively homozygous or heterozygous for calpastatin. Calves were stratified by weight and DNA marker status to treatment groups; entire or castrated male, in a 2 X 3 factorial design with entire males and castrates that were either positively homozygous, heterozygous or negatively homozygous for the calpastatin gene as the factors. The design was restricted by the power test given the genetic pool of available animals. There were only 12 animals out of a possible 80 were homozygous positive for the calpastatin gene and as a consequence, the starting liveweight of this genotype, for both entire males and castrates, was numerically lower than the liveweight of animals that were homozygous negative or heterozygous for the calpastatin gene. Calves were branded, tagged, dehorned, vaccinated and calves that were allocated to the castrate treatment group were surgically castrated in May 2009. Weaning took place two weeks after processing in an attempt to reduce the stress induced upon on the animal. Calves were approximately 5-7

months-old (Figure 4.1) when weaned and grown out or 'backgrounded' on Buffel grass pastures (*Cenchrus ciliaris*). Calves were between 18-21 months-of-age before they achieved the mean feedlot entry weight of 300 kg. Both treatment groups had access to a commercial supplement (phosphorus, calcium and urea) during the dry season (April-October) to improve pasture utilisation and control body weight.

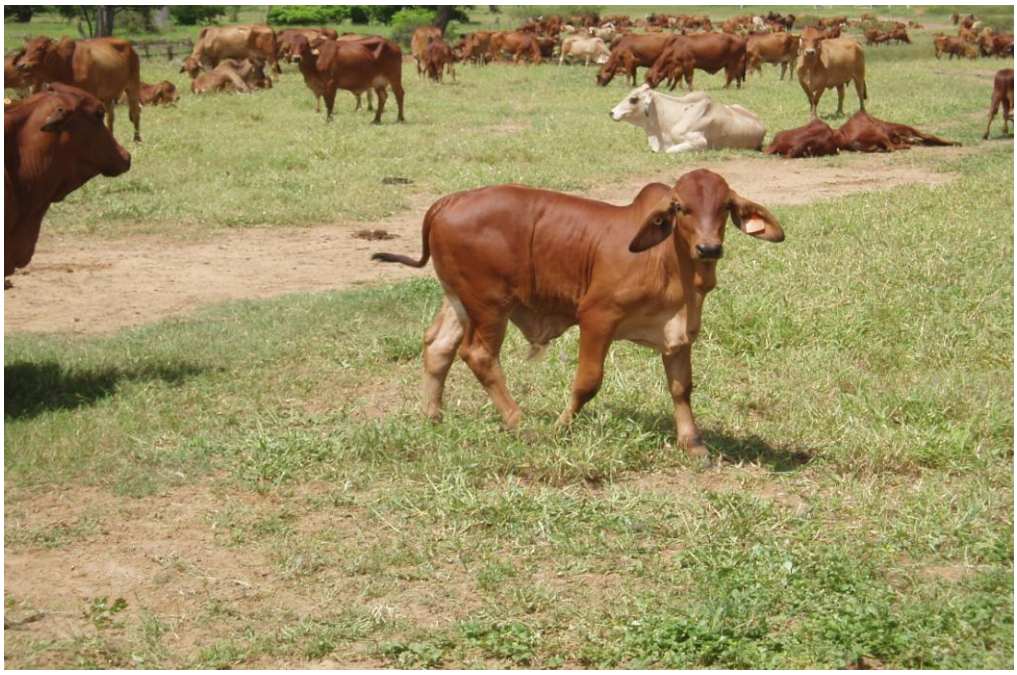

Figure 4.1. The cows and calves prior to weaning at the Fletcherview research station

Following backgrounding cattle (n = 80) were relocated approximately 1100 km to a commercial feedlot to be within close proximity to the selected processing facility. Upon arrival cattle were subject to standard industry induction protocols where they were drenched, ear tagged and received a vaccination against Bovine Respiratory Disease (BRD). Contrary to the industry protocol, however, neither treatment group were implanted with a HGP. This step was taken to remove any confounding factors that may influence the original research question of measuring the profitability, growth, carcass and meat quality of entire *vs.* castrated male cattle. The entire consignment was drafted into one yard for the whole feeding period to avoid social and behavioural stress that is apparent when mixing mobs. Cattle were fed a barley and sorghum grain blend for 70 days to comply with the Ausmeat standard for certified grain fed beef for the domestic GFYG market. The carcass specifications required to supply into this market included a dressed weight of 200-250 kg and a fat depth of 5-12 mm between the 12th and 13th rib.

4.3.2 Data collection

Cattle from both treatment groups were weighed every 2-3 months throughout the duration of the study. Cattle were muscle and fat scanned in approximately 60 days intervals using an ESAOTE Pie medical ultrasound with a 3.5 MHz backfat probe (Gresham, ND). Images were taken from a cross-section scan at the 12th and 13th rib (Figure 4.2), measuring the eye muscle area and subcutaneous fat depth (Gresham, ND). An image of the rump site was also measured for fat depth.

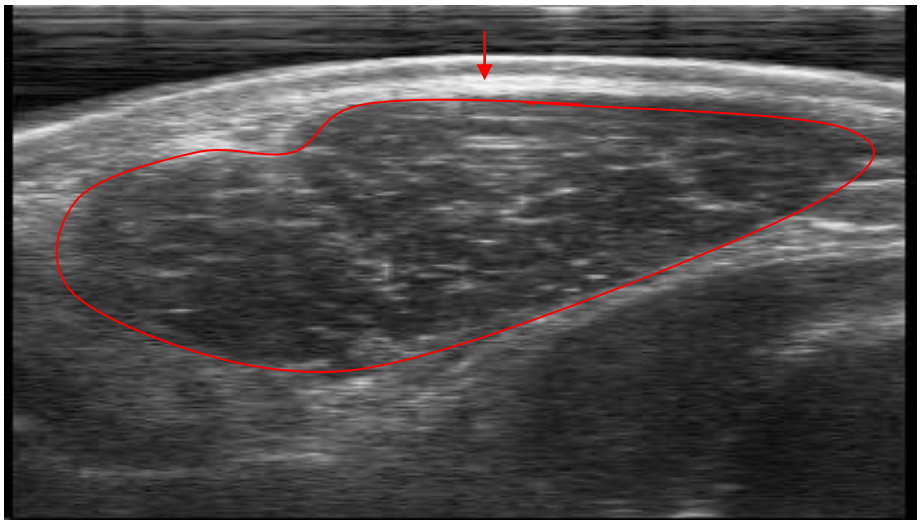

Figure 4.2. The image of the eye muscle area (encircled) and fat thickness (arrow) as displayed on the ESAOTE Pie medical ultrasound using a 3.5MHz backfat probe

Flight speed was taken by measuring the time taken, in hundredths of a second, for entire and castrated males to break an infra-red beam from two lasers placed 2m apart located 0.5 m from the exit of the crush (Burrow et al., 1988). Flight score is an objective measurement of temperament where a quicker speed may indicate an undesirable temperament (Meridy et al., 2006). Flight speed was measured in December 2009. Cattle were held in the crush, without having their head restrained, for approximately 10s and aloud to exit the crush unassisted. Cattle were not exposed to weighing or scanning prior to having their flight score measured.

4.3.3 Statistical design and analysis

The experiment was a 2 X 3 factorial design with entire males and castrates that were either positively homozygous, heterozygous or negatively homozygous for the calpastatin gene as the factors. Each individual animal was an experimental unit. Results

were based on REML models with castrate or entire treatment, calpastatin and day as fixed effects with animal ID as a random effect. All interactions were considered in the analysis and those determined to be non-significant were re-run through the statistics model before being removed from the thesis. All modelling and significance tests were performed in Genstat and all means produced were based on the fitted values from these models. 2-way ANOVA's were conducted with starting liveweight as a co-variant for final liveweight and carcass weight to ensure a bias was not affecting results. The co-variant analysis demonstrated no change to the outcome of the original analysis and was subsequently removed from the results.

4.4 Results

Table 4.1. The REML fitted means of liveweight for entire and castrated male cattle that were either positively homozygous, heterozygous and negatively homozygous for the calpastatin gene over time*

Treatment	Genotype	n	DAY 0	55	89	113	136	172	235	297	417	465	512
Entire	homo +	6	92^{a}	134^{a}	152^{a}	158^{a}	170^{a}	164^{a}	172^{a}	203^{a}	299^{a}	310^{a}	339^{a}
	hetero	18	122^{b}	165^{bc}	186^{b}	197^{b}	210^{b}	201^{b}	208^{b}	241^{b}	343^{b}	366^{b}	389^{b}
	homo -	17	120^{b}	168^{b}	186^{b}	197^{b}	210^{b}	206^{b}	215^{b}	241^{b}	344^{b}	355^{c}	395^{b}
Overall		41	111^{ab}	156^{c}	175^{c}	184^{c}	197^{c}	190^{c}	198^{c}	229^{c}	329^{c}	340^{d}	374^{c}
Castrate	homo +	6	102^{ab}	153^{c}	174^{c}	183^{c}	193^{c}	189^{c}	193^{c}	223^{c}	325^{c}	337de	351^{d}
	hetero	19	118^{ab}	165^{bc}	185^{bc}	191^{bc}	207^{b}	200^{b}	210^{b}	233^{bc}	328^{c}	341^{d}	372^{c}
	homo -	14	116^{ab}	159^{bc}	174^{c}	183^{c}	195^{c}	190^{c}	204^{bc}	223^{c}	312^{d}	329^{e}	360^{d}
Overall		39	112^{ab}	159^{bc}	178^{bc}	186^{c}	198^{c}	193^{bc}	202^{bc}	226^{c}	322^{c}	336de	361de
LSD			26	9	9	9	9	9	9	9	9	9	9

^{a,b,c,d,e} Means in the same column with superscripts that do not have a common letter differ ($P < 0.05$)

*The co-variant analysis showed that starting liveweight did not affect final liveweight between castration treatment and genotype (Appendix xxvi)

There was a significant 3-way interaction between castration treatment, genotype and day ($P = 0.035$)

Table 4.2. The means of rib fat (mm) measured at the 12th rib for entire and castrated males from day 113 to 512

Day	n	**113**	**172**	**235**	**297**	**417**	**512**
Entire	41	0.24[a]	0.19[a]	0.29[a]	0.31[a]	0.39[a]	0.51[a]
Castrate	39	0.23[a]	0.17[a]	0.26[b]	0.29[a]	0.40[a]	0.55[b]
LSD		0.029	0.029	0.029	0.029	0.029	0.029

[a,b] Means in the same column with superscripts that do not have a common letter differ ($P < 0.05$)

Rib fat measurement demonstrated a significant interaction between castration treatment and day ($P < 0.001$). Entire males had significantly lower rib fat measurements at day 512 compared to castrates, however, castrates had less rib fat than bulls at day 235. There was no significant difference between the three genotypes ($P = 0.9$). There was a drop in rib fat from day 113 to day 172 due to poor pasture quality and a late break to the wet season.

