# Growth and Carcass Characteristics of Beef-Cross-Dairy-Breed Cattle: Breed and Sex Effects.

A thesis presented in partial fulfilment of the requirements for the degree of

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# Abstract

Approximately two thirds of New Zealand's annual cattle slaughter originates from the dairy industry in the form of cull cows, bobby calves and calves retained for beef finishing. Bobby calf slaughter for pet food and veal is a system of low production efficiency, making up 41.1% of the annual cattle slaughter on a per head basis, but comprising only 4.3% of the total annual carcass weight produced in New Zealand. These underutilised surplus calves provide an opportunity to increase beef production by finishing them at either the traditional slaughter age of around 24 months, or in a novel yearling system finishing cattle before 12 months.

This study aimed to investigate different factors influencing the performance of beef-cross-dairy-breed cattle through two separate experiments. The objective of the first experiment (chapter 3) was to investigate the effect of dam breed from dams with varying proportions of Friesian and Jersey genetics on growth traits and carcass characteristics of their dairy-beef progeny slaughtered between 24 and 30 months of age. The primary objective of the second experiment (chapter 4) was to investigate the effect of sex on carcass and meat quality characteristics of 11-month-old Stabilizer-Friesian-Jersey heifers and steers.

The first experiment involved 142 heifers and 203 steers born in the spring of 2018 to Friesian (F), Friesian-cross (FX), Friesian-Jersey (FJ) and Jersey-cross (JX) cows. Calves were artificially reared before drafting into four management herds and were slaughtered between October 2020 and March 2021. Calves from F dams took less time to reach a set weaning weight (100kg), and had greater live weights throughout the study than those from other dam breeds. Carcass weights were greater for progeny from F dams (286kg) than those from FX (297kg), FJ (275kg) and JX (276kg) dams. Yellow fat score was greatest for progeny of JX dams (3.33) than for progeny of F (3.01), FX (3.04) and FJ (3.05) dams. The frequency of yellowness scores of ≥ 5 (on a 1-9 scale) was also greatest for progeny of JX dams (17.1% compared to 2.6%, 5.6% and 9.2% for progeny of F, FX, and FJ dams, respectively). Therefore, calves from dams with a greater proportion of Jersey genetics will have lower live and carcass weights and yellower fat than those from dams with a greater proportion of Friesian genetics.

The second experiment involved 24 Stabilizer-Friesian-Jersey cattle (12 heifers and 12 steers) born in the spring of 2018 and artificially reared before finishing as one herd until slaughter at 11 months of age. The Stabilizer is a four-breed composite comprising 25% each of the Angus, Hereford, Simmental and Gelbvieh breeds. Carcass weight and dressing out was greater for steers (157kg and 48.6%) than heifers (148kg and 47.1%). Heifers had a greater muscle to bone ratio (7.76) than steers (7.09). Cooking loss was greater in heifers (37.8%) than in steers (35.6%) but all other meat quality characteristics were similar between the sexes. Therefore, meat from yearling beef-cross-dairy-breed heifers and steers could be classed as one product. Aging decreased shear force of meat (4.65kg for aged compared to 5.51kg for unaged). Unaged beef was still highly tender, suggesting that aging was unnecessary to provide tender beef.

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# Chapter 1. General Introduction

The dairy industry is arguably New Zealand's most important primary sector, with a herd of 6.2 million cattle and being the largest goods exporter (Ballingall & Pambudi, 2017; Statistics NZ, 2021). Two thirds of the annual beef kill originates from the dairy industry in the form of cull cows, bobby calves and calves retained for beef finishing (Burggraaf, 2016; Martin et al., 2020). The long-term forecasted increase in global beef consumption provides an opportunity for the New Zealand beef industry to increase profits from exported beef and co-products by increasing the productivity of beef finishing systems (OECD & FAO, 2019; USDA, 2019; Beef + Lamb New Zealand, 2020). Currently, bull beef finishing is one of the most productive finishing systems utilising bull calves of dairy origin, although this system utilises almost exclusively Friesian and Friesian-cross bull calves (Morris & Kenyon, 2014). Slaughter of four day-old bobby calves for veal and/or pet food, on the other hand, is a system of little monetary value that also creates ethical and welfare issues that jeopardize the image of the dairy industry (Jolly, 2016; Hunt, 2019). While beef-cross-dairy-breed heifers and steers are finished for beef, utilisation of surplus dairy calves, particularly those with Friesian-Jersey and Jersey genetics, for heifer and steer finishing could be further increased. This would have mutualistic benefits for both industries, with increased productivity in the beef industry and improved image of the dairy industry through reduction in the bobby calf slaughter.

This thesis consists of a review of the current literature which provides the reader with relevant information that provides a background on beef production in New Zealand. The next two chapters (Chapters 3 and 4) relate to two separate experiments investigating different aspects of the performance of beef-cross-dairy-breed heifers and steers. A final chapter provides a general discussion on the implications of both experiments as well as suggestions for future research.

# Chapter 2. Literature Review

## 2.1 New Zealand Beef Industry

### 2.1.1 Industry overview

The New Zealand beef industry is based on extensive pastoral farming, with over 95% of beef production being based on grazing of pasture or crops (Morris & Kenyon, 2014). The temperate climate favours year-round pasture growth, providing a low-cost and sustainable feed source which allows the industry to compete on a global scale (Malau-Aduli & Holman, 2014). The industry is heavily export focused, with 94% of beef and veal produced being exported (Beef + Lamb New Zealand, 2020). Despite having a national cattle herd below the global top ten, New Zealand typically is the 5th largest exporter of beef by volume (USDA, 2019). As of 2019, the national beef herd consisted of 3.8 million cattle, including both breeding and finishing animals (Beef + Lamb New Zealand, 2020). This is a decrease of 17% since 2004 as a result of loss of sheep and beef land to other agricultural and horticultural sectors, although the total volume of beef produced has increased as a result of increased productivity of beef cattle (USDA, 2019). The dairy industry plays an increasingly important role in beef production, with approximately 70% of beef produced in New Zealand being of dairy origin (Burggraaf, 2016). Including dairy animals, the national cattle herd consists of around 10 million and is expected to remain around this number (USDA, 2019).

### 2.1.2 Export volume and value

For the year ended 2020, a total of 4,590,762 cattle were slaughtered in New Zealand for local and international consumption (MPI, 2020). The total volume of beef and veal sent for export equated to 453,000 metric tonnes, which was worth $8,227 per tonne, with the total beef and veal on board being worth $3.73 billion (Table 1). Including co-products, the total freight on board was worth $4.23 billion, being a record high and the first time this value has surpassed $4 billion (Beef + Lamb New Zealand, 2020). While the forecasted volume of beef and veal meat exports for the 2020-2021 season is also 453,000 metric tonnes, the expected value is lower at $3.37 billion

(Table 1). This can be attributed to the global covid-19 pandemic, which has created uncertainty in markets, although the premium associated with New Zealand beef products keeps the industry in a good position to withstand this uncertainty (Beef + Lamb New Zealand, 2020).

**Table 1** – Volume and value of New Zealand beef and veal exports over recent years (Beef + Lamb New Zealand, 2020).

| Year | 000 tonne | $ / tonne | $m FOB (beef and veal meat) | $m FOB (meat and co-products) |
|---|---|---|---|---|
| 2015-2016 | 423 | 6,996 | 2,962 | 3,524 |
| 2016-2017 | 396 | 6,898 | 2,792 | 3,262 |
| 2017-2018 | 431 | 7,123 | 3,073 | 3,624 |
| 2018-2019 | 453 | 7,451 | 3,377 | 3,908 |
| 2019-2020 $^{f}$ | 453 | 8,227 | 3,728 | 4,232 |
| 2020-2021 $^{e}$ | 453 | 7,445 | 3,370 | 3,850 |
| $^{f}$Forecast \| $^{e}$Estimate | | | | |

## 2.1.3 Global beef consumption

Global meat consumption over the past 50 years has increased markedly, with beef and veal meat comprising 22% of total meat consumption (Beef + Lamb New Zealand, 2017). Between 2016 and 2018, average annual global consumption of beef and veal was 68.6 million tonnes at carcass weight equivalent, and is projected to rise to 77.6 million tonnes at carcass weight equivalent by 2028 (OECD & FAO, 2019). The driver of this predicted increase in consumption is mainly due to increases in population number and disposable income in Asian and Latin American countries, with the rise in beef consumption in developing countries expected to be four times that of developed countries (OECD & FAO, 2019). In Western countries, consumer demand is growing for products which have high quality credence attributes such as animal welfare and environmental sustainability (Yang & Renwick, 2019). This has resulted in a decline in red meat consumption as livestock products are considered highly intensive, which is further fuelled by advances in food technology allowing new and acceptable plant-based protein alternatives to be produced (Beef + Lamb New Zealand, 2018; Yang & Renwick, 2019). It is also this demand for products with high credence attributes which could make New Zealand grass fed beef particularly appealing, given that consumers have a high willingness to pay for grass-based products with high food safety and nutritional value (Yang & Renwick, 2019; (Beef + Lamb New Zealand, 2020).

### 2.1.4 Markets for New Zealand beef

The two countries receiving the majority of New Zealand's beef and veal exports are China and the United States (Figure 1). Most of the beef exported to the United States is processing beef (mainly from bulls and cull dairy and beef cows), with the majority of this going towards burger manufacturing (Beef + Lamb New Zealand, 2018). Until 2018, the United States was the largest market for New Zealand export beef, but this spot has now been overtaken by China (Figure 1). This is partly attributed to the recent outbreak of African swine flu which resulted in half of China's pigs being culled, further increasing beef consumption in China (Beef + Lamb New Zealand, 2019). For the 2019-2020 season, beef and veal export receipts from the United States totalled $1.16 billion, while those from China totalled $1.56 billion (Meat Industry Association, 2020). The third, fourth and fifth largest markets for New Zealand beef and veal were Japan ($217 million), Taiwan ($168 million) and Canada ($120 million), respectively (Meat Industry Association, 2020). The total volume of beef and veal exported to China over this season was 195,767 tonnes, while 141,129 tonnes was exported to the United States (Meat Industry Association, 2020). While Europe is only a small importer of New Zealand beef, as a result of a tariff rate quota of only 1,300 tonnes, export value is greatest for beef in Europe, at $14.98/kg compared to the average export value of $8.28/kg (Meat Industry Association, 2020).

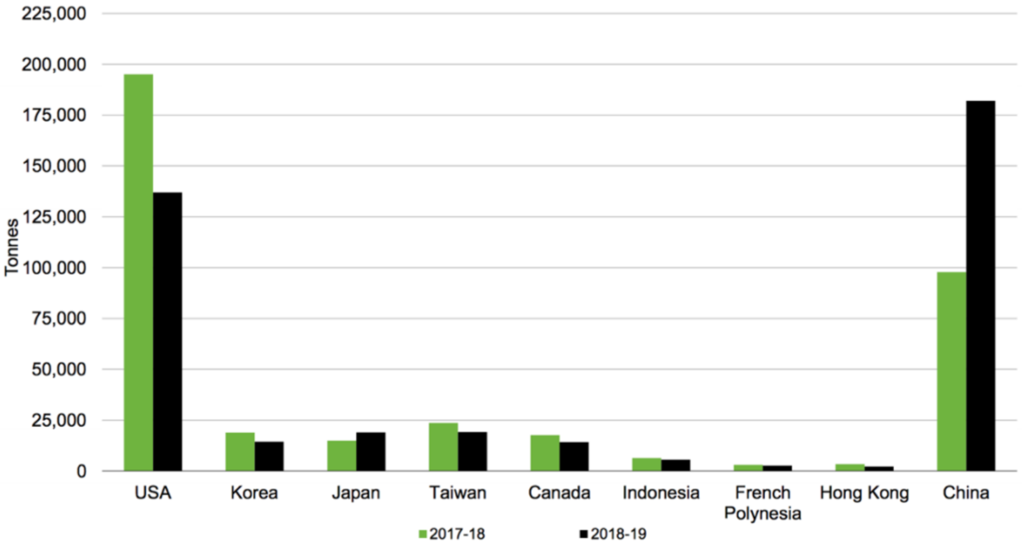


**Figure 1** – Volume of New Zealand beef export by country for the 2017-2018 and 2018-2019 seasons (Beef + Lamb New Zealand, 2020).