Table 4.3. The means of Eye Muscle Area measurement (cm^2) for entire and castrated males

	n	EMA
Entire	41	43.32
Castrate	39	42.77

Eye muscle area did not differ throughout the growth period with no differences between castration treatment and genotypes for these variables.

Table 4.4. The means of flight score (secs) for entire and castrated males at 12-14 months of age that were either positively homozygous, heterozygous and negatively homozygous for the calpastatin gene

	n	homozygous +	heterozygous	homozygous -
Entire	41	0.95	0.93	0.89
Castrate	39	0.86	1.18	0.82

Flight score demonstrated no interaction between castration treatment and genotype. In addition, there were no differences between the three genotypes or castration treatment (Table 4.4).

4.5 Discussion

4.5.1 Genotype

Animals that were either negatively homozygous or heterozygous for the calpastatin gene were heavier ($P < 0.05$) than animals that were positively homozygous at the final weighing event (Table 4.1). The growth pattern for both entire males and castrates and the three genotypes shows a parallel pattern throughout the experiment. However, entire males that were positively homozygous had the lowest liveweight throughout ($P < 0.05$) and at the completion of the experiment ($P < 0.05$). It must be stated, however, that although an attempt was made to balance the design on marker status, the low frequency of animals that were positively homozygous created an unavoidable imbalance. Therefore, starting liveweight was used as a co-variant in showing that the imbalance in design did not affect final liveweight outcomes (Appendix 27). Café et al., (2010) encountered similar problems in a study involving a Brahman herd, which may suggest there is a low frequency of such genes in *Bos indicus* populations. There was no difference in liveweight between entire males that were either negatively homozygous or heterozygous, however, in contrast, castrated males that were heterozygous were heavier than castrates that were negatively homozygous for the calpastatin gene ($P < 0.05$).

In explaining these data it has been reported that entire male cattle can record up to 80% higher calpastatin activity compared to castrates (Morgan et al., 1993a). Higher calpastatin concentrations in muscle have also been associated with increased protein synthesis. *M. Longissimus dorsi* and *M. Semimembranosus* from lambs with the callipyge gene were reported to have greater levels of calpastatin concentrations and muscle weights were 40% heavier than lambs without the gene at slaughter (Duckett et al., 2000). These conclusions were unable to explain the result seen with entire males in the present study, as entire males that were positively homozygous had lighter live weights compared to negatively homozygous animals. Therefore, based on the outcome

of the present study, selecting entire male cattle that are positively homozygous may reduce growth potential.

Entire male cattle that were positively homozygous for the calpastatin gene were the only entire male group to be lighter ($P < 0.05$) than castrates in the corresponding genotype at the final weighing event. Although the genomic relationship is largely unknown, it is proposed that there is a gonad x calpastatin interaction that may explain much of the variation in liveweight. It may be that the calpastatin gene interferes with the anabolic processes of entire males or perhaps influences the maturity pattern that affects puberty. This is an area in need of further investigation.

The genotypes of the animals within the experiment were tested in the Pfizer laboratory and this service is available to commercial producers who endeavour to select for meat tenderness as a breeding objective. In improving meat tenderness, it is advised that producers select animals that have lower levels of calpastatin. Thus, producers should select animals that are negatively homozygous for the calpastatin gene. In addition to the potential meat tenderness benefits in selecting animals that are negatively homozygous for the calpastatin gene, both entire and castrated males of this genotype in the present study produced heavier live weights at the completion of the experiment (Table 4.1). This result has not previously been seen in the literature and is in need of future investigation. Further investigation is also required to define the economic benefit for producers to select for, and produce a product that is deemed 'more tender'.

4.5.2 On-farm performance

Liveweight performance between entire and castrated male cattle over time is presented in Table 4.1. The liveweight changes between the entire males and castrates over time show a parallel growth pattern. Although the overall mean liveweight of entire males began to show a numeric advantage over castrates from 297 days, it wasn't until 512 days that there was a difference ($P < 0.05$). The animals were approximately 19-21 months-of-age at the final weighing interval. These data support previous findings by Bailey *et al.*, (1966) and Kellaway (1971) who suggested that no differences in liveweight would be seen between entire and castrated male cattle prior to the onset of puberty.

Although the exact point in time that the animals in the present study reached puberty is unknown, the marked growth response of entire males suggest that the animals reached this point sometime between 17-21 months of age. These data are supported by studies that found Brahman entire male to reach puberty between 16-17 months of age (Silva-Mena, 1997). That study noted however, that there was considerable variation in the age of entire males reaching puberty with perhaps body weight a more accurate indicator of sexual maturity (374 kg ± 22.5 kg). This is supported by Mukasa-Mugerwa (1989) who states, that puberty is influenced by body weight and growth pattern rather than age or a specific point in time. This may help explain the later onset of puberty in both entire and castrated male cattle in the present study (374 kg *vs.* 361 kg at 17-21 months).

In further explaining the later onset of puberty in the present study, mean liveweight for both entire and castrated male cattle in Table 4.1, indicate that the cattle experienced a slowed growth rate from 89 days through until 235 days. This period coincides with poor feed quality that comes with managing tropical pastures in northern Australia through the dry season. As discussed in earlier chapters, failing to reduce the age at the point of sale will affect not only meat quality traits but profitability. In maximising these outcomes, cattle in the present experiment, which were representative of the northern industry, should have been fed an energy supplement throughout this period of poor nutrition. It is logical to assume that an earlier onset of puberty may have taken place and the benefit as measured in liveweight would have been greater at an earlier age for entire males compared to castrates.

The pronounced growth response of entire males compared to castrates ($P < 0.05$) from the final weighing event was driven by a hormonal response in sexually mature entire males and an elevated level of nutrition. The liveweight changes between entire and castrated male cattle were further enhanced at this point as the overall mean of the last weighing interval represented a 27% growth advantage in favour of entire males. These data are higher than what has been previously stated by Field (1971), who found across 14 studies that post-pubertal entire male cattle grew on average 17% faster than castrates. In explaining this difference, it is suggested that combined with the onset of puberty the animals in the present study may have experienced some compensatory gains in the first few weeks of the feedlot. In the two months prior to entering the feedlot entire male cattle experienced a more severe growth restriction compared to

castrates (239 g/day vs. 291 g/day). This theory is supported by Hornick et al.,*(2000)* who suggests "the simultaneous occurrence of puberty with re-feeding can exert a synergistic effect on growth". Furthermore, 40 years of genetic improvement may have also contributed to this result.

Castration took place when the calves were approximately 4-5 months-of-age. This did not have any negative affects on growth between entire males and castrates ($P > 0.05$). The overall means from the following weighing interval showed the same numeric difference in liveweight compared to the weighing interval prior to the procedure (Table 4.1). Lent *et al.*,(2001) revealed similar findings when castrating 2-3 month-old calves. No differences in average daily gain occurred between castrates and entire male calves for the 28 days post-surgery. In contrast, ZoBell et al.,(1993) stated that eight month old entire male cattle gained 68-73% more liveweight than castrates in the 50 days following the procedure. These data suggest that in the present study, the castration or sex effect had little impact on the growth of the either castrates or entire males given the appropriate timing of the operation.

Both castrates and entire males began to increase the deposition of rib fat (RF) from approximately 18-21 months of age (Table 4.2). The pattern of fattening shows an almost parallel trend between entire males and castrates and a strong visual correlation with liveweight and subsequent maturity. Entire males deposited more fat ($P < 0.05$) compared to steers at approximately 10-12 months, or at day 235. The reason for the difference is unknown, however, entire males were numerically fatter than castrates during much of the pre-pubertal phase.

Coinciding with the estimation in the timing of puberty, castrates showed signs of increasing the level of rib fat deposition compared to entire males at approximately 17-21 months. The final scanning event, which occurred after 47 days in the feedlot, showed castrates to be significantly fatter than entire males ($P < 0.05$). These data coincide with past research that suggests that castrated male cattle will partition more fat than entire males during the post-pubertal phase (Bailey et al., 1966). Another contributing argument to the degree of fattening between castrates and entire males can be explained by Hornick et al.,(2000), who suggested that following a period of

compensatory gain the cattle may be predisposed to a higher level of fattening. It is thought this outcome may be more pronounced in castrates compared to entire males.

There was no difference in Eye Muscle Area (EMA) between castration treatment groups ($P = 0.5$) or genotype ($P = 0.3$) (Table 4.3). Given there was a difference in liveweight ($P < 0.05$) between castrates and entire males at the final weighing event, it was hypothesised there may be a corresponding difference in EMA. Johnson et al., (1986) supported this hypothesis where it was reported that correlations between liveweight and EMA had a moderate relationship ($r = 0.34$). These results may be explained by the findings from Brackerbusch *et al.,* (1991), who found that the *M. Longissimus dorsi* muscle, where the EMA is measured, only accounts for 3.5% of the total carcass weight in cattle. It is known that entire males develop the muscles in the neck, shoulders and rear legs post-puberty and it is anticipated that the majority of the weight advantage for entire male cattle is within these muscle groups of the live animal. In further explaining the outcome, Stolowski *et al.,* (2006) found that the *M. longissimus dorsi* has low levels of calpastatin, which has been linked to higher rate of protein synthesis (Duckett et al., 2000).

4.5.3 Behaviour

There were no differences in flight score between castration treatment, genotype or any interaction between these variables (Table 4.4). These data in the present study is contrary to previous work that suggests that entire male cattle have a less desirable temperament when compared to castrates (Seideman et al., 1982). In previous work, however, behavioural issues were apparent for pubertal and post-pubertal entire male cattle (Seideman et al., 1982). This may be supported by the assumption that both entire and castrated male cattle in the present study didn't reach puberty until 17-21 months. These cattle were only 12-14 months at the time flight score was recorded (Figure 4.3).

Figure 4.3. The picture illustrates the physical development of the cattle at approximately 12-14 months of age

Flight score was only recorded once throughout the duration of the experiment as it has been shown to be a highly repeatable measurement over time (0.46) (Meridy et al., 2006). Given the impact puberty has been shown to have on behaviour of entire male cattle, it may be argued that another measurement should have been taken in the post-pubertal phase prior to slaughter. However, given both entire and castrated males remained in the same cohort for the entire experiment combined with the frequency of handling, it is concluded that flight score would have remained highly repeatable.

In further explaining why there was no difference in flight score between either castrates or entire males, it is suggested that the social hierarchy had already been established given the herd had remained together since weaning. Mornier *et al.*, (2006) recommended that bulls could be successfully incorporated into a finishing production system provided they are not constantly subjected to unfamiliar animals and environments. It was noted in both the research conducted by Mornier *et al.*,(2006) and the present study, that entire males were not aggressive and showed no signs of anxiety compared to castrates when separated from the group and/or handled. Mornier *et al.*,(2006) attributed this type of behaviour to an already established social hierarchy.

Historically, specialised producers of beef from entire male cattle suggested that there was no problem in the handling, husbandry or incidences of herd injuries when comparing an entire or castrated male cattle production system (Hinch and Thwaites, 1979). These findings are well supported by the present experiment with only fence damage being a notable problem during the latter stages of backgrounding. It is thought this issue was attributed to older fences that were not electrified. It was also observed that age combined with handling frequency may have attributed to the good temperament of the entire male cattle in the present study. These observations may help explain the broader industry perception that entire male cattle that are difficult to handle are perhaps older, handled infrequently and are re-mixed before and after mating.

4.6 Conclusion

As hypothesised there was no difference in liveweight between castrates and entire males prior to the onset of puberty. Following puberty it was thought that an elevated level of nutrition combined with some compensatory gain led to a 27% growth advantage in entire over castrated male cattle. There was no difference in EMA between entire or castrated males to correspond with the marked growth response in entire males. It was concluded that low activity levels of calpastatin and the size of the *M. Longissimus dorsi* were major factors in this result.

Contrary to industry belief there were no behavioural problems associated with the production of entire male cattle. Some minor fence damage was evident late in backgrounding; however, this issue was easily resolved with appropriate management. In addition to these observations, there was no difference in temperament between castrates and entire males. It was concluded that cattle remaining in the same cohort, and the frequency of handling in this study contributed to the result. Given this result it is hypothesised that temperament will play little role in affecting meat tenderness. This hypothesis was tested in the results tested in the following chapter.

From the findings of this experiment it appears that the superior liveweight gains of animals that are negatively homozygous would potentially benefit the profitability of a north Australian beef enterprise. Both entire and castrated male cattle that were negatively homozygous for the calpastatin gene produced higher liveweight gains

compared to animals that were positively homozygous. The subsequent effect of castration treatment and genotypes on meat tenderness will be analysed and discussed in the following chapter to determine if selecting for animals that are negatively homozygous in an attempt to improve meat quality can decrease tenderness.

CHAPTER 5

THE CLASSIFICATION, QUALITY AND PROFITABILITY OF CARCASSES PRODUCED BY ENTIRE MALE AND CASTRATED *BOS INDICUS* CATTLE IN A NORTH AUSTRALIAN PRODUCTION SYSTEM

5.1 Abstract:

The classification, quality and profitability of carcasses from high grade grain fed *Bos indicus* entire and castrated males from a vertically integrated north Australian beef enterprise was investigated. The experiment analysed carcass and meat quality parameters and the subsequent grading and gross values between entire and castrated male cattle that were either positively homozygous, heterozygous or negatively homozygous for the calpastatin gene. Entire males produced a heavier carcass ($P = 0.005$) that had less marbling ($P = 0.001$) and were at a more advanced stage of maturity ($P = 0.007$) when compared to castrates. Entire male cattle also produced *M. Longissimus dorsi* samples that were lighter in colour ($P = 0.007$) and that were less tender after aging for 14 days ($P = 0.001$) and 28 days ($P = 0.005$). Entire males that were either heterozygous ($P < 0.05$) or negatively homozygous ($P < 0.05$) were heavier than castrates of similar genotypes while both entire and castrated males that were positively homozygous produced the lightest carcass weights. The objective grading model was unable to differentiate between carcasses from either entire or castrated males. Therefore, entire male cattle qualified for the GFYG descriptor under the Ausmeat selection criteria. The GFYG qualification combined with the heavier carcass weights resulted in entire males producing a carcass that had a superior gross value when compared to castrates ($P = 0.009$). Entire male cattle that were either negatively homozygous or heterozygous for the calpastatin gene can be produced profitably from a north Australian beef enterprise in accordance with domestic market specifications.

5.2 Introduction

The importance of meat quality in the Australian beef industry has been subject to much focus over the past three decades. The combination of increased competition for protein sources and the inconsistencies in beef eating quality has led to the dramatic decline in domestic beef consumption. The subsequent development of the MSA grading tool has further emphasised the focus the industry is placing on improving meat quality.

Alternate practices such as producing beef for the domestic market from entire males is poorly adopted under Australian conditions. With MLA encouraging producers to increase sale weights and reduce the age at the point of sale (Meat and Livestock Australia (MLA), 2010), the concept of producing beef from entire males warrants investigation under such conditions. Although the on-farm production and lean meat yield benefits of entire males are well documented (Seideman et al., 1982, Field, 1971), the current MSA grading tool fails to account for beef from entire males.

The conflicting argument between authors concerning the quality of meat from entire male cattle is significant (Seideman et al., 1982, Woodward et al., 2000, Morgan et al., 1993a, Arthuad et al., 1977). There is, however, enough evidence to suggest that differences in eating quality between meat cuts from entire and castrated male cattle would be undetectable. If so, with minor alterations to current on farm management and the adjustment of the discount relative to castrates, producing beef from entire males could be an alternative method of increasing farm profitability.

The following chapter analyses the differences in classification, quality and profitability of carcasses produced by entire males or castrated *Bos indicus* cattle. Analysis was undertaken to investigate interactions between castration treatment and genotype and the subsequent effect on the following carcass, quality and the economic parameters: tenderness, temperature and pH decline, carcass weight, rib fat, marbling, colour, grade and gross carcass value. It was hypothesised that entire male cattle would produce a leaner and heavier carcass that would be awarded a lower grade due to fatness and a more advanced stage of carcass maturity compared to castrates, with a subsequent pricing discount.

5.3 Materials and Methods

The field experiment was conducted across two sites in Queensland, Australia. The experimental cattle were sourced and grown out on Fletcherview research station before being relocated to be grain fed at Wallumba feedlot. The collection of meat samples took place following slaughter at a Dinmore processing facility, located west of Brisbane. Further analysis of the meat samples took place at the meat laboratory of the University of New England's Armidale campus. The project protocol was approved by the James Cook University Ethics Committee, approval number A1424.

5.3.1 Slaughter protocol and sample collection

After 70 days on feed, both entire and castrated male cattle were transported approximately 300 km to the commercial processing facility (JBS Swift Australia, Ipswich QLD). Each carcass was Electrically Stimulated following slaughter and exsanguination. Carcasses from each treatment group were then skinned, gutted, split and hung in the chiller at 1º C using the Achilles Tendon method. The time between the animal being slaughtered and entering the chiller was ~ 40 minutes.

Certified MSA graders collected information from individual carcasses in the chiller on a Data Capture Unit. Research staff observed and manually recorded this data. In complying with MSA and Ausmeat standards, temperature and pH decline at approximately one hour intervals for six hours post slaughter were recorded for individual carcasses. Ultimate pH and ultimate loin temperature was also recorded after 24 hours post-slaughter. Further information recorded by the MSA graders included carcass weight, eye muscle area between the 12^{th} and 13^{th} rib, cold rib fat between the 12^{th} and 13^{th} rib, ossification (objective measurement from 100 – 590) and hump height (Ausmeat, 2011). Hump height was measured as the greatest height of the hump from the spinal column as an indication of the *Bos indicus* content (Wolcott et al., 2009).

A sample of the strip loin, ranging from 1.8 kg – 3 kg, from each carcass was preserved in cryovac packaging and labeled before being placed onto dry ice in an insulated box and transported to the University of New England's meat science laboratory in Armidale, NSW. Upon arrival the strip loin samples for each individual carcass were cut into 300 g portions to be aged for 7, 14 and 28 days. While the samples were aging

they were stored in a refrigerator at 4º C. Following aging the samples were stored in a -20º C freezer for later analysis.

5.3.2 Laboratory analysis

The samples were removed from the -20º C freezer and were left to thaw at room temperature for 12 hours. The epimysium was removed from each sample and 200 g blocks were weighed and placed into plastic bags. The samples were then cooked in a water bath for 60 minutes at 70º C (Perry et al., 2001). Following cooking, shear force of the samples was measured using the method described by Wolcott *et al.*, (2009) (Figure 5.1). A 4 mm flat blade was pulled upward at 100 mm/sec through cooked samples at right angles to the fibre direction. Shear force was measured in kilograms of force and the mean of six samples was recorded. Shear force was measured for each sample at each of the aging times.

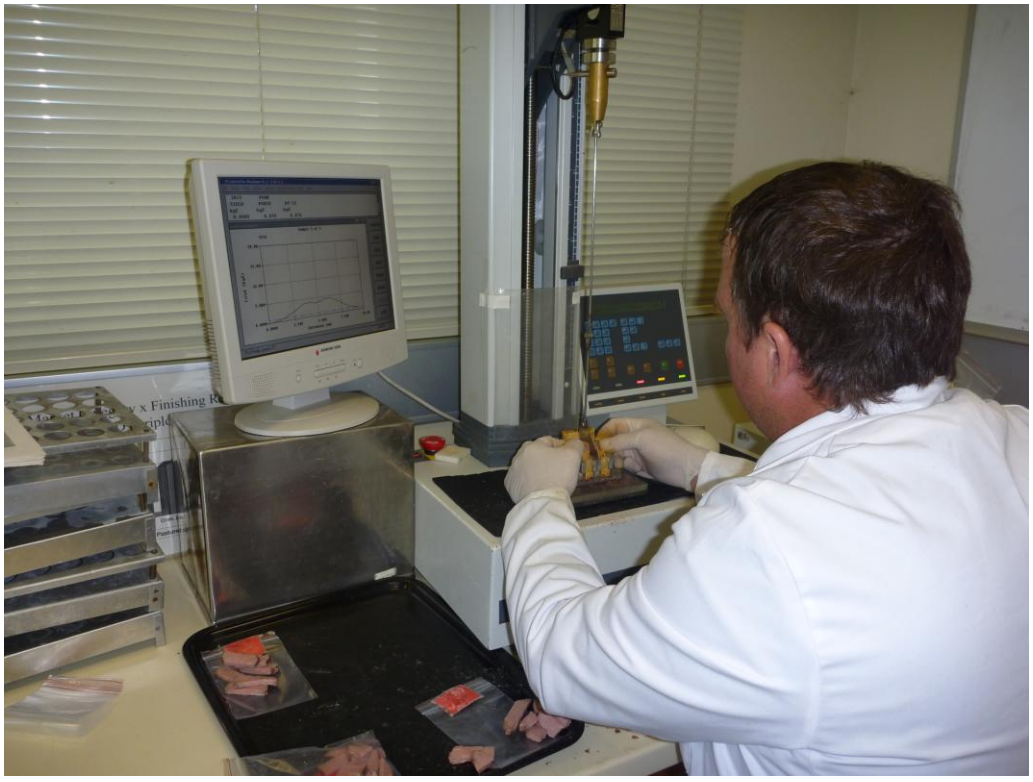

Figure 5.1. Performing the Warner Bratzler Shear Force assays at The University of New England's Armidale meat science laboratory

Ultimate pH was taken using the insertion probe of a WP-80 Waterproof pH-mv temperature meter (TPS Pty Ltd Australia, 2011). Ultimate pH was recorded on 14 day

aged samples that had been thawed at room temperature using methods described by Schutt et al., (2009). Meat colour was measured using separate thawed samples that had also been aged for 14 days. Three images were captured using a hand held Minolta CR-300 Chroma Meter (Konica Minolta Sensing Americas inc, 2011) and recorded using the L*-, a*-, b*- colour scale(Anon (c), 2007). The scale is recorded from a maximum L* value of 100 (white) to a minimum L* value of 0 (black), a positive a* value (red) to negative a* value (green) and a positive b* value (yellow) to a negative b* value (blue). The a* and b* values have no numeric limit (Anon (c), 2007).