# 2.2 Beef Production Systems in New Zealand

## 2.2.1 Breeds used

There is a diversity of cattle breeds used for beef production in New Zealand, with 26 breeds in the national beef herd, including beef, dual-purpose and dairy breeds (Beef + Lamb New Zealand, n.d.). The beef herd is comprised of 54% British beef breeds (predominantly Angus and Hereford), 21% crossbred animals, 17% Friesian or Friesian types, and 7% European breeds and specialist beef breeds such as the Japanese Black/Wagyu (Bown et al., 2016). Crossbred animals comprise the second greatest breed group as crossbreeding is an established method of increasing animal productivity through breed complementarity and hybrid vigour (Gregory & Cundiff, 1980). The Friesian has similar growth potential and can produce a carcass with similar lean meat yield, yield of primal cuts and meat quality to that of the British beef breeds (Bown et al., 2016). Fewer Jersey and Jersey-cross calves are retained for beef production than Friesian calves as they are less productive under similar conditions as a result of having slower growth rates (Hickson et al., 2014; Jolly, 2016). Friesian-Jersey cattle (Kiwicross) have become the most popular breed used in the dairy herd, and as a result the proportion of Jersey genetics in the beef herd has increased (Beef + Lamb New Zealand, 2020; Hickson et al., 2014).

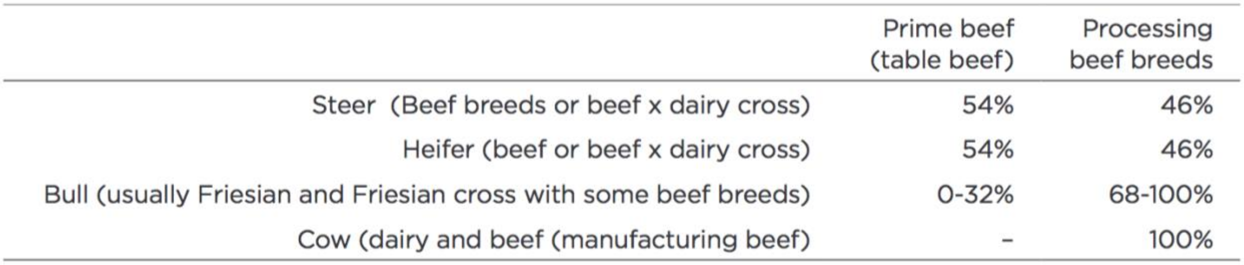
### 2.2.2 Typical production systems

Beef production systems in New Zealand are either classed as breeding systems or finishing systems (Morris & Smeaton, 2009). In a traditional beef breeding system, beef breeding cows produce calves for heifer and steer finishing systems (Beef + Lamb New Zealand, 2017). Heifer calves may also be kept and used as replacements if the system is self-replacing (Morris & Smeaton, 2009). Finishing systems can be classed into two main categories; heifer and steer finishing and bull-beef finishing. Heifers and steers are sourced either from beef breeding systems or as calves from the dairy industry, while bulls for finishing are sourced almost exclusively from the dairy industry (Morris & Kenyon, 2014). Along with finishing systems, an increasingly large proportion of beef comes from the cull of cull cows and surplus calves from the dairy industry (Morris, 2012).

### 2.2.3 Types of beef produced

The two main types of beef produced in New Zealand are prime beef and processing beef (Table 2). Prime beef (also referred to as table beef) typically comes from the hindquarters of beef breed steers and heifers, and is mainly exported in chilled form, which receives the highest price per kilogram relative to other beef products (Beef + Lamb New Zealand, 2017). The main export market for chilled prime beef is Asia, with China and Japan being New Zealand’s two largest chilled beef markets (MIA, 2020). Processing beef typically comes from bulls and cull cows, although parts of heifer and steer carcasses also become processing beef (Beef + Lamb New Zealand, 2017). While 46% of prime heifer and steer carcasses typically goes towards processing beef, between 70-100% of bull and cow carcasses goes towards processing beef (Beef + Lamb New Zealand, 2017). Processing beef comprises the greatest volume of beef destined for export in frozen form (Beef + Lamb New Zealand, 2017). Meat produced from bobby calves is used in pet food manufacturing or for human consumption, either as veal or included in processing beef (Jolly, 2016).

**Table 2** - Sources of prime and processing beef (Beef + Lamb New Zealand, 2017).



| | Prime beef (table beef) | Processing beef breeds |
|---|---|---|
| Steer (Beef breeds or beef x dairy cross) | 54% | 46% |
| Heifer (beef or beef x dairy cross) | 54% | 46% |
| Bull (usually Friesian and Friesian cross with some beef breeds) | 0-32% | 68-100% |
| Cow (dairy and beef (manufacturing beef) | – | 100% |

# 2.3 Role of the Dairy Industry in New Zealand Beef Production

## 2.3.1 Dairy industry overview

The dairy industry is a major primary industry in New Zealand, being the country's largest goods exporter with an average export revenue of $14.4 billion (Ballingall & Pambudi, 2017). The national dairy herd is considerably larger than the beef herd, with 6.4 million dairy cattle compared to 3.8 million beef cattle as of 2019 (Beef + Lamb New Zealand, 2020). Dairy cow breeds are bred for high milk production, with almost 50% of cows being Friesian-Jersey cross, 33% being Friesian, 9% being Jersey and the remaining being other dairy breeds or dairy breed crosses (LIC & Dairy NZ, 2020). This is a major shift from 20 years ago, when the national dairy herd consisted of 57% Friesian, 19% Friesian-Jersey and 16% Jersey cows (LIC & Dairy NZ, 1998). Annually, around 5 million dairy cows and heifers are put in calf (Beef + Lamb New Zealand, 2020). Sires for replacements to the dairy herd are chosen based on the ability to produce profitable daughters with high milk production (Burggraaf, 2016). The remaining are typically chosen based on ease of calving, gestation length and easy identification of beef calves, with little regard given to their potential for beef production (Burggraaf, 2016). Approximately 93% of annual income for dairy farmers comes from the production of kilograms of milk solids, while only 6% of total profit comes from beef derived from surplus calves and cull cows (Cook, 2014). The price per head for bobby calves is typically only between $80 and $150, but can be as low as $25 (Schouten, 2019; Cook, 2014). For some farmers, the costs of feeding, handling and transport of surplus calves may exceed the returns from processed or sold calves (Cook, 2014; Jolly, 2016).

### 2.3.2 Sources of animals from the dairy industry

There are three main ways by which the dairy industry contributes animals to the beef industry. Cull cows and bobby calves are two direct contributions when sent to slaughter, while calves finished on beef cattle farms are indirect contributions (Figure 2). In 2018-2019, 796,197 of the 999,033 cows slaughtered in New Zealand were from dairy farms, equating to 78% of the annual cow kill (Ministry for Primary Industries, 2020). Over this same period, 1,816,185 bobby calves were sent to slaughter (Ministry for Primary Industries, 2020). While bobby calves make up 41.1% of the annual cattle slaughter, they comprise only 4.3% of the total annual carcass weight (Ministry for Primary Industries, 2020).

The annual retention of calves from the dairy industry for beef production is typically around 0.44 million calves, which equates to 35-40% of calves entering the national beef herd each year (Pike, 2019). Bull calves make up the largest proportion of retained calves, followed by heifers and then steers (Ministry for Primary Industries, 2020). Typically, bull calves are purchased after weaning at around 3-4 months and farmed until 16-20 months of age at 550-580kgs. Some bull, heifer and steer calves of dairy origin are also retained on dairy farms and finished for beef as a secondary enterprise (Figure 2). The dairy industry also acts as an annual source of beef-cross-dairy-breed heifers as replacements for the beef breeding cow herd, with beef-cross-dairy-breed cows having greater efficiency than straightbred Angus cows (Hickson et al., 2014).

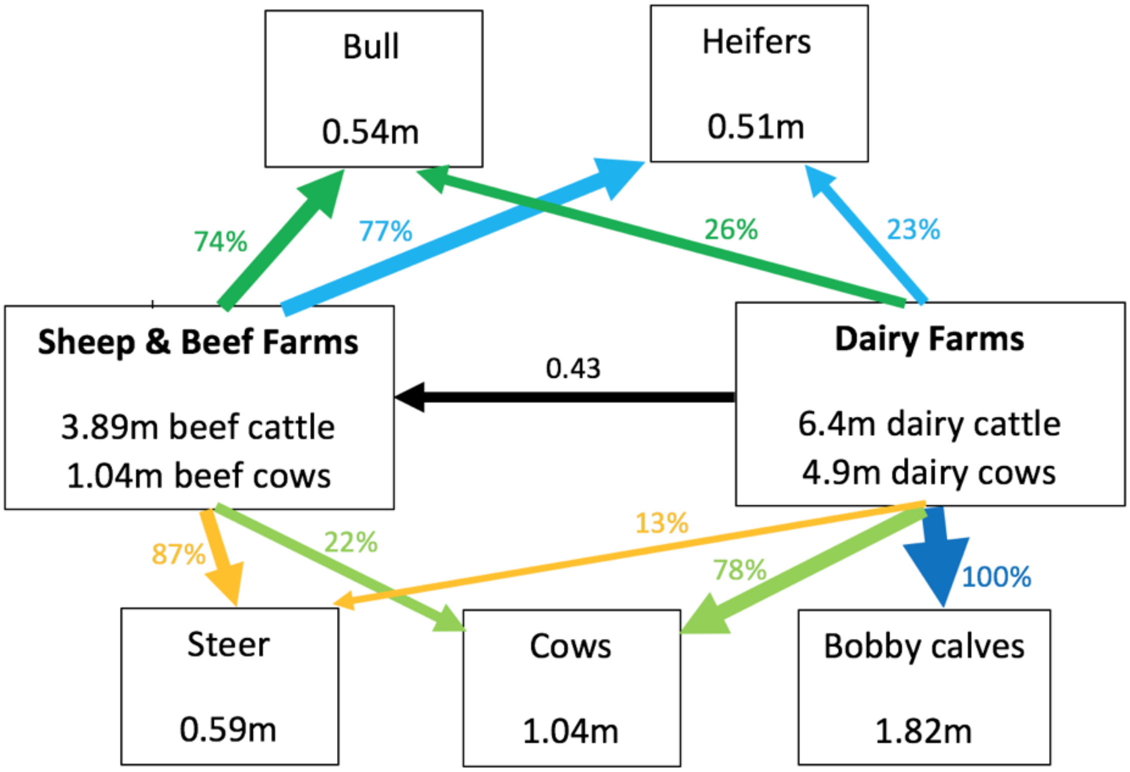


**Figure 2** – Domestic supply chains for slaughter of cattle from beef and dairy farms (Adapted from Jolly, 2016 with updated data from B+LNZ, 2020 and Ministry for Primary Industries, 2020). Arrows indicate the cattle at end of life. Different colours indicate a different stock class.

### 2.3.3 Challenges associated with surplus calves

The dairy industry produces a considerable surplus of calves each year. In 2019, 4,506,000 calves were born to dairy heifers and cows (Stats NZ, 2020). Only a quarter of these calves are kept as replacements for the dairy herd annually (Boulton et al., 2018). This creates an issue as to what dairy farmers do with surplus calves. While 450,000 to 500,000 enter the national beef herd for bull beef and heifer and steer production each year, just over 2 million are sent to slaughter for veal and pet food production (Morris, 2012; Boulton et al., 2018; Ministry for Primary Industries, 2017). Another 500,000 calves are estimated to be euthanised on-farm each year as a means of disposal (Jolly, 2016).