5.3.3 Statistical design and analysis

The experiment was a 2 x 3 factorial design with each individual animal as an experimental unit. Results were based on Restricted Estimated Mixed Linear (REML) models with castration treatment, calpastatin genotype and day as fixed effects and animal ID as a random effect. All interactions were considered in the analysis and non-significant interactions were re-run through the statistics model before being removed from the thesis. All modelling and significance tests were performed in Genstat (Adept Scientific plc, 2011) and all means produced were based on the fitted values from these models. Given the imbalance in design due to low frequency of animals that were negatively homozygous for the calpastatin gene, a 2-way ANCOVA was run with starting liveweight as a co-variant for carcass weight to ensure a bias was not affecting the accuracy of results.

5.4 Results

Table 5.1. The means and least squares difference for Warner Bratzler Shear Force measurements (kg) of the *M. Longissimus dorsi* from *Bos indicus* entire and castrated males measured after 7 days, 14 days and 28 days of aging at 4º Celsius

Treatment	n	Day 7	Day 14	Day 28
Entire	41	5.65^{a}	5.62^{a}	4.28^{c}
Castrate	39	5.53^{a}	4.79^{b}	3.74^{d}
LSD		0.427	0.427	0.427

[a, b] Column means with unlike superscripts differ ($P < 0.01$)

[c, d] Column means with unlike superscripts differ ($P < 0.05$)

Warner Bratzler Shear Force (WBSF) measurements of the *M. Longissimus dorsi* demonstrated no gender effect at day 7 but there were gender effects for both day 14 (P = 0.001) and day 28 (P = 0.005). Genotype had no effect on WBSF values.

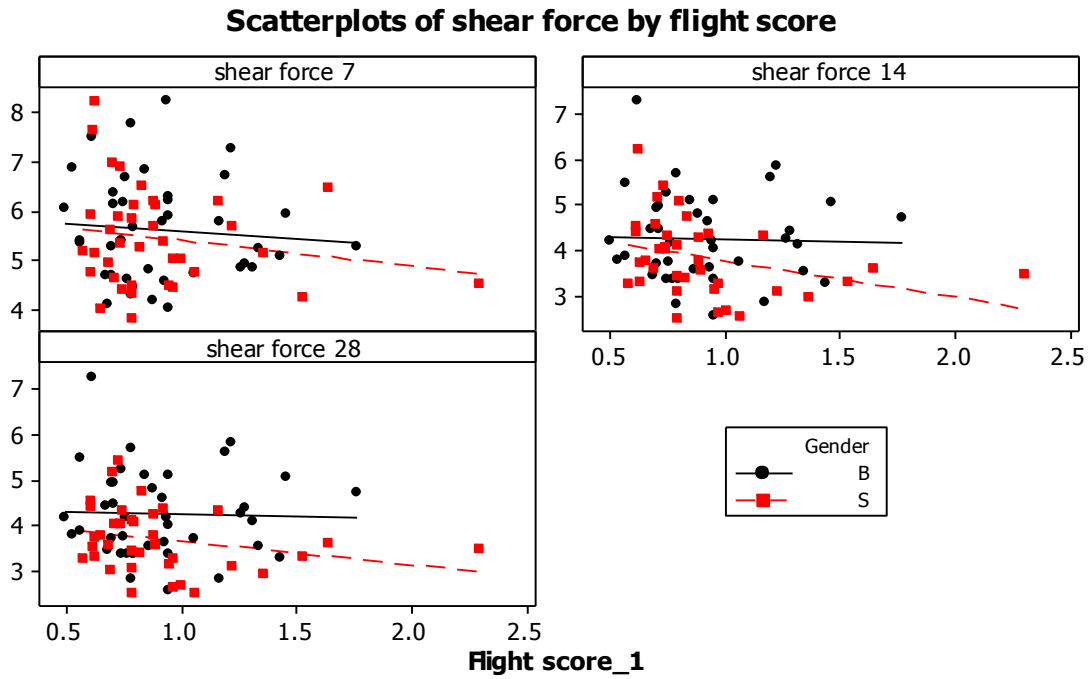

Figure 5.2. Scatterplots of WBSF (kg) of the *M. Longissimus dorsi* and flight score (sec) at three aging periods (7, 14 and 28) for entire (B) and castrated (S) male cattle

Flight score did not affect WBSF at any of the aging periods for either entire or castrated male cattle (Figure 5.2).

Table 5.2. The carcass weights of entire or castrated male cattle that were positively homozygous, heterozygous or negatively homozygous (0) for the calpastatin gene and carcass parameters (Mean ± sed) measured at the abattoir by MSA graders and in the laboratory by research staff ^

	n	Entire	Castrate	sed
n		41	39	
Carcass Wt (kg)				
- Overall mean		236.6[a]	222.4[b]	4.85
- Homozygous +	12	217.0[a]	215.2[a]	10.4
- Heterozygous	37	240.5[a]	226.6[b]	10.2
- Homozygous -	31	239.1[a]	219.9[b]	7.6
Ossification		140[a]	131[b]	3.25
Meat colour				
- L		37.18[a]	28.69[b]	0.547
- A		18.41[a]	18.58[a]	0.398
- B		7.88[a]	8.16[a]	0.26
USMB		213.8[a]	256.4[b]	12
Laboratory pH		5.65[a]	5.62[b]	0.014
Ultimate pH		5.50[a]	5.49[a]	0.024
Ultimate loin temperature (ºC)		6.28[a]	6.07[b]	0.095
Hump height		161[a]	146.8[b]	5.48

There were no difference in rib fat between the genders (P = 0.75)
^ [a, b] Row means with unlike superscripts differ (P < 0.05)

Entire males produced a heavier carcass compared to castrates (P < 0.05) (Table 5.2) and were physiologically older with a higher ossification score (P < 0.05) (Table 5.2). Carcass weight of entire and castrated male cattle that were positively homozygous did not differ (P > 0.05), however, entire males that were either negatively homozygous or heterozygous produced heavier carcasses than castrates of the same genotype (P < 0.05). Initial liveweight did not affect carcass weights between the genders or genotypes (Appendix). Castrates had a higher degree of marbling compared to entire males (P < 0.05) but rib fat did not differ (P = 0.75). Entire male cattle produced samples that were shown to be lighter in colour or reflectance (L*) compared to castrates (P = 0.007),

however, there were no differences between genders in the degree of overall meat colour acceptance (a* b*). Castrates produced meat that had a lower laboratory pH (P = 0.014), although samples from each gender were considered acceptable under industry guidelines. Ultimate loin temperature was significantly lower for castrates compared to entire males indicating a faster rate of cooling (P = 0.032). The REML analysis also showed that there were no interactions between hump height and shear force at 7d, 14d or 28d.

Table 5.3. The means ± SEM of pH and temperature (º C) for *Bos indicus* entire and castrated males measured at one hourly time intervals for six hours post-slaughter to determine if there was any incidence of cold shortening

	Time 1	Time 2	Time 3	Time 4	Time 5
pH					
Entire	6.04	5.83	5.66	5.53	5.45
Castrate	5.97	5.70	5.55	5.46	5.40
SEM	0.020	0.021	0.017	0.013	0.008
Temp					
Entire	32.7	25.9	19.7	15.7	13.3
Castrate	31.1	24.7	18.8	14.7	12.8
SEM	0.568	0.646	0.476	0.336	0.279

There was no evidence of cold shortening based on the degree of cooling in relation to the effect of glycolysis on subsequent pH decline (Table 5.3).

Table 5.4. The number of animals graded into classes according to number of days on feed, dentition, fat depth, meat colour, fat colour and secondary sexual characteristics

Grade	n	Q	WA	WB	WC	WD	WE
Entire	41	1	31	4	4	0	1
Castrate	39	0	31	7	1	0	1

Q = Entire

WA – WE = The grading model used by JBS Swift Australia for classifying grain fed castrates with 'A' given to a superior carcass and 'E' given to a lower grade carcass (Rosey, 2010). The JBS Swift Australia grade corresponds to an Ausmeat certified product with a branded symbol of Grain Fed Young Beef or *GFYG*. The requirement for this product includes minimum 70 days on feed, 0-2 permanent incisor teeth, minimum fat depth at the P8 site of 5mm, meat colour score of 1 a-b-c-3 and fat colour score of 0-3.

Table 5.5. The $/kg and $/carcass for fitted means of entire and castrated male cattle that were positively homozygous, heterozygous or negatively homozygous for the calpastatin gene

	Entire	Castrate	sed
$/kg	$3.34[a]	$3.32[a]	0.03
$/carcass	$794.40[a]	$739.40[b]	20.4
Genotype			
- Homozygous +	$716.90[a]	$712.50[a]	43.6
- Heterozygous	$804.70[a]	$758.10[b]	43.7
- Homozygous -	$800.10[a]	$725.00[b]	32.0

$\wedge$ [a, b] Row means with unlike superscripts differ ($P < 0.05$)

There was no difference in $/kg between entire or castrated male cattle ($P = 0.3$), however, given the difference in carcass weight between entire and castrated males (see Table 5.2), entire males were more profitable under the experimental environment ($P = 0.009$). There was no difference in $/kg of carcass weight between entire or castrated males that were positively homozygous for calpastatin ($P < 0.05$), however, entire males with that were negatively homozygous or heterozygous were more profitable ($P < 0.05$) than castrates of the same genotype.

Figure 5.3. The development of bulls and steers in the feedlot after 30 days on feed

Figure 5.4. This example illustrates the degree of intramuscular fat or marbling in a *M. Longissimus dorsi* sample

5.5 Discussion

5.5.1 Tenderness

Entire male cattle produced less tender meat than castrates after aging for 14 days (P = 0.001) and 28 days (P = 0.005) (Table 5.1). There was, however, no difference in tenderness between the genders after the samples had been aged for seven days (Table 5.1). A breed affect may be partially responsible for this result given the evidence of a higher degree of background toughness associated with meat from *Bos indicus* animals (Crouse et al., 1989). In contrast to the aging affect seen in castrates, there was no aging affect between day seven and day 14 in entire males. These outcomes are in agreement with previous work that has shown that entire males from multiple species produce objectively tougher meat than castrates (Field, 1971). It has been suggested, however, that aging meat from entire males can offset the differences in tenderness between entire males and castrates in *Bos taurus* cattle, however, this was not seen in the present study (Cahill et al., 1956).

The difference in tenderness between genders was less pronounced after 28 days compared to 14 days of aging. Similar findings have been observed where differences in tenderness between genders were less pronounced after longer periods of aging (O'Connor et al., 1997, Cahill, 1964). Further investigation may be needed to determine the cost of extra refrigeration and storage with aging beef from entire males for longer periods compared to castrates. In addition, it would be worthwhile to complete an analysis to determine the breakeven point from extra refrigeration and storage costs against the extra kilograms of beef produced from the production of entire males.

It has been widely accepted that the calpain proteolytic system is largely responsible for the aging effect in beef (Koohmaraie, 1990) and although much still remains unclear, it has been suggested that calpastatin activity may explain some of the difference in tenderness between entire and castrated male cattle. Morgan et al., (1993a) concluded that entire males had higher levels of calpastatin compared to castrates, which subsequently led to entire males producing less tender beef. Although 24 hour calpastatin activity hasn't been included in the current study, it is hypothesised that this may have partly contributed to the delayed aging affect and subsequent higher shear force values in entire male cattle.

The exact reason for the lack of difference in tenderness between entire and castrated males after seven days of aging is largely unknown. It was hypothesised that much of the difference between genders would have occurred within the first seven days of aging before becoming less pronounced. In explaining this hypothesis, it is known that μ-calpain and calpastatin decrease rapidly in the first 48 hours post-mortem (Sinclair et al., 2001). Thus, it was believed much of the aging difference would have occurred within the first seven days. A possible explanation why there was a lack of difference may be due to the *Bos indicus* content of the cattle used in the experiment (Thrift et al., 2002). O'Connor et al., (1997) found that the rate of tenderisation in cattle of *Bos indicus* origin was slower from day four to day seven when compared to cattle of *Bos taurus* decent. The corresponding rate of tenderisation in *Bos indicus* cattle was, however, faster from day 7 to day 35. It was concluded that higher levels of calpastatin activity in *Bos indicus* cattle were responsible for the delayed aging affect. Based upon this evidence, it is concluded that combined with a higher degree of background toughness, calpastatin activity may have been responsible for the lack of difference in tenderisation between genders after seven days of aging in the present study.

In further explaining the lack of difference in tenderness between genders after seven days of aging, it is hypothesised that the likelihood of compensatory gain may have increased the level of calpastatin activity at slaughter. It was concluded, as discussed in earlier chapters, that both genders experienced a growth check prior to feedlot entry that resulted in a marked growth response given the elevated level of nutrition. There is contradicting evidence surrounding the exact role the calpain system plays in times of high growth (Therkildsen et al., 2002). Further findings state that calpastatin activity is higher in entire males and cattle of *Bos indicus* decent where decreased protein degradation is the result of an elevated level of calpastatin (Therkildsen et al., 2002). As stated, there are numerous studies that are contradicting, however, Thompson et al., (1992) supported the above hypothesis by concluding a feed restriction of two weeks in lambs increased the level of calpastatin at slaughter. While it cannot be concluded that compensatory gain contributed to the delayed aging affect in the present study, it still remains unclear what effect growth and compensatory gain has on the calpain system with the effect varying in breed, gender and muscle type between studies.

There were no differences in tenderness at any of the aging periods between the genotypes. It was hypothesised that animals that were either negatively homozygous or heterozygous for calpastatin would produce less tender beef than animals that were positively homozygous. Casas et al., (2006) stated that the reason why there was no significant difference in tenderness between *Bos indicus* cattle with or without calpastatin genes was due to the 'present marker system not being adequately matched to functional alleles to be useful in *Bos indicus* populations'. In addition, Purchas et al., (2002) suggested that differences in tenderness between entire and castrated male cattle was driven largely by background toughness (i.e. connective tissue), lower content of intramuscular fat (Table 5.2), decreased proteolytic activity, higher ultimate pH (Table 5.2) and a corresponding higher cooking loss. These factors combined with the low numbers of animals that were positively homozygous may partially explain why the marker system was unable to predict improvements in beef tenderness between genders or genotype.

5.5.2 Temperament

The lack of difference in flight score between entire and castrated cattle during the on-farm testing in the present study supports a conclusion that temperament did not affect meat tenderness (Figure 5.2). The frequency of handling and the ability to manage the herd in the same cohort since weaning are believed to have contributed to the result. Flight score has been shown to have a moderate to strong negative relationship with shear force (r = -0.48) in the *M. Longissimus dorsi* (Reverter et al., 2003). The same authors also stated that flight score had a heritability estimate of 0.31 and concluded that selecting for animals with a more desirable temperament could have a significant affect on the production and profitability of a north Australian beef enterprise. Although entire male cattle have been continually shown to be more aggressive than castrates in a confined setting (Seideman et al., 1982), it is concluded that with frequent handling and allowing a herd to remain unmixed from weaning until slaughter, that both entire and castrated male cattle can be selected upon individual disposition without comprising meat tenderness.

5.5.3 Carcass parameters

Given the pubertal affect combined with the 70 days in the feedlot, entire males produced a carcass that was significantly heavier than the mean carcass weight of castrates (P = 0.005; Table 5.2; Figure 5.3). Previous studies have consistently indicated that post-pubertal entire male cattle yield a heavier carcass at slaughter compared to castrates (Seideman et al., 1982, Tanner et al., 1970). Cattle from either gender that were negatively homozygous or heterozygous for the calpastatin gene were heavier than cattle that were positively homozygous. In addition, entire males that were negatively homozygous or heterozygous produced a carcase that was significantly ($P < 0.05$) heavier than the mean carcass weight of castrates with the same genotype.

There was no evidence of cold shortening in carcasses from either entire or castrated males (Table 5.3). Cold shortening is a potential problem in entire male cattle due to the inability to fatten or finish in the same time period as castrates (Seideman et al., 1982). The amount of subcutaneous fat surrounding the carcass acts as insulation and can influence the rate the carcass cools post slaughter. Cold shortening can occur if the internal temperature of meat drops below 10^{o} C while the pH remains around 6.0-6.2 (Savell et al., 2005) This has been traditionally considered a drawback to the acceptance of producing beef from entire males, however, in the present study given the lack of difference in rib fat depth between entire males and castrates (P=0.75) (Table 5.2) and the lower ultimate loin temperature of castrates (P = 0.032) (Table 5.2), it is concluded that cold shortening was not an issue and had no affect on meat quality for entire males or castrates.

Hinch and Thwaites (1979) and Seideman et al., (1982) both stated that handling a bigger carcass and difficulties in removing the hide would be drawbacks from the processing sector towards the acceptance of producing beef from entire males. However, in the present study there were neither observations of nor any negative feedback surrounding any difficulties in handling or removing the hide from the carcasses. Given meat graders were unable to differentiate between carcasses from either entire or castrated male cattle (Table 5.4), based upon Ausmeat selection criteria, it is highly unlikely that the processing staff experienced any significant problems processing the carcasses from entire male cattle. The perception of the above authors

perhaps relates to older cast for age entire male cattle rather than young grain finished animals supplied to domestic market specifications.

Entire male cattle were physiologically older than castrates at slaughter as measured by ossification score ($P < 0.05$) (Table 5.2) and is agreement with previous research, which stated that entire males displayed higher ossification scores compared to castrated males of similar chronological ages (Glimp et al., 1971, Seideman et al., 1982, Seideman et al., 1989). Contrary to the knowledge that faster on-farm growth rates result in a younger animal being slaughtered subsequently with a lower ossification score (Meat and Livestock Australia (MLA), 2000), it is suggested that the superior post-pubertal growth rates exhibited by entire male cattle leads to a more advanced stage of physical maturity in the carcass compared to castrates. More advanced carcass maturity has also been associated with meat that has a darker appearance (Anon, 2001).

Entire male cattle in the present study produced samples that were considered lighter compared to the *M. Longissimus dorsi* samples produced by castrates ($P = 0.007$). Although not measured, this result can be explained by samples from entire males having a lower water holding capacity compared to castrates. These samples therefore, excreted more water to the surface of the sample which caused a greater white light reflectance (Aberle et al., 2001). The higher water holding capacity in samples of entire males may have been influenced by the slower rate of cooling in the post-mortem period ($P < 0.05$) where some protein denaturising may have occurred.

There was no differences in overall colour acceptance in a* and b* measurements between genders. This result was in contrast to previous findings that state that entire male cattle produce meat that is darker and ultimately less appealing to the consumer (Seideman et al., 1982, Field, 1971). Field (1971) suggested that beef from entire males was darker due to the unpredictable temperament of entire male cattle and its effect on glycogen reserves within the muscle. In addition, Purchas et al., (2002) has stated that time in transit and lairage have a greater affect on the meat colour and pH of entire compared to castrated male cattle. The animals in the present study did spend approximately 12 hours in lairage prior to slaughter, however, given social hierarchies had already been established in the herd combined with the lack of difference in flight

score, it is concluded that the lack of difference in temperament may partially explain why there is no difference in meat colour.

Although there was no difference in colour acceptability of meat produced entire and castrated males, it is understood that a higher pH is often associated with a darker colour. In the present study, after 14 days of aging, entire males produced a sample from the *M. longissimus dorsi* that had a higher pH compared to castrates (P = 0.014). These findings were similar to Purchas et al., (2002), who found that entire males had higher pH measurements compared to castrates (5.55 *vs.* 5.47). It has been stated that detection of a darker colour at the consumer level becomes apparent when the pH reaches 5.7 or above and darker appearance can be associated with a less tender product with a shorter shelf life (Boles and Pegg, ND). This information forms the basis of the MSA grading model with the window of acceptance for pH ranging between 5.3-5.7 (Meat and Livestock Australia (MLA), ND-b). Given the above information, carcasses from both genders in the present study would achieve the pH window of acceptance under MSA guidelines.