Another issue created by surplus dairy calves is potential welfare and ethical issues associated with the management of bobby calves. The handling and methods of on-farm slaughter of bobby calves in New Zealand has drawn past public criticism to the dairy industry. The transport of week-old bobby calves also has the potential to draw criticism. In 2008, initial measures were made to improve bobby calf welfare and in 2015 the Bobby Calf Action Group (BCAG) were formed (Ministry for Primary Industries, 2017). As a result, bobby calf mortality rate prior to slaughter has decreased; halving from 0.25% to 0.12% between 2015 and 2016 (Ministry for Primary Industries, 2017). Although this is considerable progress, it still means that approximately 2,500 bobby calves die each year during transport to or lairage before slaughter, and is a basic indicator of poor animal welfare status (Boulton et al., 2018).

## 2.4 Finishing Ages of cattle in New Zealand and Overseas

### 2.4.1 Typical finishing ages and weights in New Zealand

Due to reliance on pastoral-farming, slaughter age of cattle in New Zealand is strongly affected by environmental conditions which dictate feed supply (Morris, 2012). Ideally, cattle are finished before their second winter, at 18-22 months of age, as it is more efficient for cattle to spend only one winter on farm. However, under New Zealand conditions this is commonly not achieved, and many farmers “carry-through” steers and bulls past a second winter, sending them to slaughter between 27 and 34 months of age (Morris, 2012). The slaughter age for heifers is more flexible. Heifers that fail to get in calf at their first mating, at 15 or 27 months of age, are usually slaughtered for domestic consumption as smaller cuts are preferred by New Zealand consumers (Beef + Lamb New Zealand, 2017). Heifers can also be finished in a once-bred heifer system, where they are sent for slaughter after weaning their first calf at around 30 months of age (Keeling et al., 1991).

Beef breed steers tend to produce the heaviest carcass weights, followed by dairy breed bulls then heifers (Beef + Lamb New Zealand, 2017; Morris, 2012). However, Friesian and Friesian-cross cattle of the same sex and age tend to produce similar carcass weights to beef cattle breeds when raised under the same conditions (Muir et al., 2000; Barton & Pleasants, 1997). Average steer carcass weight for export is 316kg, while average bull carcass weight is 309kg and average heifer carcass weight is between 220-250kg (Beef + Lamb New Zealand, 2017). Steers have a target carcass weight of 300kg, and should achieve a weaning weight of around 250kg and a growth rate of 1kg/day or more to achieve this target (Beef + Lamb New Zealand, 2017). Those with slower growth rates are usually carried through to a second winter to reach a carcass weight of 300kg (Beef + Lamb New Zealand, 2017). Heifers are usually finished for local consumption, where smaller cuts are preferred, and have an average carcass weight of 220-250kg (Beef + Lamb New Zealand, 2017).

### 2.4.2 Veal and yearling production overseas

Other large beef exporting countries such as Australia, Brazil and the United States typically slaughter cattle well past 24 months of age (Campbell et al., 2014; Lala et al., 2018; Drouillard, 2018). Some countries which rely on their dairy industries for supply of beef animals have developed yearling beef systems to accelerate beef production. One of these systems is veal production, which is a particularly large industry in Europe, with 80% of global veal production produced within the EU (Pardon et al., 2014). In these systems, veal calves are sourced from herds (typically dairy herds) and either milk- or grain-fed (Ngapo & Gariepy, 2006). Milk-fed veal calves produce white veal and make up the largest proportion of the EU veal industry, while grain-fed veal calves produce rosé veal (Pardon et al., 2014). Another of these systems is yearling beef production, which is now the largest type of beef production in Argentina, after an increase in competition with other industries for land use (Arelovich et al., 2011). Slovakia also has a similar system of yearling beef production, where animals produced for meat are typically dairy breed bulls which are slaughtered by 1 year of age (Vrskova et al., 2012). These animals produce lean carcasses greater than 150kg in weight and with dressing out percentages greater than 50% if average daily gains of over 1kg/day are achieved (Vrskova et al., 2012).

## 2.4.3 Potential for yearling systems in New Zealand

Bobby calves represent a by-product of the dairy industry which is hugely underutilised. Retaining more calves from the dairy industry and finishing them as yearlings would increase productivity in the beef industry within a short time period (Morris, 2012; Pike et al., 2019). If the percentage of dairy cows mated to beef cattle breed sires increased from the current level of 19% to 38%, the number of bobby calves slaughtered annually is estimated to decrease by 25% as a result of more calves being suitable for beef cattle finishing (McDermott et al., 2005). This could have the potential to alleviate public concern over dairy practices, namely the transport of week-old bobby calves. Breeding a higher proportion of dairy cows to beef breed sires also provides an opportunity to regulate the genetics entering the beef industry. Using beef breed semen with proven easy calving ability during artificial insemination incurs no further increase in labour requirements for dairy farmers, and beef breed semen of high genetic merit is 20% cheaper than premier dairy breed semen (Burggraaf, 2016).

Implicating this system of yearling beef production from cattle of dairy origin could also increase the eco-efficiency of beef farming as less cattle would be carried through a second winter, reducing the number of urine patches and nitrogen losses through leaching (Mackay et al., 2012). This system could also aid in the uncertainty of our export markets. In South East Asia, particularly in Singapore, there has been a consumer push towards “young lean beef” from primal cuts of carcasses slaughtered before two years of age (Beef + Lamb New Zealand, 2017). Increasing yearling beef production could allow diversification of New Zealand beef exports into these markets.

It should be noted that while 2 million surplus calves are available from the dairy industry for beef finishing, currently only 1.64 million bulls, heifers and steers are finished in New Zealand each year (Ministry for Primary Industries, 2020). The lower feed requirement per head of yearling cattle compared to 24 month old cattle could allow for a greater stocking rate, along with the increased number of cattle for slaughter annually due to a lower slaughter age. However, keeping all surplus bobby calves for a yearling beef finishing system would still be unfeasible, mainly due to a lack of land available for beef finishing (Hunt, 2019; USDA, 2019).

## 2.5 Growth Characteristics

### 2.5.1 Growth of cattle

When growth is represented as a function of time, a s-shaped growth curve is produced (Mazzini et al., 2003). Although the shape of this weight-time curve differs between animals of different species, breed and sex, all animals show nonlinear growth (Gerrard & Grant, 2006). In these growth curves the inflection point occurs around the onset of puberty, and represents a shift from a phase of accelerating growth to one of decelerating growth (Teleken et al., 2017). These two phases are associated with differences in growth composition, as well as the efficiency of growth; how much input (feed) is required per unit of output (liveweight gain). The accelerating phase is a period of maximal muscle deposition and minimal fat deposition, while the decelerating phase is a period where muscle deposition begins to slow and fat deposition increases (Berg & Butterfield, 1976). Compared to lean tissue deposition, fat tissue deposition requires four times more energy as more water is stored with deposited protein than with deposited fat (Chizzotti et al., 2007). As a result, both the ratio of lean to fat in the carcass, and feed efficiency decrease as cattle reach maturity.

### 2.5.2 Breed and growth

Growth traits such as growth rate, birth weight, weaning weight and yearling weight have medium levels of heterosis, typically between 5-10% (Weaber et al., 2010). While heterosis for growth traits is typically desirable, heterosis for birth weight is undesirable as it increases the risk of dystocia, particularly in smaller framed cows such as those with Jersey genetics (Hickson et al., 2014). Heterosis for growth traits is greater in crosses between British and European beef breeds than for crosses between British breeds, and greatest in crosses between *Bos taurus* and *Bos indicus* breeds (Weaber et al., 2010). Limited literature is available on heterosis for growth traits of beef-cross-dairy-breed cattle, particularly on the influence of dairy dam genetics on growth traits of their beef-cross-dairy-breed progeny. Compared to progeny of traditional beef breed cows, progeny of typical New Zealand dairy breed cows, namely Friesian and Friesian-Jersey, have similar growth potential, while progeny of Jersey cows tend to have slower growth rates than those from Friesian cows (Hickson et al., 2014; Bown et al., 2016).

There are some differences between dairy breeds in growth traits. While straightbred Jersey calves tend to be lighter at birth compared to Friesian and Friesian-Jersey calves, beef-sired progeny from dams with Friesian, Jersey and Friesian-Jersey genetics have similar birthweights (Everitt & Jury, 1972; Hickson et al., 2015; Law et al., 2013). Growth rates and weaning weights were lower in progeny from beef-cross-dairy-breed cows with Jersey genetics compared to those from dams with Friesian and Friesian-Jersey genetics (Law et al., 2013). When growth traits of beef-sired progeny from dairy cows were studied by Burggraaf (2016), no relationship was found between the dam's percentage of Friesian relative to Jersey and growth traits of their beef sired progeny. This study only involved Friesian and Friesian-Jersey cows, however, with no cows with over 50% Jersey genetics being included. Cows with a greater proportion of Jersey genetics would produce smaller progeny with slower growth rates (Coleman, 2016; Martin et al., 2020).

### 2.5.3 Sex and growth

While differences in growth patterns are most observable when comparing bulls to steers and/or heifers, there are observable differences in the growth patterns of steers and heifers. The main difference between the two sexes is the time at which the onset of fattening occurs. In heifers, the onset of fattening is associated with the onset of puberty at around 12 to 14 months (Berg & Butterfield, 1976). This shift from the accelerating to decelerating growth period occurs earlier in heifers relative to steers (Berg & Butterfield, 1976). While an increase in fat deposition occurs earlier in heifers, the total rate of fat deposition relative to muscle deposition both before and after the inflection point is similar in steers and heifers (Figure 3). This could be attributed to heifers and steers having similar levels of estrogen, a hormone which facilitates fat deposition in ruminants (Henricks & Torrence, 1977; Gerrard & Grant, 2006). A second hormone which promotes lipogenesis is insulin, which also does not differ in concentration in the plasma of steers and heifers (Gettys et al., 1998).