Castrated males produced a carcass that had a higher USMB (United States Marbling) score compared to entire males (P = 0.001) (Table 5.2). These outcomes are widely accepted as it has been consistently proven that beef from entire males has less marbling than that of castrates (Martin and Stob, 1978, Seideman et al., 1982, Bailey et al., 1966). There is however, evidence to suggest there is no difference in marbling between castrates implanted with a HGP and entire males (Schoonmaker et al., 2002). Although the extent of the relationship between marbling and eating quality is currently not quantified, it has been included as an input variable in the MSA grading model due to its known positive effect on eating quality (Meat and Livestock Australia (MLA), ND-a). Although there is a difference in USMB between genders (P = 0.001), in the present study under MSA guidelines, both entire and castrated males would have the *M. Longissimus dorsi* given a 3 star or ‘good everyday’ rating.

Surprisingly there was no difference in rib fat between the genders. The reason behind this outcome is unknown given the amount of data supporting the theory that post-pubertal castrates produce a fatter carcass than entire males. This evidence is based on

comparisons between entire males and castrates that didn't receive a HGP implant and were grain or grass fed. These animals were from a range of genotypes including dairy and *Bos taurus* and were fed for approximately 100 days (Bailey et al., 1966, Kellaway, 1971, Seideman et al., 1982). Given the differences in carcass weight (P = 0.005), carcass maturity or ossification (P = 0.007) and marbling (P = 0.001), it was expected that castrated males would have produced a carcass with more rib fat than entire males. This is due to the partitioning of fat in cattle follows the sequence of visceral, subcutaneous and then intramuscular deposition (University of Guelph, ND). In addition, castrated male cattle produced more rib fat than entire males when live carcass measurements were recorded using ultrasound technology. These outcomes were discussed in the previous chapter.

5.5.4 Grading and profitability

Objective grading of individual carcasses at the abattoir appeared to remove any pricing bias that is systematically in place against the production of entire males under the traditional pricing grid. The objective grading model, using Ausmeat selection criteria, was unable to differentiate between carcasses from either entire or castrated males (Table 5.4) and as a result, carcasses from entire males were able to qualify as GFYG. 76% of entire male carcasses were graded as superior grain fed steer compared to 78% of castrates. Only one entire male carcass was graded as a 'bull' and received a subsequent pricing discount of $0.95/kg or in excess of $300/carcass compared to the remainder of the cohort. It was concluded that the carcass was downgraded due to a combination of secondary sexual characteristics and insufficient fattening. Inability to finish or fatten entire male cattle in a similar time period to castrates has previously been identified as a constraint to the commercial viability of producing beef from entire male cattle (Johnson et al., 1988, Seideman et al., 1982).

What remains unclear in these data is why only one beast was graded as a 'bull'? This cohort of animals was slaughtered following the processing of a consignment of castrated and entire male cattle from a concurrent study (Meat and Livestock Australia, 2010a). Research staff was on the kill floor taking samples, recording data and observing the procedure while both consignments were being processed. It is possible that the MSA and abattoir graders were aware, to some degree, of the nature of the experiments which may have subsequently affected the objective nature of the grading.

What is clear from these findings, however, is that a carcass produced by a young grain fed entire male is likely to be similar to that of a grain fed castrate as to qualify as GFYG under Ausmeat selection criteria.

The post-pubertal liveweight effect resulted in entire male cattle producing a heavier carcass at slaughter compared to castrates ($P = 0.005$; Table 5.2). Given the Ausmeat grading model awarded both entire and castrated male carcasses a similar grade; carcasses from entire male cattle received a superior value compared to the awarded price under the traditional pricing model. These factors combined confirm that entire males can be a profitable alternative in an attempt to i) reduce the age at slaughter and or ii) produce a carcass with a higher lean meat yield. In the present study, entire males were more profitable than castrates ($P = 0.009$; Table 5.5).

There was no significant difference in profitability between entire and castrated males that were positively homozygous for calpastatin (Table 5.5). Entire male cattle that were either negatively homozygous or heterozygous, however, produced carcasses that were significantly more profitable than those produced by castrates of the same genotype ($P < 0.05$). As indicated previously, it has been shown in the present study and supported by others (Casas et al., 2006), that little confidence can be taken from selecting *Bos indicus* animals that will produce tender beef based on the current marker system. As concluded in earlier chapters, it may be detrimental to the profitability of a north Australian beef enterprise that is producing *Bos indicus* animals that are positively homozygous for calpastatin. In making this conclusion, it must also be re-stated that an attempt was made to balance the design on marker status, and as was also seen in a study by Café et al., (2010) with *Bos indicus animals*, the low frequency of animals that are positively homozygous created an imbalance to the study design.

In supporting the above concept there appears to be a clear relationship between calpastatin genotype and carcass weight, while the processing industry continues to pay on liveweight and fat depth. For example an entire male that is negatively homozygous for calpastatin produced a carcass that grossed $93.20 more than a carcass of an entire male that was positively homozygous for calpastatin. Therefore, entire males that were positively homozygous would need a premium of $0.22/kg Hot Standing Carcass Weight (HSCW) to match the profitability of an entire male that was negatively

homozygous. Given there was no interaction with any of the calpastatin genotypes and tenderness (Table 5.1), it is concluded that selecting animals that are negatively homozygous for the calpastatin gene, although the animals of this genotype didn't have improved meat tenderness, the on-farm production advantages would be beneficial to profitability.

Although finishing young entire male cattle for the domestic trade is uncommon under Australian conditions, there is anecdotal evidence to suggest that male calves that are not mustered at marking / castration are being located in subsequent musters and sent to a feedlot to be fattened (McDonald. A, 2010). Although number of entire male cattle from this scenario will only make up a small percentage of a consignment, it is evidence to suggest that there is a percentage of beef from entire males being marketed into the domestic market. Outcomes of this analysis confirms that under Ausmeat selection criteria and without declaration or visual recognition of the live animal, that young entire males can be graded and therefore produced profitably in accordance with domestic market specifications.

5.6 Conclusion

Entire males produced a heavier carcass in comparison to a carcass from a castrate. Entire male carcasses also showed an advanced stage of maturity and had less marbling. There was, however, no difference in the degree of fattening and subsequently both castrates and all except one entire male were classified as GFYG. The qualification of carcasses from entire males under the GFYG descriptor combined with the superior carcass yields resulted in entire males being more profitable than that of castrated males. Under the study conditions carcasses from entire male cattle satisfied the market requirement for a 'grain fed steer', however, the underlying variability in *M. Longissimus dorsi* samples from entire males could potentially have larger implications on the industry.

The variability in beef from entire males including differences in colour, laboratory pH, marbling and particularly tenderness after aging for 14 days and 28 days, is a concern for the industry, given entire males were awarded the same classification as castrates and presumably the same retail marketing as GFYG. Variability and inconsistencies in eating quality have been recognised as primary factors in the decreasing trend of beef

consumption over the past 40 years. Therefore, allowing meat that has the potential to give the consumer a poor eating experience may in fact be detrimental to the future of beef consumption. Before recommendations can be made it is suggested that sensory analysis be undertaken on samples from carcasses that are graded as GFYG to determine if everyday consumers can identify the differences in tenderness that were detected objectively in the laboratory from samples from either entire males or castrates.

Both genders that were positively homozygous produced a carcass that was lighter and less profitable than animals that were negatively homozygous or heterozygous. Entire males that were either negatively homozygous or heterozygous for calpastatin produced a heavier carcass that was subsequently more profitable than castrates with the came genotype. In addition, there was no interaction between marker status and tenderness, which suggests, under the study conditions, selecting animals that are negatively homozygous for calpastatin in an attempt to improve tenderness will not improve meat tenderness, however, selecting animals of this genotype will increase growth rates and carcass yields in *Bos indicus* populations.

In conclusion, entire male cattle can be produced profitably in accordance with domestic GFYG specifications. In addition, selecting animals that are negatively homozygous for calpastatin will improve on-farm profitability without having any affect on meat tenderness in *Bos indicus* herds. Sensory testing is recommended on GFYG samples to detect any differences between genders by the everyday consumer before recommendations can be made about updating of the present pricing system.

CHAPTER 6
GENERAL DISCUSSION

The present study provides further evidence to the growing body of data that supports the argument that post-pubertal entire male cattle grow faster and produce a leaner higher yielding carcass compared to that of castrates (Field, 1971). It also agrees with past findings that although entire males produce more edible lean beef, there is inherent variability in objective tenderness and other meat quality parameters (Seideman et al., 1982). What is unique about the design and findings of this research, however, is the application and commercial significance to the profitability of northern beef enterprises in Australia.

The study design was established based on anecdotal evidence supporting the already successful production of beef from entire males through a vertically integrated production system. Although not widely practiced, a number of producers were sending uncastrated male calves that had been miss-mustered at marking and found at the subsequent muster before being sent with a consignment of castrates to a feedlot to be finished. The early on-farm testing began in an attempt to i) avoid a setback from castrating older calves and ii) capitalise on superior growth and efficiency of bulls and reduce the age at the point of slaughter. Given the data that supports the growth, yield and efficiency of entire compared to castrate male calves, a hypothesis was established to answer the question; could entire males be controlled under current management and produce a carcass of similar grade and quality to castrates?

6.1. Preliminary investigation

The economic modelling was used as a preliminary investigation into the profitability of a vertically integrated north Australian beef system. Giving the model further industry significance were the assumptions that were used as input variables were typical of the management, animals and regions of northern Australia. The findings from the model suggested that under the current pricing model the production of castrates had greater gross margins despite producing smaller carcasses compared to entire males. These findings were primarily driven by higher market values upon exit of the breeding and backgrounding phases and ultimately a superior price/kg awarded to castrates at slaughter.

The assumption that entire male cattle would have an accelerated growth response while in the feedlot resulted in entire males having greater gross margins for the final phase of the system. Despite the greater gross margins in the feedlot, entire males were unable to make up for the earlier losses in the pre-pubertal period during the breeding and backgrounding sectors. Given the low market value of young entire male cattle in the store market, combined with little differences in growth and efficiency with castrates prior to puberty, it was concluded that the supply of entire males at a feedlot entry weight would be a major limiting factor in producing beef from entire males in the current system.

There is a body of evidence that is supported by the present study that states that there is variability in the key meat quality parameters of entire male cattle (Bailey et al., 1966, Seideman et al., 1982). Contrary to this there is also evidence to indicate that although there is differences in objective meat quality when measured in the laboratory, the same differences in tenderness and appearance can go undetected at the consumer level (Woodward et al., 2000). These conflicting views suggest that the present traditional pricing grid for entire males is not based on information from young animals but perhaps reflects beef from old cast for age animals that no longer have any value as breeding animals.