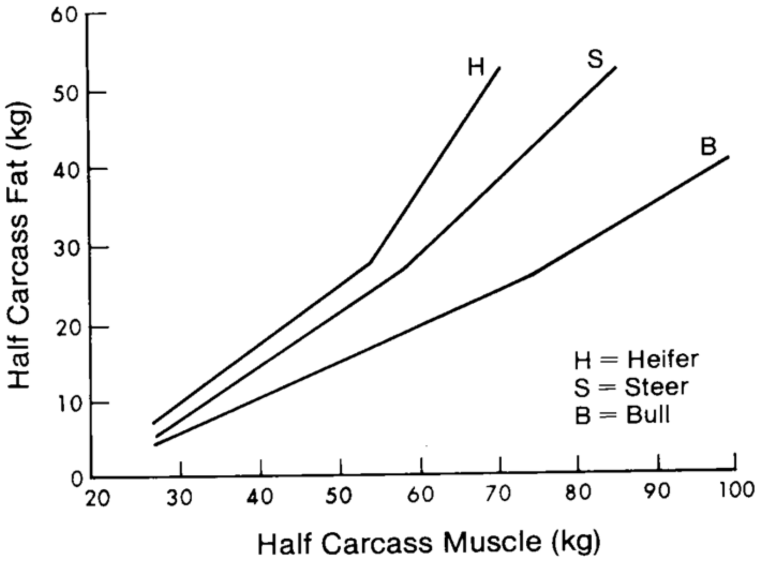


**Figure 3** – Growth of fat relative to muscle in heifers, steers and bulls (From Berg et al., 1979).

## 2.6 Carcass Characteristics

### 2.6.1 Key quality characteristics

The four key carcass quality characteristics are dressing out percentage (DO%), carcass composition, tissue distribution and carcass conformation (Purchas et al., 1989). DO% indicates what proportion of the animal's body weight is carcass (Warriss, 2010). Although DO% is influenced by non-carcass components, it is still considered a carcass characteristic as it defines the total muscle, fat and bone (Purchas et al., 1989). Carcass composition is determined by the relative proportions of tissue components of the carcass, namely muscle, fat and bone (Purchas et al., 1989). Carcass composition is a useful characteristic for both selection of breeding animals as well as for carcass grading and assigning value. Tissue distribution refers to the distribution of fat, muscle and bone across the carcass (Purchas et al., 1989). The distribution of these components across a carcass is an important characteristic as it determines the value of a carcass, with meat and fat having different value in different areas of the carcass (Wythes & Ramsay, 1981). Intramuscular fat, which occurs between muscle fibres, is particularly valuable as it contributes to both the eating and nutritional quality of meat (Robelin, 1986). Subcutaneous fat is less valuable as it is subject to trimming if the allowable level of fat is surpassed (Purchas et al., 1989). Cuts of beef from the loin are more valuable than those from areas such as the shoulder or brisket due to having superior palatability attributes (Dikeman, 2017). Carcass conformation refers to the shape of the carcass, which reflects muscularity (Warriss, 2010). Ideal carcass conformation is a high muscle thickness relative to skeletal size, which generally results in a higher muscle to bone weight ratio (M:B) and increased lean meat yield (LMY) (Warriss, 2010). Although muscularity is typically correlated to M:B and LMY, significant effects of breed and gender are found, meaning M:B cannot always be used as an unbiased predictor of LMY (Purchas et al., 2002).

## 2.6.2 Measurement of carcass characteristics

DO% is estimated as a ratio of hot carcass weight (HCW), measured immediately after slaughter, to liveweight, measured prior to slaughter (Janiak et al., 2016). This can also be done using cold carcass weight, but DO% will be lower as a result of water loss during chilling (Muir et al., 2008). In cattle, DO% usually ranges between 48%-58%, but can be as low as 45% or as high as 65% (Wythes & Ramsay, 1981). This variation is due to a number of factors including fatness, breed and stage of maturity, but namely whether empty or fresh liveweight is used in the calculation (Muir et al., 2008). DO% is often used to estimate the carcass weight of an animal of known liveweight, as meat producers are paid on the basis of carcass weight (Wythes & Ramsay, 1981). On live animals, carcass composition can be directly measured using ultrasound. On the carcass, it is measured directly using physical dissection of parts of the carcass, or indirectly using indicators such as fat depths and eye muscle area (Purchas et al., 1989). In cattle, fat depth is typically measured over the eye muscle at the 12th rib over the deepest part of the muscle, and at the P8 site over the rump (Purchas et al., 1989). If physical dissection is used, carcass composition is calculated as the percentage of fat, muscle or bone in the carcass (Warriss, 2010). Alternatively, ratios such as M:B can be used (Purchas et al., 1989).

Tissue distribution is measured after slaughter using either the relative weight of retail cuts or by physical dissection of the carcass. Fat distribution is measured as the weight or depth of fat at different sites within a fat depot relative to total carcass fat (Purchas et al., 1989). Muscle distribution is measured as the weight of individual muscles relative to total muscle weight (Purchas et al., 1989). Carcass conformation and muscling can be subjectively measured by comparing them against standard photographs (Price, 1995). Muscularity can also be measured objectively by physical dissection to find muscle weights and bone length then expressing this as muscle depth per unit of bone length (Purchas et al., 1989).

### 2.6.3 Breed and carcass characteristics

There is a belief amongst beef producers, processors and consumers that carcasses of dairy origin are inferior to traditional beef breeds (Bown et al., 2016). While dressing out percentages are typically lower in dairy breeds than beef breeds at the same liveweight, extensive literature has consistently found no difference in lean meat yield and yield of higher priced cuts between New Zealand dairy breeds and traditional British beef breeds when raised under similar management (Bown et al., 2016). When comparing straightbred dairy breeds, Friesian cattle tend to produce heavier carcasses than Jersey cattle, and Friesian-Jersey cattle tend to produce intermediate carcass weights (Barton et al., 1994). Muir et al. (2001) found no difference in carcass weight between Friesian bulls and bulls with ¾ Friesian and ¼ Jersey genetics, while bulls with ½ Friesian and ½ Jersey genetics had lighter carcasses. Straightbred Jersey cattle also tend to have yellower fat than Friesian and Friesian-Jersey cattle (Morgan et al., 1969; Barton et al., 1994).

As with growth potential, limited literature is available on the effects of dam breed and maternal heterosis on carcass characteristics of cattle, particularly for beef-cross-dairy-breed cattle. Compared to growth characteristics, carcass characteristics show low levels of heterosis of between 0-5% (Weaber, 2010). Of the carcass characteristics, carcass weight typically shows the highest amount of heterosis (Weaber, 2010). Of the typical dairy breeds in New Zealand, Friesian cows tend to produce progeny with greater carcass weights than Jersey cows (Morris et al., 1987; Burke et al., 1998). Relative to Angus dams, purebred Friesian dams produced progeny that had carcass weights 10kg greater while purebred jersey dams produced progeny with 10kg lighter carcass weights (Morris et al., 1987). The increase in the proportion of Jersey genetics in Irish dairy cows from 0 to 100% (with the remaining genetics being Friesian) resulted in a decrease in carcass weights of their Angus sired progeny (Berry et al., 2018).

Dam breed appears to have little effect on fat colour on progeny from beef-cross-dairy breed cows originating from the dairy herd. Beef-cross-dairy-breed steers from beef-breed-cross-Jersey dams had similar fat colour to steers from beef-breed-cross-Friesian and beef-breed-cross-Friesian-Jersey dams (Schreurs et al., 2014; Coleman et al., 2016). However, beef-cross-dairy-breed heifers from straightbred Jersey dams had yellower fat scores than those from straightbred Friesian dams (Burke et al., 1998). This indicates that dam breed may affect yellowness of fat when dams are straightbred Jersey, but not when dams are equal to or less than 50% Jersey.

## 2.6.4 Sex and carcass characteristics

### Dressing out percentage

Differences in DO% between steers and heifers are small and inconsistent, and vary depending on breed, level of finish and diet (Table 3). On a 100% grain-based concentrate diet, British-European beef breed-cross steers had greater DO% compared to heifers, however, on a silage-based diet, no difference in DO% was observed between steers and heifers (Rahnefeld et al., 1983). Klosterman & Parker (1976), however, found no difference in DO% between Hereford steers and heifers on both a silage-based and a corn-based concentrate diet. In late maturing Friesian-Limousin cattle, heifers had a greater DO% than steers across a range of levels of finish (Forrest, 1981). However, when finished at 14 months, Pirenaica steers, another late maturing breed, had a greater DO% than heifers (Blanco et al., 2020). Other studies found no difference in DO% between steers and heifers (Steen, 1995; Lage et al., 2012).

### Muscularity

As with DO%, differences in EMA between steers and heifers are also inconsistent (Table 4). While multiple studies have found EMA to be numerically greater in steers than in heifers, the difference was insignificant (Reiling et al., 1992; Crews et al., 2002; Lage et al., 2012; Carvalho et al., 2018). The effect of sex on EMA may also vary with diet; Hereford steers had a greater EMA than heifers on a silage-based diet, but there was no difference on a concentrate-based diet (Klosterman & Parker, 1976). When measuring carcass composition by dissection of the 6th rib, Blanco et al. (2020) found no difference in muscle as a percentage of carcass between steers and heifers. Despite having similar muscularity to steers, heifers tend to have greater M:B as a result of having finer bones (Purchas et al., 2002).

### Fat characteristics

Typically, heifers have a greater fat content in the carcass compared to steers at both the same slaughter age and carcass weight (Table 5). In earlier maturing beef breeds, subcutaneous fat depth is typically greater in heifers than in steers when compared at the same age (Klosterman & Parker, 1976; Carvalho et al., 2018). This difference could be explained by the fact that heifers begin to fatten at a lighter weight and faster rate than do steers (Wythes & Ramsay, 1981). Friesian-Limousin heifers also had greater subcutaneous fat depths than steers when compared at greater liveweights (Forrest, 1981). However, when compared at younger ages or lighter liveweights, late-maturing steers and heifers have similar subcutaneous fat depths (Reiling et al., 1992; Lage et al., 2012; Blanco et al., 2020). Heifers tend to have greater intramuscular fat (IMF) content compared to steers (Carvalho et al., 2018; Blanco et al., 2020). They also tend to receive greater marbling scores compared to steers, which is a visual measure of the amount of IMF in muscle (Carvalho et al., 2018; Blanco et al., 2020).

**Table 3**– The effect of breed and diet on dressing out percentage (%) of steers and heifers.

| Breed | Finish | Diet | Steers | Heifers | Reference |
|---|---|---|---|---|---|
| Hereford | 385-450kg | Corn silage | 61.4$^{a}$ | 60.8$^{a}$ | Klosterman & Parker (1976) |
| | | Corn-based concentrate | 60.7$^{a}$ | 60.3$^{a}$ | |
| Friesian-Limousin | 200-500kg | Barley-based concentrate | 58.6$^{a}$ | 59.4$^{b}$ | Forrest (1981) |
| British-European | 13.5m | Barley-based concentrate | 60.88$^{a}$ | 60.26$^{b}$ | Rahnefeld et al. (1983) |
| | | Cereal silage | 60.11$^{a}$ | 59.90$^{a}$ | |
| British Friesian-cross | 510-610kg | 67: 33 concentrate: silage | 54.4$^{a}$ | 54.2$^{a}$ | Steen (1995) |
| Zebu-cross | 22m | 70: 30 concentrate: silage | 56.44$^{a}$ | 57.60$^{a}$ | Lage et al. (2012) |
| Angus-Wagyu | - | Sugarcane silage & corn concentrate | 54.9$^{a}$ | 53.7$^{b}$ | Carvalho et al. (2018) |
| Pirenaica | 14m | Grain-based concentrate &hay | 60.30$^{a}$ | 57.14$^{b}$ | Blanco et al. (2020) |

**Table 4** - The effect of breed and diet on eye muscle area (cm$^2$) (EMA) of steers and heifers.

| Breed | Finish | Diet | Steers | Heifers | Reference |
|---|---|---|---|---|---|
| Hereford | 385-450kg | Corn silage | 61.30$^a$ | 56.78$^b$ | Klosterman & Parker (1976) |
| | | Corn-based concentrate | 61.29$^a$ | 61.94$^a$ | |
| Friesian-Limousin | 200-500kg | Barley-based concentrate | 76.5$^a$ | 77.9$^a$ | Forrest (1981) |
| British-European | 13.5m | Barley-based concentrate | 82.58$^a$ | 76.34$^b$ | Rahnefeld et al. (1983) |
| | | Cereal silage | 76.75$^a$ | 75.53$^b$ | |
| Beef-dairy crosses | - | - | 79.7$^a$ | 77.5$^a$ | Reiling et al. (1992) |
| Beef breed composite | 500kg | Grain-based concentrate | 83.06$^a$ | 80.21$^a$ | Crews et al. (2002) |
| Zebu-cross | 22m | 70: 30 concentrate: silage | 62.62$^a$ | 58.82$^a$ | Lage et al. (2012) |
| Angus-Wagyu | - | Sugarcane silage & corn concentrate | 87.3$^a$ | 79.5$^a$ | Carvalho et al. (2018) |

**Table 5** - The effect of breed and diet on carcass fat characteristics of steers and heifers (SFD = subcutaneous fat depth, IMF% = intramuscular fat percentage).

| Breed | Diet | Characteristic | Steers | Heifers | Reference |
|---|---|---|---|---|---|
| Hereford | Corn silage | SFD | 7.1 | 12.7 | Klosterman & Parker (1976) |
| | Corn-based concentrate | SFD | 12.7 | 9.4 | |
| Friesian-Limousin | Barley-based concentrate | SFD | $12.9^a$ | $17.0^b$ | Forrest (1981) |
| British-European | Barley-based concentrate | SFD | $15.7^a$ | $15.0^b$ | Rahnefeld et al. (1983) |
| | Cereal silage | SFD | $10.5^a$ | $10.8^b$ | |
| Beef-dairy crosses | - | SFD | $10.1^a$ | $9.1^a$ | Reiling et al. (1992) |
| Zebu-cross | 70: 30 concentrate: silage | SFD | $4.96^a$ | $4.01^a$ | Lage et al. (2012) |
| Angus-Wagyu | Sugarcane silage & corn concentrate | SFD | $11.2^a$ | $16.4^b$ | Carvalho et al. (2018) |
| | | Marbling score | $3.1^a$ | $4.6^b$ | |
| Pirenaica | Grain-based concentrate &hay | SFD | $11.0^a$ | $12.5^a$ | Blanco et al. (2020) |
| | | IMF% | $1.5^a$ | $2.8^b$ | |

## 2.7 Carcass Classification in New Zealand

The term carcass classification refers to the sorting of carcasses based on specific criteria to define payment for the farmer (Dikeman, 2017). Beef producers are paid on the basis of HCW, and carcasses eligible for export are given a classification (Price, 1995). In New Zealand, beef carcasses are classified according to maturity, sex, fat depths and muscling based on guidelines from the New Zealand Meat Classification Authority (NZMCA). Carcasses are sorted into a type of animal class which allocates for sex and age (based on the number of erupted permanent incisors), and carcass weight and fat class are combined with a conformation score to give a carcass classification (NZMCA, 2004). All carcasses, excluding M cows, are assigned one of three conformation scores based off subjective visual assessment focused on muscles of the hindquarter when hanging (NZMCA, 2004). Carcasses receiving a conformation score of 1 receive a premium of 5 cents/kg while those receiving a score of 3 are penalised by up to 10 cents/kg (Bown et al., 2016). Carcasses are also penalised around 10 cents/kg if fat depth is less than 3mm or over 11mm (NZMCA,2004; Bown et al., 2016). The M grade includes steers and heifers which are either under 145kg or have excessively yellow fat or cows which are either under 160kg or have excessively yellow fat (NZMCA, 2004). While not necessary for carcass grading in New Zealand, ossification scoring is used in the USDA and MSA grading systems as a measure of physiological maturity. Ossification is a measure of the degree of calcification of the sacral, lumbar and thoracic vertebrae which occurs in conjunction with physiological age, reflecting changes associated with meat tenderness as an animal ages (Gudex et al., 2018; Meat and Livestock Australia, 2013).

As the current system of carcass classification is based off only subjective assessment of fatness and conformation, carcasses with dairy genetics are often penalised despite having similar yield of saleable meat compared to beef breed carcasses (Bown et al., 2016). This means farmers have less flexibility with beef-cross-dairy-breed animals as there is little room for error to avoid grading penalties, so often have to take beef-cross-dairy-breed animals to greater slaughter weights to avoid these penalties (Cook, 2014; Bown et al., 2016). A separate carcass classification system for cattle of dairy origin, or a more objective system, may be more appropriate given that beef-cross-dairy-breed animals comprise two thirds of the annual beef kill (Burggraaf, 2016).

## 2.8 Meat Quality Characteristics

### 2.8.1 Key meat quality characteristics

The meat quality characteristics most commonly measured on cattle are ultimate pH, tenderness, lean meat colour, fat colour, water-holding capacity (WHC) and juiciness. Lean meat and fat colour are appearance characteristics, while tenderness and juiciness are palatability characteristics, and water-holding capacity is a processing property (Purchas et al., 1989). Lean meat colour is important as it influences consumers' perception of meat quality, with a bright, light red colour being associated with freshness (Dikeman, 2017). It is also the most important characteristic in determining retail selection of meat (Seideman et al., 1984). Fat colour also influences consumers' perception of meat quality. Creamy white coloured fat is considered desirable, and yellow fat undesirable (Purchas et al., 1989). In the New Zealand carcass grading system, carcasses with visibly yellow fat (assessed subjectively) are downgraded and used for manufacturing (Purchas et al., 1989).

Most consumers identify tenderness as the most important sensory attribute of eating quality of meat, and are willing to pay a premium if tenderness is guaranteed (Reddy et al., 2015; Holloway & Wu, 2019). WHC refers to the ability of meat to retain water under different conditions (Purchas et al., 1989). As it affects meat appearance, behaviour during cooking and juiciness during mastication, WHC is an important measure of meat quality (Lawrie, 1991). Juiciness is determined by both the water content of meat, having an inverse relationship with cooking loss, and the degree of salivation, affected mainly by intramuscular fat content (Purchas et al., 1989). A direct positive relationship exists between juiciness and intramuscular fat content (Dikeman, 2017). While water content predominantly determines initial juiciness, the stimulatory effect of fat on salivation determines sustained juiciness after initial chewing (Lawrie, 1991).

Ultimate pH affects the appearance, palatability and processing properties of meat (Dikeman, 2017), making it an especially important measure of meat quality. High ultimate pH is associated with an undesired phenomenon called dark-cutting beef, which occurs as a result of muscle fibres being more tightly packed and less able to scatter light to the same extent as the more open surface of meat with a lower pH (Holloway & Wu, 2019). Tenderness is dependent on ultimate pH. The relationship between tenderness and pH is curvilinear, with tenderness decreasing as pH rises from 5.5 to 6.1, then increasing again up till a pH of 7 (Figure 4). As ultimate pH rises above 6.1, water holding capacity also appears to increase as a result of decreased cooking loss (Purchas & Aungsupakorn, 1993).

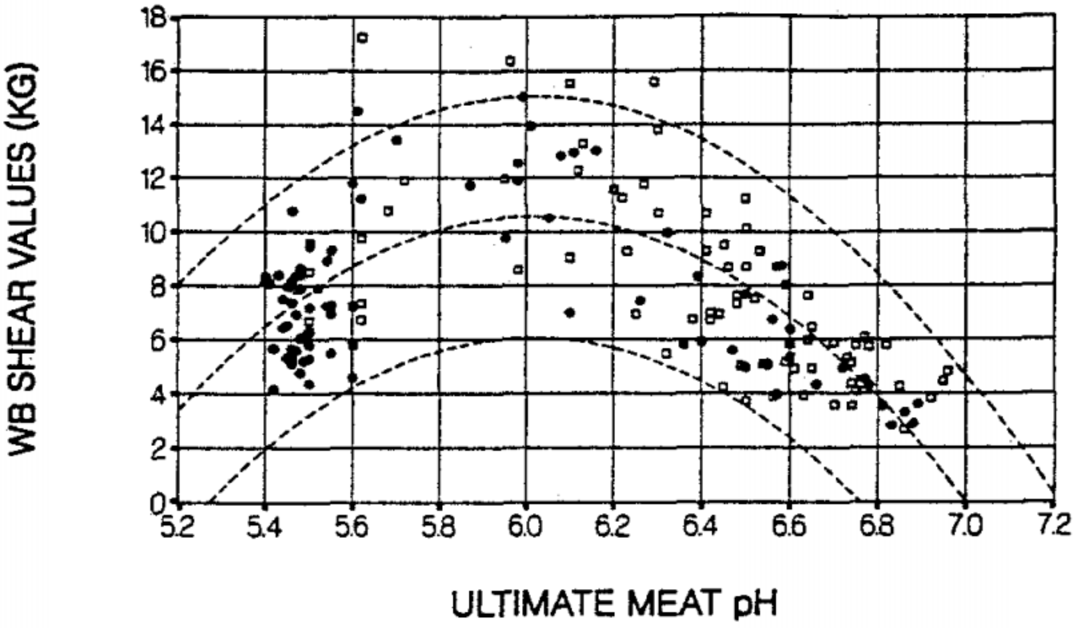


**Figure 4** – Relationship between ultimate pH of meat and Warner-Bratzler shear force values (From Purchas, 1990).

## 2.8.2 Measurement of meat quality characteristics

Lean meat colour can be measured both objectively, using imaging instruments, and subjectively, using a standard series of colours/photographs for reference (Purchas et al., 1989). One instrument used to objectively measure colour is a colorimeter, which produces CIE, L*(lightness), a*(redness) and b*(yellowness) color parameters at different points on a cut surface of meat

(Holloway & Wu, 2019). Another is hyperspectral imaging, which scans the entire surface of a cut of meat (Holloway & Wu, 2019).

Tenderness can be measured both subjectively by sensory panels, and objectively. The two most common objective measurements of tenderness are Warner-Bratzler Shear Force (WBSF) and Slice Shear Force (SSF), both of which measure the amount of force taken to shear through a cooked sample of meat (Dikeman, 2017). Meat considered very tender by New Zealand consumers has a WBSF value less than 5kg, while that considered tender has a value between 5kg and 7.9kg, that considered acceptable has a value between 8kg and 10.9kg, and that considered tough has a value over 11kg (Bickerstaffe et al., 2001).

WHC can be measured as water loss after thawing (thaw loss), in thawed uncooked meat (drip loss), or after cooking (shrink/cooking loss) (Lawrie, 1991). Juiciness refers to the sensation of moisture release from meat or lubrication during mastication (Purchas et al., 1989; Holloway & Wu, 2019). Typically, juiciness is measured subjectively by sensory panels (Purchas et al., 1989). It can also be measured objectively by measuring WHC through drip or cooking loss analysis, or by analysis for lipid content (Dikeman, 2017). Ultimate pH of meat is typically measured objectively, using a pH meter which is inserted into a cut sample of meat.

### 2.8.3 Breed and meat quality characteristics

Breed typically has little effect on the pH and colour of meat, so most literature on breed effects on meat quality focuses on tenderness and other palatability attributes (Lawrie, 1991). Compared to beef-breed cattle, dairy-breed cattle produce meat with similar shear force values and sensory panel ratings (Bown et al., 2016). Straightbred Jersey steers were found to have lower shear force values in the *Longissimus* than both Angus and Friesian steers, which was attributed to Jersey steers having a greater ability to deposit intramuscular fat (Purchas & Barton, 1976). There was no difference in shear force values in the *Psoas major* among breeds, however (Purchas & Barton, 1976).

As with carcass characteristics, meat quality characteristics exhibit low levels of heterosis (Weaber, 2010). Little is known about breed effects on the meat quality of beef-cross-dairy-breed cattle, particularly on maternal breed effects. Schreurs et al. (2014) and Coleman et al. (2016) found no difference in meat quality characteristics, including intramuscular fat content, among progeny of Friesian, Friesian-Jersey and Jersey dams sired by beef-breed bulls. Similarly, in progeny of straightbred Jersey and Friesian dams, Burke et al. (1998) found no difference in meat quality characteristics.

## 2.8.4 Sex and meat quality characteristics

**Lean meat colour**

Typically, lean meat colour of steers and heifers is similar. L*, a* and b* values of lean meat did not differ between Hanwoo heifers, cows and steers (Park et al., 2002). In Hereford-Angus cattle, heifers had greater L* values compared to steers (Martin et al., 1971). This was attributed to heifers having greater IMF content compared to steers (Martin et al., 1971). Male cattle also tend to have greater myoglobin concentration than females, leading to lower L* values seen in the lean meat of males compared to females (Seideman et al., 1984).