When the model removed the discount which is awarded to a carcass from a bull, and pitched the market and slaughter value of bulls at the same value as that of a steer; bulls yielded the greatest gross margins. The lack of difference in growth and subsequent gross margins in the early phases suggested that the superior gross margins were a result of the post-pubertal growth and efficiency advantages predicted in bulls compared to steers in the feedlot. As seen in the present study the variability in tenderness and meat colour in *M. Longissimus dorsi* samples from bulls suggest that the price of bulls shouldn't be pitched at the same value as steers, however, the current penalty that is awarded to the supply of bulls is perhaps not entirely reflective of the quality and potential retail yield of meat from young bulls.

As shown in the present experiment, young entire male cattle can produce a carcass of comparable quality compared to castrates under Ausmeat selection criteria. Given the

inherent variability in key meat quality parameters between entire and castrated males, however, it is recommended that a separate pricing system for entire males be investigated. Taking into consideration the differences in meat quality, It is recommended that key input variables such as dentition, ossification, muscle and fat colour, days on feed and fat depth be used to predict quality and to ensure a reflective price be awarded to the producer for a carcass from an entire male relative to castrates. Guidelines into the on-farm handling, pre-slaughter techniques, processing and aging procedures may also need to be reviewed for the successful adoption of beef from entire males.

6.2 Perception

The power of activism, supermarket monopolies and consumer perception has the potential to influence the sustainability of the beef industry. The consumption of beef has continued to decrease over the past four decades (Australian Bureau of Statistics, 2005) and it is important that the industry is receptive to industry bodies that can pressure and persuade the perceptions of consumers. The marketing methods to phase out the use of HGP's and the potential scrutiny over the practise of castration in cattle suggests that alternate farming practises will be needed to remain productive. Despite the inherently poor perception of entire males, beef from entire males supplied into the domestic trade may be the alternative the industry needs.

The industry is already involved in a transition from using HGP's given the marketing programs of supermarket and fast food chains. Whether the key messages in the marketing campaigns are correct or not, the power of these bodies will continue to have influence on consumer perception. The practise of implanting cattle with HGP's is registered and accepted as a safe practise within the industry (Anon, 2009a), although the information being presented to consumers through what is believed to be a partially biased marketing campaign suggests the product may be contaminated and does not have a 'clean, green and ethical' image. It has been stated that up to 40% of the national herd is implanted and the removal of HGP's would cost the industry upwards of $210 million in lost productivity or equivalent to a 10-30% decrease in growth rates and 5-15% decrease in feed conversion (Anon, 2009a).

The productivity losses as a result of not implanting are similar to the gains seen in growth and efficiency of entire compared to castrated males in the present and past research (Field, 1971, Seideman et al., 1982). Data from the present study that is supported by others (Field, 1971, Seideman et al., 1982), show that entire males can grow up to 27% faster and convert feed to liveweight up to 13% more efficiently than un-implanted castrates. The eating quality of beef from certain cuts of implanted castrates is said to be compromised by the practise and is subsequently penalised under the current meat grading model (Watson et al., 2008*c*). Given the hormonal influence, it is believed that meat from young entire male cattle would have similar characteristics to that of implanted castrates. For example, meat that has less marbling and is less tender. However, beef from young entire males is penalised under the traditional pricing grid and eliminated from the MSA grading. Further investigation is needed to determine if the production of young entire male cattle can account for the productivity losses incurred by removing the practise of implanting castrated males with HGP's. An alternative strategy may include placing entire males into a feedlot at a younger age and feeding for a longer period e.g. 120 days.

Activism may also influence the production of beef from entire males with growing concerns around the procedure of castration. Although there was no difference in liveweight change following castration between genders in the present study, it can be perceived as an inhumane practise. The majority of castration procedures in northern Australia are surgical given the efficiency of the operation. The practise is considered one of the most stressful experiences for livestock with further implications such as haemorrhaging, excessive swelling, infection and poor wound healing potentially providing strong evidence for organisations wanting to influence consumer perception (American Veterinary Medical Association, 2009). The present study provides evidence that, should the industry be forced to review alternate practises, entire male cattle can be produced profitably in a north Australian production system.

The perception of producing entire males, processing entire males and marketing and eating beef from entire males presents a problem for the Australian industry. An early survey undertaken by Hinch and Thwaites (1979) showed how negative attitudes towards handling, extra management and fencing affected the acceptance of farming entire male cattle, while the response from the processor was equally as poor. Although

there is no evidence supporting consumer perception of beef from entire males in Australia, it is hypothesised that many consumers associate beef from entire males with a dark colour, taint and toughness. These perceptions are perhaps driven by media, partial knowledge of meat from entire males of other species and the belief that the majority of beef from entire males comes from cast for age animals. The acceptance of beef from young entire males in the Australian domestic trade would require a national program educating consumers of the myths and also the advantages in production, welfare and a 'clean, green and ethical' hormone free image.

6.3 Growth, Meat Quality And Profitability

The post-pubertal growth response of entire male cattle in the present study was pronounced given the elevated level of nutrition in the feedlot following the period of feed restriction. Although not measured due to the practical limitation in a commercial bunk fed feedlot, the higher growth rates of entire males are thought to have diluted the feed conversion ratio, therefore making entire males more cost efficient in achieving the same target weights compared to castrates. Even with the superior growth rates and possibly a more efficient feed conversion ratio, entire males were not expected to be as profitable as castrates under the traditional pricing grid and the hypothesis that not all entire males would qualify as GFYG under Ausmeat selection criteria

As expected, the accelerated growth response in entire males resulted in a lean carcass with a higher dressing percentage and less marbling compared to that of castrates. The similarity in carcass qualities yet the significant price differentiation under the traditional pricing grid between entire and castrated males supports the notion that the current pricing system has been established around the consumer demand for beef from castrates.

Although all except one entire male carcass was classified as GFYG, the present experiment agreed with past studies that there is inherent variability in meat quality traits. It is fair based on the outcomes of this experiment that entire male cattle should receive the same premium price paid for castrates. Furthermore, the current discounts from the traditional pricing grid awarded to carcasses from young entire males that are graded as a bull may need to be reviewed given 40 out of 41 of the entire males in the current study were graded as GFYG under Ausmeat specifications. The inherent

limitation of toughness remains with beef from entire males and needs to be further investigated.

6.4 Management

Entire males were controlled under the same management conditions as castrates for the entire experiment. The method of running the entire consignment together since weaning was introduced by Mounier et al., (2006) and adopted successfully in the present study. Mounier et al., (2006) stated that entire male cattle could be managed under the same conditions as castrates and would be less stressed at slaughter if the mixing of mobs occurred at the start of a phase rather than after a social hierarchy had been established. Findings from the present study support these methods as behavioural problems were rarely seen. In addition, there was no evidence of behavioural stress during transit or in lairage as differences in carcass bruising or the incidence of 'dark cutting meat' was not seen between entire or castrated males.

Given historical industry perceptions (Hinch and Thwaites, 1979) and previous findings (Jago et al., 1996, Seideman et al., 1982), it was hypothesised that there may be some aggressive and/or sexual behaviour displayed by post-pubertal entire male cattle, particularly in the feedlot and/or in lairage. There were, however, no significant behavioural observations that suggested that running young entire males together was not a major problem under the experimental conditions. It was concluded that the frequency of handling during data recording and the decision to manage entire and castrated males in the same consignment contributed significantly to the results. Fence damage was a minor concern during the backgrounding phase yet with modifications from traditional fencing to electric it is suggested the problem would have be resolved.

The present study showed that with minor modifications to management entire male cattle could be handled successfully in a north Australian beef enterprise. The adoption of specialised beef production from entire males would be suited to more intensive systems where there was adequate electrified fencing and the ability to yard and handle animals frequently. Within an intensive system further developments could be made using a combination of ultrasonic and genetic tests to establish estimated breeding values for growth indices in entire males finished for beef production. Pastoral Australia, however, where the design originated from, has limitations given the lack of

control and the lack of ability to separate entire males from the breeding herd. The lack of control could have severe consequences to the genetic merit of a herd. Producing entire males from this system would be limited to supplying uncastrated males calves that were miss-mustered at the time of marking.

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APPENDIX 1

Sensitivity analysis of feedlot phase where entire males were valued the entry and exit market values as castrates (11/06/2009)

	Starting Price		$489		
Feed / Yardage + $7/hd induction costs / day.	**End Price**	$633	$658	$683	$708
	$2.50	-$56.96	-$31.66	-$6.36	$14.32
	$3.00	-$91.96	-$66.66	-$41.36	-$16.06
	$3.50	-$131.58	-$106.28	-$76.36	-$55.68
	$4.00	-$166.58	-$141.28	-$115.98	-$90.68
	$4.50	-$201.58	-$176.28	-$150.98	-$125.68

APPENDIX 2

Sensitivity analysis of the feedlot phase where castrated males are valued at their current market value (11/06/2009)

	Starting Price		$489		
Feed / Yardage + $7/hd induction costs / day.	**End Price**	$555	$577	$599	$622
	$2.50	-$137.43	-$115.23	-$89.38	-$70.83
	$3.00	-$169.77	-$147.57	-$124.38	-$103.17
	$3.50	-$207.43	-$185.23	-$159.38	-$140.83
	$4.00	-$242.43	-$220.23	-$198.03	-$175.83
	$4.50	-$277.43	-$255.23	-$233.03	-$210.83

APPENDIX 3

Sensitivity analysis of the feedlot phase where entire males were valued at their current market value (11/06/2009)

	Starting Price		$375		
Feed / Yardage + $7/hd induction costs / day.	**End Price**	$531	$544	$557	$569
	$2.50	-$44.16	-$31.51	-$18.86	-$10.83
	$3.00	-$79.16	-$66.51	-$53.86	-$41.21
	$3.50	-$118.78	-$106.13	-$88.86	-$80.83
	$4.00	-$153.78	-$141.13	-$128.48	-$115.83
	$4.50	-$188.78	-$176.13	-$163.48	-$150.83

APPENDIX 4

One way ANOVA table for Warner Bratzler Shear Force after 7 days of aging versus hump height as a categorical variable

Source	DF	SS	MS	F	P
Hump height	3	2.15	0.72	0.68	0.564
Error	77	80.76	1.05		
Total	80	82.92			

APPENDIX 5

One way ANOVA table for Warner Bratzler Shear Force after 14 days of aging versus hump height as a categorical variable

Source	DF	SS	MS	F	P
Hump height	3	2.95	0.98	0.85	0.470
Error	77	89	1.16		
Total	80	91.95			

APPENDIX 6

One way ANOVA table for Warner Bratzler Shear Force after 28 days of aging versus hump height as a categorical variable

Source	DF	SS	MS	F	P
Hump height	3	2.35	0.78	1.02	0.390
Error	77	59.4	0.77		
Total	80	61.75			