**Tenderness**

Heifers and steers typically produce meat with similar shear force values (Martin et al., 1971; Lucero-Borja et al., 2014; Li et al., 2014). There also tends to be no difference in sensory panel evaluated tenderness between heifers and steers (Martin et al., 1971; Lucero-Borja et al., 2014). While heifers tend to have greater levels of IMF, which has a positive correlation with sensory tenderness, there tends to be no difference in intramuscular connective tissue and collagen crosslinking between heifers and steers, which is negatively associated with tenderness (Bures & Barton, 2012; Lucero-Borja et al., 2014).

**Juiciness**

Typically, meat from heifers and steers receives similar scores for sensory evaluated juiciness (Martin et al., 1971; Lucero-Borja et al., 2014). When juiciness was measured objectively by measuring WHC, Angus-cross heifers and steers produced meat with similar drip loss or cooking loss (Li et al., 2014).

**Ultimate pH**

Differences in the ultimate pH of meat from steers and heifers are minimal (Martin et al., 1971; Lucero-Borja et al., 2014). Unlike bulls, steers and heifers tend to consistently produce meat within the acceptable pH range (Pogorzelska-Przybyłek et al., 2018). Steers and heifers are less susceptible to excitability or stress during lairage, which depletes glycogen and prevents lactic acid formation, so instances of high pH meat are rarer in steers and heifers (Pogorzelska-Przybyłek et al., 2018; Warris, 2010).

## 2.9 Summary of Literature and Research Objectives

The number of Friesian-Jersey cows as a percentage of the dairy herd has increased by over two fold in the last 23 years (LIC & Dairy NZ, 1998; LIC & Dairy NZ, 2021). This increase in Friesian-Jersey cows in the national dairy herd will result in an increase in Jersey genetics in surplus dairy calves available for beef finishing (Hickson et al., 2014). Of the typical dairy breeds utilised in New Zealand, cows with Jersey genetics are slower growing and produce progeny with slower growth rates and lighter carcasses than cows with Friesian genetics (Morris et al., 1987; Muir et al., 2001; Dhakal et al., 2013; Law et al., 2013; Hickson et al., 2014; Bown et al., 2016; Law et al., 2016; Berry et al., 2018; Martin et al., 2020). Cattle with Jersey genetics also tend to have yellower subcutaneous fat than those with Friesian genetics (Morgan et al., 1969; Walker et al., 1990; Dikeman, 2017). The objective of chapter 3 was to investigate the effect of dam breed on growth traits and carcass characteristics of their 24-month-old beef-cross-dairy-breed heifers and steers in a pastoral based system. It is hypothesised that progeny from Friesian dams will have greater growth rates and have greater liveweights throughout the study than progeny from Jersey-cross dams, while progeny from Friesian-cross and Friesian-Jersey dams will be intermediates. It is also hypothesised that carcass weight will be greater for progeny of Friesian dams than for progeny of Jersey-cross dams, and progeny from Jersey-cross dams will have yellower fat, while dressing out percentage, fat depth, marbling score, meat colour, pH and ossification score will not differ among dam breed groups.

Utilising surplus bobby calves by finishing them before 12 months of age could have the potential to be mutualistic for both the dairy and beef industries; Improving animal welfare and the image of the dairy industry and increasing feed, production and potentially environmental efficiency of the beef industry (Pike, 2019; Hunt, 2019). Previous research has indicated that beef-cross-dairy-breed cattle can produce high quality meat in a yearling pastoral based system (Pike, 2019). However, it is unknown whether differences in carcass and meat quality between beef-cross-dairy-breed heifers and steers exist under a yearling finishing system. International research has indicated that while carcass weights tend to be greater in young steers compared to heifers, there tends to be no difference in dressing out percentages, fat characteristics or meat quality characteristics between the sexes (Reiling et al., 1992; Lage et al., 2012; Blanco et al., 2020). While postmortem aging of meat is a well-known method of improving eating quality, mainly through increasing tenderness, it has been found that aging is not required to ensure the tenderness of meat from yearling beef-cross-dairy-breed steers (Pike, 2019). The objectives of chapter 4 were to investigate the effect of sex on carcass and meat quality characteristics of 11-month-old Stabilizer-Friesian-Jersey heifers and steers in a pastoral based system, and to investigate the effect of aging on meat quality characteristics to validate previous findings that identified a minimal effect of aging on tenderness for meat from yearling cattle. It is hypothesised that steers will have greater carcass weights, but other carcass characteristics will be similar between the sexes. Meat quality characteristics are expected to be similar between heifers and steers. It is hypothesised that aged and unaged meat will be highly tender and have similar meat quality characteristics.

# Chapter 3. Growth and carcass characteristics of beef-cross-dairy-breed heifers and steers born to different dam breeds

## 3.1 Introduction

The breed composition of the New Zealand dairy herd has shifted from 57% Friesian, 16% Jersey and 19% Friesian-Jersey (Kiwicross) in 1998 to 33% Friesian, 8% Jersey and 49% Friesian-Jersey cows in 2020 (LIC & Dairy NZ, 1998; LIC & Dairy NZ, 2021). This equates to over a 2-fold increase in Friesian-Jersey cows as a percentage of the dairy herd in the last 23 years as dairy farmers shifted to benefit from increased breeding worth as a result of better fertility of Jersey genetics. As two thirds of the annual beef kill originates from the dairy industry, the increase in Friesian-Jersey and Jersey genetics in the national dairy herd inevitably results in an increase in Friesian-Jersey and Jersey genetics entering the beef herd from retention of dairy origin calves for beef finishing (Hickson et al., 2014; Burggraaf, 2016).

Calf rearers and beef finishers prefer calves with Friesian markings to those with Jersey markings as there is a historic belief that cattle with Jersey genetics are inferior for the production of beef, mainly due to perceptions of poor growth rates and greater incidences of excessively yellow fat (Muir et al., 2001). While less literature on maternal breed effects and maternal heterosis is available on cattle with dairy genetics than on beef breed cattle, previous literature has found progeny of Jersey dams to be slower growing than those of Friesian dams, and as the proportion of Jersey genetics increases, dams produce smaller and slower growing progeny with lighter carcasses (Morris et al., 1987; Muir et al., 2001; Dhakal et al., 2013; Law et al., 2013; Berry et al., 2018; Martin et al., 2020). Straightbred Jersey cattle have yellower fat than Friesian cattle, although yellowing was not an issue in beef-cross-dairy-breed steers with only a quarter Jersey genetics (Morgan et al., 1969; Coleman et al., 2016).

The belief that animals of dairy origin are inferior beef animals to the traditional British beef breeds is not supported by scientific literature. Over 60 years of research confirms there is no difference in growth potential, saleable meat yield, primal cut yield or meat quality between New Zealand dairy breeds and British beef breeds under similar management (Bown et al., 2016). In terms of carcass composition, Jersey cattle are more similar to British beef breeds than Friesian cattle as they have similar proportions of bone, muscle and fat (Bown et al., 2016). However, as the percentage of Jersey genetics in the national dairy herd increases, the potential for excessively yellow fat from Jersey genetics of the dam could be an issue (Bown et al., 2016).

The primary objective of this experiment was to investigate the effect of dam breed from dams with varying proportions of Friesian and Jersey genetics on growth traits and carcass characteristics of their 24-month-old beef-cross-dairy-breed heifer and steer progeny in a pastoral based system. It is hypothesised that progeny from Friesian dams will have greater growth rates and be heavier at birth, weaning, yearling and slaughter than progeny from Jersey-cross dams, while progeny from Friesian-cross and Friesian-Jersey dams will be intermediates. It is hypothesised that carcass weight will be greater for progeny of Friesian dams than for progeny of Jersey-cross dams, and fat of progeny from Jersey-cross dams will be yellower than that of progeny from other dam breed groups. It is expected that dressing out percentage, fat depth, marbling score, meat colour, pH and ossification score will not differ among dam breed groups.

## 3.2 Materials and Methods

### 3.2.1 Animals and management

This experiment is part of a larger experiment progeny testing beef bulls for use over dairy cows. In this larger experiment, 26 sires from 8 beef breeds were allocated to 5 mating teams which were rotationally allocated to mating days. Semen from bulls within the allocated team was randomly allocated to cows in oestrus on each mating day. The cows used were the entire milking herd at Renown dairy farm. A total of 1600 inseminations were conducted.

Calves were born between 9th July and 17th August of 2018. Each day at around 11am, they were collected from their dam, within 24 hours of birth, and taken to the rearing shed. Calves were artificially reared at either Renown or Discovery dairy farms in Pamu's Wairakei Estate in Reporoa, Waikato. Calves were allocated to pens of up to 20 calves based on date of birth, for up to 3 weeks, then moved outside in mobs of 120 calves. Calves were reared on 4 litres of milk per day, initially on whole milk and then powder once there was insufficient waste milk. Male calves were castrated prior to weaning. Once the mob was judged to include approximately 30% weanable calves, the calves were weighed fortnightly. Calves were weaned once they reached a set weaning weight of 100kg. During the transition from milk to pasture, calves received meal until they reached a weight of 100kg. At weaning, all calves were moved to Orakonui farm within the same complex.

In January 2019, calves were drafted into 4 herds: big heifers, small heifers, big steers, small steers; where they remained for the remainder of the experiment. Calves were allocated to herds based on sex and live weight within sire group; the lightest half a sire's progeny group were allocated to the small herd and the heaviest half were allocated to the big herd. If a sire had an odd number of heifers or steers, the middle calf was allocated to a big or small herd depending on whether it was above or below the mean of all heifers or steers in the progeny test. The threshold weight for the big and small herds differed for each sire.

Cattle were grazed under commercial management until processing at a target of 500 kg live weight for heifers and 600 kg live weight for steers. Each herd, apart from the big heifers, was drafted into two sub-herds based on live weight within sire group in the lead-up to slaughter, and all cattle within a sub-herd were processed on a single day, to give 7 processing events. As with drafting into the initial herds, the threshold for drafting into these sub-herds was different depending on sire. The first processing event occurred on the 29/10/2020 and the last processing event occurred on the 30/03/2021. Processing was conducted according to standard commercial practices at Silver Fern Farms' Pacific plant in Hawkes Bay, New Zealand. This experiment used a subset of the calves; those born to the 345 cows in the herd for which pedigree was fully recorded.

### 3.2.2 Measurement of live animals

Calves were weighed on arrival at the calf shed, prior to being fed, as a measure of birth weight. Date of birth was recorded as the date of arrival at the calf shed, and gestation length was calculated from the mating records for the dam and sire of the calf. Parentage was assigned using DNA (Genemark, LIC). Unfasted live weight was recorded at weaning, and approximately 200, 400, 600 days of age, and prior to slaughter. The age of animals in days was also recorded at weaning, as yearlings and at slaughter.

### 3.2.3 Measurement of carcass characteristics

Immediately after dressing, carcasses were weighed to give hot carcass weight. The DO% was calculated as the ratio of hot carcass weight to preslaughter liveweight and expressed as a percentage. The carcasses were graded under Silver Fern Farms' Eating Quality (EQ) System® by an accredited master grader. Graders visually assessed fat colour, meat colour, marbling and ossification against a set of reference standards (Meat and Livestock Australia, 2013). Fat colour was scored on a scale from 0 (white) to 9 (deep yellow), while meat colour was scored on a scale from 1 (light red) to 7 (dark red), ossification was scored on a scale from 100 (no ossification) to 590 (complete fusion of sacral vertebrae, complete ossification of lumbar vertebrae and thoracic vertebrae outlines barely visible) and marbling was scored on a discrete scale from 100 to 1,190, in increments of 10. Fat depth and meat pH were measured objectively using a ruler and a pH meter, respectively.