APPENDIX 7

Two-way ANOVA table for Laboratory pH of the *M. Longissimus dorsi* sample aged for 14 days

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Gender ignoring Genotype	1	0.016474	0.016474	4.09	0.047
Gender eliminating Genotype	1	0.016320	0.016320	4.05	0.048
Genotype ignoring Gender	2	0.002272	0.001136	0.28	0.755
Genotype eliminating Gender	2	0.002119	0.001059	0.26	0.770
Residual	77	0.310432	0.004032		
Total	80	0.329025	0.004113		

APPENDIX 8

Two-way ANOVA table for the colour scale L of the *M. Longissimus dorsi* sample aged for 14 days

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Gender ignoring Genotype	1	45.537	45.537	7.56	0.007
Gender eliminating Genotype	1	46.218	46.218	7.67	0.007
Genotype ignoring Gender	2	0.777	0.389	0.06	0.938
Genotype eliminating Gender	2	1.459	0.729	0.12	0.886
Residual	77	463.869	6.024		
Total	80	510.865	6.386		

APPENDIX 9

Two-way ANOVA table for the colour scale a* of the *M. Longissimus dorsi* sample aged for 14 days

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Gender ignoring Genotype	1	0.809	0.809	0.25	0.616
Gender eliminating Genotype	1	0.648	0.648	0.20	0.654
Genotype ignoring Gender	2	2.334	1.167	0.37	0.695
Genotype eliminating Gender	2	2.173	1.087	0.34	0.713
Residual	77	246.085	3.196		
Total	80	249.067	3.113		

APPENDIX 10

Two-way ANOVA table for the colour scale b* of the *M. Longissimus dorsi* sample aged for 14 days

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Gender ignoring Genotype	1	1.666	1.666	1.23	0.271
Gender eliminating Genotype	1	1.536	1.536	1.13	0.290
Genotype ignoring Gender	2	0.678	0.339	0.25	0.779
Genotype eliminating Gender	2	0.548	0.274	0.20	0.807
Residual	77	104.328	1.355		
Total	80	106.542	1.332		

APPENDIX 11

Two-way ANOVA table for carcass weight (CWT) of entire and castrated males that were negatively homozygous, heterozygous or positively homozygous for the calpastatin gene

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Gender ignoring Genotype	1	3947.3	3947.3	8.33	0.005
Gender eliminating Genotype	1	4030.2	4030.2	8.50	0.005
Genotype ignoring Gender	2	2695.9	1348.0	2.84	0.064
Genotype eliminating Gender	2	2778.8	1389.4	2.93	0.059
Residual	77	36493.4	473.9		
Total	80	43219.6	540.2		

APPENDIX 12

Two-way ANOVA table for hump height of entire and castrated males that were negatively homozygous, heterozygous or positively homozygous for the calpastatin gene

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Gender ignoring Genotype	1	4025.6	4025.6	6.66	0.012
Gender eliminating Genotype	1	4088.4	4088.4	6.77	0.011
Genotype ignoring Gender	2	664.7	332.4	0.55	0.579
Genotype eliminating Gender	2	727.5	363.7	0.60	0.550
Residual	77	46517.9	604.1		
Total	80	51271.0	640.9		

APPENDIX 13

Two-way ANOVA table for eye muscle area (EMA) of entire and castrated males that were negatively homozygous, heterozygous or positively homozygous for the calpastatin gene

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Gender ignoring Genotype	1	390.89	390.89	9.40	0.003
Gender eliminating Genotype	1	431.73	431.73	10.38	0.002
Genotype ignoring Gender	2	386.30	193.15	4.64	0.012
Genotype eliminating Gender	2	427.14	213.57	5.13	0.008
Residual	77	3203.52	41.60		
Total	80	4021.56	50.27		

APPENDIX 14

Two-way ANOVA table for ossification (OSS) of entire and castrated males that were negatively homozygous, heterozygous or positively homozygous for the calpastatin gene

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Gender ignoring Genotype	1	1640.0	1640.0	7.73	0.007
Gender eliminating Genotype	1	1608.9	1608.9	7.58	0.007
Genotype ignoring Gender	2	51.3	25.6	0.12	0.886
Genotype eliminating Gender	2	20.2	10.1	0.05	0.954
Residual	77	16339.8	212.2		
Total	80	18000.0	225.0		

APPENDIX 15

Two-way ANOVA table for USMB of entire and castrated males that were negatively homozygous, heterozygous or positively homozygous for the calpastatin gene

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Gender ignoring Genotype	1	36309	36309	12.53	< 0.001
Gender eliminating Genotype	1	36533	36533	12.61	< 0.001
Genotype ignoring Gender	2	9	4	0.00	0.998
Genotype eliminating Gender	2	233	116	0.04	0.961
Residual	77	223080	2897		
Total	80	259622	3245		

APPENDIX 16

Two-way ANOVA table for $/kg of entire and castrated males that were negatively homozygous, heterozygous or positively homozygous for the calpastatin gene

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Gender ignoring Genotype	1	0.01607	0.01607	0.95	0.334
Gender eliminating Genotype	1	0.01558	0.01558	0.92	0.341
Genotype ignoring Gender	2	0.01685	0.00843	0.50	0.611
Genotype eliminating Gender	2	0.01635	0.00808	0.48	0.620
Residual	77	1.30889	0.01700		
Total	80	1.34132	0.01677		

APPENDIX 17

Two-way ANOVA table for GrValueEXGST of entire and castrated males that were negatively homozygous, heterozygous or positively homozygous for the calpastatin gene

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Gender ignoring Genotype	1	59876	59876	7.12	0.009
Gender eliminating Genotype	1	60842	60842	7.24	0.009
Genotype ignoring Gender	2	40101	20051	2.38	0.099
Genotype eliminating Gender	2	41068	20534	2.44	0.094
Residual	77	647343	8407		
Total	80	748287	9354		

APPENDIX 18

Two-way ANOVA table for Ultimate pH of entire and castrated males that were negatively homozygous, heterozygous or positively homozygous for the calpastatin gene

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Gender ignoring Genotype	1	0.00280	0.00280	0.24	0.624
Gender eliminating Genotype	1	0.00156	0.00156	0.13	0.715
Genotype ignoring Gender	2	0.11379	0.05689	4.90	0.010
Genotype eliminating Gender	2	0.11254	0.05627	4.85	0.010
Residual	77	0.89414	0.01161		
Total	80	1.00949	0.01262		

APPENDIX 19

Two-way ANOVA table for Ultimate pH of entire and castrated males that were negatively homozygous, heterozygous or positively homozygous for the calpastatin gene

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Gender ignoring Genotype	1	0.8759	0.8759	4.80	0.031
Gender eliminating Genotype	1	0.8652	0.8652	4.75	0.032
Genotype ignoring Gender	2	0.2956	0.1478	0.80	0.448
Genotype eliminating Gender	2	0.2849	0.1425	0.78	0.461
Residual	77	14.0392	0.1823		
Total	80	15.2000	0.1900		

APPENDIX 20

REML model tables for Warner Bratzler Shear Force for entire and castrated males that were negatively homozygous, heterozygous or positively homozygous for the calpastatin gene

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Gender	15.86	1	15.86	233.0	<0.001
Genotype	0.53	2	0.26	233.0	0.769
Day	115.27	2	57.64	233.0	<0.001
Genotype.Day	0.35	4	0.09	233.0	0.986

APPENDIX 21

REML model tables for on-farm eye muscle area (EMA) for entire and castrated males that were negatively homozygous, heterozygous or positively homozygous for the calpastatin gene

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Gender	0.46	1	0.46	480.0	0.497
Calpastatin	5.30	2	2.65	480.0	0.072
Day	1607.58	5	321.52	480.0	<0.001

APPENDIX 22

REML model tables for on-farm back fat (BF) for entire and castrated males that were negatively homozygous, heterozygous or positively homozygous for the calpastatin gene

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Gender	0.35	1	0.35	473.0	0.552
Day	1329.98	5	266.00	473.0	<0.001
Gender.Day	20.52	5	4.10	473.0	0.001
Calpastatin	0.22	2	0.11	473.0	0.895

APPENDIX 23

REML model tables for on-farm rump fat (RF) for entire and castrated males that were negatively homozygous, heterozygous or positively homozygous for the calpastatin gene

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Gender	2.14	1	2.14	476.0	0.144
Day	1236.09	5	247.22	476.0	<0.001
Calpastatin	2.27	2	1.13	476.0	0.322

APPENDIX 24

REML model tables for on-farm liveweight change (LWT) for entire and castrated males that were negatively homozygous, heterozygous or positively homozygous for the calpastatin gene

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Gender	9.28	1	9.28	830.0	0.002
Day	5849.84	10	584.98	830.0	<0.001
Calpastatin	67.29	2	33.64	830.0	<0.001
Gender.Day	9.92	10	0.99	830.0	0.448
Gender.Calpastatin	36.18	2	18.09	830.0	<0.001
Day.Calpastatin	3.07	20	0.15	830.0	1.000
Gender.Day.Calpastatin	4.03	20	0.20	830.0	1.000

APPENDIX 25

REML model tables for on-farm flight score for entire and castrated males that were negatively homozygous, heterozygous or positively homozygous for the calpastatin gene

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Gender	0.02	1	0.02	77.0	0.892
Calpastatin	1.54	2	0.77	77.0	0.465
Gender.Calpastatin	1.68	2	0.84	77.0	0.435

APPENDIX 26

REML model tables for on-farm flight score x shear force for entire and castrated males that were negatively homozygous, heterozygous or positively homozygous for the calpastatin gene

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Gender	0.02	1	0.02	77.0	0.892
Calpastatin	1.54	2	0.77	77.0	0.465
Gender.Calpastatin	1.68	2	0.84	77.0	0.435

APPENDIX 27

2-way ANOVA using starting liveweight as a co-variant for end liveweight versus gender and genotype

Source	DF	Seq SS	Ajd SS	Adj MS	F	P
Gender	1	7324	3092	3092	6.99	0.01
Genotype	2	11672	3078	1539	3.48	0.03
Gend*Genot	2	4587	2902	1451	3.28	0.04
Initial lwt	1	37993	37993	37993	85.94	0.00
Error	74	32713	32713	442		
Total	80	94920				

APPENDIX 28

2-way ANOVA using starting liveweight as a co-variant for carcass weight versus gender and genotype

Source	DF	Seq SS	Ajd SS	Adj MS	F	P
Gender	1	3947	3785	3785	13.04	0.01
Genotype	2	2778	608	304	1.03	0.36
Gend*Genot	2	650	279	139	0.48	0.62
Initial lwt	1	14065	14065	14065	47.80	0.00
Error	76	21777	21777	294		
Total	80	43219				