### 3.2.4 Data handling

A subset of dams from the herd were selected for this experiment. The selection criteria for inclusion in the subset was that all 16/16ths of breed proportions were known, and that Friesian and/or Jersey made up at least 14/16ths of the individual's breed. These dams were classified into five breed groups based on breed composition (Handcock et al. 2019) (Table 6). Only two cows were classified as Jersey, so these two cows were excluded from the experiment.

**Table 6** – Breed composition and number of records for Friesian (F), Friesian crossbred (FX), Friesian-Jersey crossbred (FJ), Jersey crossbred (JX) and Jersey (J) dams.

| Breed group | Breed composition | N |
|---|---|---|
| F | F ≥ 14/16 | 40 |
| FX | 10/16 ≤ F ≤ 13/16 | 113 |
| FJ | F < 10/16 and J < 10/16 | 148 |
| JX | 10/16 ≤ J ≤ 13/16 | 42 |
| J | J ≥ 14/16 | 2 |

### 3.2.5 Statistical analysis

Data was analysed in SAS version 9.4 (SAS institute). Live weights and carcass characteristics were analysed using a general linear model that included the fixed effects of dam breed and the random effect of sire. Birth weight and weaning age included the fixed effect of sex. Rearing location (Renown or Discovery) was included as a fixed effect for weaning age and yearling weight, and mob was added as a fixed effect for yearling and slaughter weight. Weaning weight was included as a covariate for weaning age and yearling age was included as a covariate for yearling weight. All carcass characteristics included a fixed effect of slaughter group. Fat depth and marbling score included carcass weight as a covariate, while meat colour included pH as a covariate and ossification score included age deviation within slaughter group as a covariate. The proportion that were too yellow (fat colour score ≥ 5) was analysed using a generalised linear model based on a binomial distribution. For all characteristics, the least squared means were calculated for dam breed group.

## 3.3 Results

### 3.3.1 Growth traits

Gestation length was similar among dam breed groups. Calves born to Friesian dams had the greatest birth weight (P<0.05, Table 7). Calves born to Friesian-cross and Jersey-cross dams had intermediate birth weight (P<0.05, Table 7). Calves born to Friesian-Jersey dams had the lowest birth weight, although there was no difference in birth weight between calves born to Friesian-Jersey and Jersey-cross dams (P>0.05, Table 7).

Calves born to Friesian dams took less time to reach weaning weight compared to calves born to the other dam breeds (P<0.05, Table 7). There was no difference in time till weaning weight was reached between calves born to Jersey-cross, Friesian-cross and Friesian-Jersey dams (P>0.05, Table 7). Calves born to Friesian dams had greater yearling weight than those born to Friesian-Jersey dams (P<0.05, Table 7). Calves born to Friesian dams had similar yearling weight to those born to Friesian-cross and Jersey-cross dams (P>0.05, Table 7). Calves born to Friesian-Jersey dams also had similar yearling weights to those born to Friesian-cross and Jersey-cross dams (P>0.05, Table 7).

Average daily gain from birth to weaning, and from weaning to yearling age was not affected by dam breed group (P>0.05, Table 8). From yearling age to slaughter, however, progeny of Friesian dams had a greater average daily gain than progeny from Friesian-Jersey dams (P<0.05, Table 8).

**Table 7**- Growth traits from weaning until slaughter for beef-cross-dairy-breed progeny from Friesian (F), Friesian-cross (FX), Friesian-Jersey (FJ) and Jersey-cross (JX) dams. Values are least squared means, including the standard error of the mean.

| Trait | Dam breed | | | | P value* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | FX | FJ | JX | Breed | Sire | Sex | Rearing | Mob | WWt | YAge |
| n | 40 | 113 | 148 | 44 | - | - | - | - | - | - | - |
| Gestation length (d) | 282 ± 0.68 | 281 ± 0.40 | 281 ± 0.36 | 281 ± 0.63 | 0.5029 | <0.0001 | 0.0516 | - | - | - | - |
| Birthweight | 41.48 ± $0.77^{a}$ | 37.97 ± $0.47^{b}$ | 36.75 ± $0.44^{c}$ | 36.77 ± $0.72^{bc}$ | <0.0001 | <0.0001 | <0.0001 | - | - | - | - |
| Weaning age (d) | 92.8 ± $2.31^{a}$ | 98.6 ± $1.36^{b}$ | 101.1± $1.23^{b}$ | 102.3 ± $2.13^{b}$ | 0.0154 | <0.0001 | 0.0001 | <0.0001 | - | <0.0001 | - |
| Yearling weight | 225.12 ± $3.36^{a}$ | 221.48 ± $1.98^{ab}$ | 217.92 ± $1.81^{b}$ | 219.24 ± $3.09^{ab}$ | 0.0002 | <0.0001 | - | <0.0001 | <0.0001 | - | 0.0659 |
| Slaughter weight | 594 ± $5.06^{a}$ | 580 ± $2.94^{b}$ | 571 ± $2.70^{c}$ | 574 ± $4.72^{bc}$ | <0.0001 | <0.0001 | - | - | <0.0001 | - | - |

*Breed = breed of the dam, Sire = individual sire of the animal, Rearing = rearing location, Mob= herd animal was raised in, Wwt = weaning weight , Ywt = yearling weight.

$^{a\text{-}c}$Values with different superscript are significantly different from one another.

**Table 8** – Average daily gain (kg) throughout the study of beef-cross-dairy-breed progeny from Friesian (F), Friesian-cross (FX), Friesian-Jersey (FJ) and Jersey-cross (JX) dams. Values are least squared means, including the standard error of the mean.

| Time period | Dam breed* | | | | |
|---|---|---|---|---|---|
| | F | FX | FJ | JX | P-value |
| Preweaning | 0.665 ± 0.01 | 0.650 ± 0.01 | 0.646 ± 0.01 | 0.652 ± 0.01 | 0.341 |
| Weaning-Yearling | 0.519 ± 0.01 | 0.524 ± 0.01 | 0.515 ± 0.01 | 0.519 ± 0.01 | 0.125 |
| Yearling-Slaughter | 0.680 ± 0.1$^{a}$ | 0.655 ± 0.01$^{ab}$ | 0.643 ± 0.01$^{b}$ | 0.650 ± 0.01$^{ab}$ | 0.002 |

*F = Friesian, FX = Friesian-cross, FJ = Friesian-Jersey cross, JX = Jersey-cross.
$^{a-b}$Values with different superscript are significantly different from one another.

### 3.3.2 Carcass Characteristics

Carcass weight was heaviest for progeny of Friesian dams and lightest for progeny of Friesian-Jersey dams (P<0.05, Table 9). Progeny of Friesian-cross and Jersey-cross dams had intermediate carcass weight, although there was no difference in carcass weight between calves Jersey-cross and Friesian-Jersey dams (P>0.05, Table 9). There was no difference in dressing out percentage between dam breed groups (P>0.05, Table 9). Progeny of Jersey-cross dams had yellower fat colour scores than those of all other dam breed groups (P<0.05, Table 9). There was no difference in fat colour between progeny of Friesian, Friesian-cross and Friesian-Jersey dams (P>0.05, Table 9). There was no difference in fat depth between dam breed groups (P>0.05, Table 9).

There was no difference in marbling score among dam breed groups both with and without adjustment for carcass weight (P>0.05, Table 9). Neither meat colour score nor pH differed among dam breed groups (P<0.05, Table 9). Ossification score was highest for progeny from Jersey cross dams and lowest for progeny from Friesian-Jersey dams (P<0.05, Table 9), with progeny from Friesian and Friesian cross having intermediate ossification scores (P>0.05, Table 9).

**Table 9** – Carcass characteristics for beef-cross-dairy-breed progeny from Friesian (F), Friesian-cross (FX), Friesian-Jersey (FJ) and Jersey-cross (JX) dams. Values are least squared means, including the standard error of the mean.

| Trait | Dam breed | | | | P value[***] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | F | FX | FJ | JX | Breed | Sire | Kill group | Age deviation | Carcass weight | pH |
| n | 38 | 107 | 141 | 41 | - | - | - | - | - | - |
| Carcass weight | 286 ± 2.79$^{a}$ | 279 ± 1.62$^{b}$ | 273 ± 1.49$^{c}$ | 276 ± 2.58$^{bc}$ | **<0.0001** | <0.0001 | <0.0001 | - | - | - |
| Dressing out % | 48 ± 0.002 | 48 ± 0.001 | 48 ± 0.001 | 48 ± 0.002 | 0.3086 | 0.1369 | <0.0001 | - | - | - |
| Fat colour | 2.85 ± 0.15$^{a}$ | 3.04 ± 0.09$^{a}$ | 3.05 ± 0.8$^{a}$ | 3.33 ± 0.14$^{b}$ | **0.0367** | 0.0080 | <0.0001 | - | - | - |
| Frequency of yellow score ≥ 5[*] | 2.6 (1.9,3.27) | 5.6 (4.9,6.3) | 9.2 (8.5,9.9) | 17.1 (16.4,17.8) | - | - | - | - | - | - |
| Fat depth | 3.01 ± 0.36 | 3.71 ± 0.21 | 3.64 ± 0.20 | 3.51 ± 0.33 | 0.8255 | 0.0542 | <0.0001 | - | 0.3786 | - |
| Marbling score[**] | 316 ± 18 | 319 ± 10 | 318 ± 9 | 302 ± 16 | 0.3422 | <0.0001 | <0.0001 | - | - | - |
| Marbling score adjusted | 313 ± 18 | 319 ± 10 | 322 ± 9 | 305 ± 16 | 0.3531 | <0.0001 | <0.0001 | - | 0.2824 | - |
| Meat colour | 3.41 ± 0.11 | 3.64 ± 0.06 | 3.59 ± 0.06 | 3.68 ± 0.10 | 0.6827 | 0.2801 | <0.0001 | - | - | <0.0001 |
| PH | 5.62 ± 0.02 | 5.61 ± 0.01 | 5.59 ± 0.01 | 5.59 ± 0.02 | 0.6599 | 0.6557 | <0.0001 | - | - | - |
| Ossification score | 162 ± 2.76$^{ab}$ | 159 ± 1.59$^{ab}$ | 157 ± 1.46$^{a}$ | 164 ± 2.53$^{b}$ | **0.0047** | 0.0002 | <0.0001 | 0.5532 | - | - |

[*] Confidence limits (0.05) are presented instead of standard errors as means are back transformed.
[**] On a scale from 100 to 1,190.
[***] Breed = breed of the dam, Sire = individual sire of the animal, Rearing = rearing location, Mob= herd animal was raised in, Wwt = weaning weight , Ywt = yearling weight.

# 3.4 Discussion

## 3.4.1 Growth characteristics

### Gestation length

The similarities in gestation length among breed groups is consistent with previous reports for Friesian, Jersey and crossbred dams (Everitt & Jury, 1972; Norman et al., 2009; Dhakal et al., 2013; Hickson et al., 2014). The gestation period of 280-281 days is also consistent with similar literature on beef-cross-dairy-breed cattle (Coleman et al., 2018).

### Birth weight

While gestation length was unaffected by dam breed group, birth weight was greatest for calves born to Friesian dams. It is well documented that Friesian cows produce heavier calves at birth compared to other dairy breeds including Jersey, Ayrshire and Guernsey (Fitch et al., 1924; Everitt & Jury, 1972; Dhakal et al., 2013; Hickson et al., 2014). This is likely a reflection of Friesian cattle having a greater mature size than the other dairy breeds (Fitch et al., 1924). When expressed as a percentage of dam weight, Fitch et al. (1924) found the birthweight of calves born to Friesian dams was greater than those born to other dairy breed dams. Live weight of cows in this study was not recorded so these comparisons could not be made in this instance. According to Hickson et al. (2014), the breed effect of Friesian dams increases birthweight by 3.7kg while that of Jersey dams decreases birthweight by 5.7kg relative to Angus dams.

Birth weight was lowest for calves born to Friesian-Jersey dams, while calves born to Friesian-cross and Jersey-cross dams had intermediate birthweights. This is consistent with previous literature, as calves born to crossbred dairy cows tend to have intermediate birthweights (Dhakal et al., 2013).

### Weaning age

Weaning age was affected by dam breed group, with progeny from Friesian dams reaching weaning earlier than all other dam breed groups. This is often attributed to differences in growth rates, as it is well documented that Friesian cattle grow faster than Jersey cattle so would reach a set weaning weight earlier (Baker et al., 1990; Barton et al., 1994). In the current study, while no difference in growth rates between dam breed groups was observed between birth and weaning, growth rates of Friesian progeny were numerically greater which would have affected time until weaning weight was reached. In addition, the calves were heavier at birth, and so required less live weight to gain to reach weaning weight than calves of other breeds did. A scaled weaning weight could have been more relevant as calf rearers typically either wean once a certain liveweight gain has been achieved or have separate weaning weight targets for different breed calves. It is recommended that artificially reared calves gain at least 18kg liveweight before weaning, and the target weaning weight is 100kg, 90kg and 80kg for Friesian, crossbred and Jersey calves, respectively (Beef + Lamb New Zealand, 2018; On-Farm Research, n.d.).

There was no difference in weaning age between progeny from Friesian-cross, Friesian-Jersey and Jersey-cross dams. This is inconsistent with previous literature, where progeny from Angus-Friesian-Jersey dams had intermediate growth rates between Angus-Friesian and Angus-Jersey dams (Law et al., 2013; Coleman 2016) but, these calves were reared with their dams, compared to artificially reared calves in this study. Milk production is the most important factor affecting preweaning growth, so the effect of dam breed is usually confounded with varying milk production between dam breeds in beef cow studies (Morris et al., 1987; Arthur et al., 1997).

### Yearling weight

The greater yearling weight of progeny from Friesian dams is consistent with previous literature, in which Friesian or Friesian-cross steers were heavier at 12-13 months compared to Jersey and Jersey-cross steers (Morris et al., 1987; Baker et al., 1990). As with weaning age, there was no difference in growth rates between dam breed groups between weaning and yearling age. Baker et al., (1990) and Barton et al., (1994) observed a greater yearling weight of Friesian progeny which was explained by differences in weaning age, in that Friesian progeny were weaned earlier so were on milk for less time than progeny from Friesian-Jersey and Jersey cross dams. Weaning age is congruent with physiological age in that an earlier weaning age accelerates rumen development (Eckert et al., 2015; Mirzaei et al., 2018). As progeny from Friesian dams were weaned earlier they may have had an advantage due to having greater rumen development, which is associated with improved post weaning growth performance (Mirzaei et al., 2018).

Yearling weights were approximately 100kg and 50kg lower than those reported by Pike (2019) and Coleman (2016) for beef-cross-dairy-breed steers and heifers, respectively. This suggests that the growth of the animals in this study was restricted relative to previous studies, which could explain why less of a difference was observed between breed groups as the animals were unable to exhibit their full growth potential.

## 3.4.2 Carcass characteristics

### Carcass weight and dressing out

Cattle with Friesian genetics have heavier carcass weights compared to cattle with Jersey or Friesian-Jersey genetics (Morris et al., 1987; Morris et al., 1990; Barton et al., 1994; Barton & Pleasants, 1997), and this was observed in this experiment. While progeny of Friesian-Jersey dams had the lightest carcass weights, they did not differ from progeny of Jersey-cross dams. This is in contrast with Barton et al. (1994) who found Friesian-Jersey steers to have heavier carcasses than Jersey steers, although these animals were straightbred so would have had twice the amount of Friesian genetics as did the animals in the current experiment. Coleman (2016) found no difference in carcass weights between beef-cross-dairy-breed progeny of dams with Jersey and Friesian-Jersey genetics. Dam breed group had no effect on dressing out percentage. While this is consistent with Coleman (2016) and Barton et al. (1994), other literature has found cattle with Jersey genetics to have lower dressing out percentages (Butler-Hogg & Wood, 1982; Morris et al., 1987; Morris et al., 1990; Purchas & Morris, 2007). This was attributed to Jersey steers depositing greater amounts of fat in non-carcass components relative to Friesian steers, particularly around the kidneys (Purchas & Morris, 2007).

### Fat depth and colour

Dam breed group did not have an effect on fat depths. There is no difference in fat depth between straight Friesian and Jersey cattle, and between beef-cross-dairy-breed cattle from Friesian, Jersey and Friesian-Jersey dams (Morris et al., 1990; Barton et al., 1994 Coleman, 2016). Fat depth was low compared to beef breed cattle, as cattle with dairy genetics have different patterns of fat distribution (Bown et al., 2016). However, only 5 out of the 327 animals processed were graded as L (less than 3mm) for fat depth, meaning beef-cross-dairy-breed heifers and steers can reach a sufficient level of finish under the current grading system before 32 months of age.

Progeny of Jersey-cross dams had yellower fat colour scores than progeny from all other breed groups. It is well documented that Jersey cattle, and cattle with Jersey genetics have yellower fat than cattle with Friesian genetics (Morgan et al., 1969; Walker et al., 1990). The yellowing of fat is due to carotenoid pigments in the diet, which are typically converted into Vitamin A before absorption (Dikeman, 2017). Jersey cattle lack the enzyme required to catalyse this reaction and carotenes are absorbed into the bloodstream and deposited in adipose tissue as they are lipophilic compounds (Dunne et al., 2009). Numerically, the difference between mean fat colour scores was less than 0.5. While statistically significant, this difference may be too small to be detectable by consumers. Differences in fat colour between dam breed groups have greater implications when expressed as the frequency of a yellowness score of 5 or greater, the score at which carcasses may be downgraded to M grade (regardless of carcass weight, fat cover or muscling), which received $1.45/kg less than P grade at the time of slaughter (Farmers Weekly, 2021). The loss of return from downgrading to M grade is 4% greater in the Jersey-cross dam breed group than in the Friesian dam breed group (Table 10).

**Table 10** – Incidence of yellowness score ≥ 5 and loss from downgrading to M grade for beef-cross-dairy-breed progeny from each dam breed (Return of \$5.28/kg for P grade and \$3.83/kg for M grade).

| Dam breed | Carcass weight (kg) | Return P grade (NZD) | Return M grade (NZD) | Loss per head from yellowness $ | Yellowness frequency (%) | Loss from yellowness (%) |
|---|---|---|---|---|---|---|
| Friesian | 286 | 1510 | 1095 | 415 | 2.63 | 0.7 |
| Friesian-cross | 280 | 1478 | 1072 | 406 | 5.61 | 1.5 |
| Friesian-Jersey | 274 | 1447 | 1049 | 398 | 9.22 | 2.5 |
| Jersey-cross | 276 | 1457 | 1057 | 400 | 17.07 | 4.7 |
| Loss from yellowness (%) = ((loss per head X yellowness frequency)/(return P grade X 100)) X 100 | | | | | | |

The greater incidence of excessive yellowness in the fat of Jersey-cross cattle can be partially overcome by different management of cattle with Jersey genetics. Levels of carotenes in pasture vary between seasons (McDowall & McGillivray, 1963; Dunne et al., 2009). This is associated with the effect of climactic conditions on the stage of growth and maturity of pastures (McDowall & McGillivray, 1963). $\beta$-carotene and xanthophyll concentrations are greater when ryegrass is immature, between late spring to early summer pastures, and results in greater blood and adipose concentrations of carotene in cattle over this period (McDowall & McGillivray, 1963). This is consistent with the current study; 24% of the first steer group sent to slaughter in early November had excessively yellow fat while none of the steers sent to slaughter in late January had excessively yellow fat.

To reduce the loss from yellow fat, farmers could send beef-cross-dairy-breed cattle with Jersey genetics to slaughter in mid to late summer, however this may not be feasible depending on feed availability and variations in seasonal carcass prices. Certain sire breeds, such as European beef breeds, are also more effective over Jersey cows at reducing yellowness of fat, although this is less practical as carcass characteristics of progeny are not a priority to dairy farmers, who typically select beef sires based off calving ease, gestation length and easy identification of beef sired calves (Morgan et al., 1969; Burggraaf, 2016). Another potential way to overcome the issue of downgrading from yellowness in Jersey-cross cattle would be to investigate if a new market for yellow fat could exist. Yellow fat indicates that cattle have been grass fed, which is an important credence attribute to consumers (Dunne et al., 2009; Yang & Renwick, 2019). Beef from grass fed cattle also has a lower total fat content, a higher proportion of low density lipoprotein and cholesterol-neutral stearic acid, and a higher proportion of n-3 polyunsaturated fatty acids compared to grain fed cattle (Lukic et al., 2021). Beef products being nutritionally rich is also important to consumers, furthering the possibility of creating a market for yellow fat (Yang & Renwick, 2019).

### Marbling

Dam breed group did not affect marbling score in this study, which is consistent with previous studies comparing marbling scores and intramuscular fat content of beef-cross-dairy-breed cattle from dams with Friesian, Jersey and Friesian-Jersey genetics (Baker et al., 1984; Coleman, 2016). Previous literature on straightbred Jersey and Friesian steers has found Jersey steers to have greater potential for deposition of intramuscular fat as a result of being earlier maturing than Friesians (Purchas et al., 1976). This may not be observed in the crossbred progeny from this and previous experiments as they contained a percentage of Jersey genetics of 50% or less. The mean marbling scores for each breed group were well below the target marbling score for Silver Fern Farms' eating quality grading system for beef (EQ) of 350, indicating that a greater degree of finish would be necessary to achieve this.

### Meat colour and pH

Dam breed group had no effect on meat pH. It is well documented that breed and genotype has little effect on pH of beef (Purchas & Barton, 1976; Lawrie, 1991). Variation in pH between cattle is usually explained by differences in sex, age and treatment pre- and post-slaughter, as opposed to breed or genotype (Lawrie, 1991). As with pH, there was no difference in meat colour between dam breed groups. Lean meat colour is highly correlated with pH, and as a result is affected mostly by sex, slaughter age and management (Lawrie, 1991). While differences in lean colour between breed groups (e.g. dairy breeds, Continental beef breeds and British beef breeds) have been found, lean meat colour is typically similar between breeds within a breed group (Koch et al., 1976; Chambaz et al., 2003).

**Ossification**

Ossification score is likely affected more by age, physiological maturity and sex than by breed (Bonny et al., 2018). Differences among breed groups in ossification score may be explained by differences in degree of maturity of the progeny among the breeds. Compared to Friesian cattle, Jersey cattle are earlier maturing (Coleman, 2016). The greater ossification scores observed in progeny of Jersey-cross dams could therefore be explained by the greater proportion of earlier maturing genetics in these animals (Bonny et al., 2016). Actual ossification scores for progeny of all breed groups were lower than those reported by Bonny et al. (2018) for beef breed cattle of a similar age, but were similar to the standard ossification scores of the MSA grading system for 24-month-old cattle (Meat and Livestock Australia, 2013).

## 3.4.3 Limitations

**Number of dams in breed groups**

The number of animals in each breed group was inconsistent, with the Friesian-Jersey dam group consisting of over three times as many dams as the Friesian dam group. A power analysis using the smallest sample size of 38 animals (for carcass characteristics for the Friesian dam breed group) and the largest samples size of 141 animals (for carcass characteristics for the Friesian-Jersey dam breed group) gave a power of 0.20. A greater sample size of 96 animals for the Friesian dam breed group would be needed to give a more ideal power value of 0.80.

**Lack of Jersey dams**

Ideally, this experiment would have included a fifth dam breed group; cows with ≥14/16ths Jersey genetics. It would have been useful to determine if a difference in growth and carcass characteristics exists between progeny of Jersey and Jersey-cross dams. Nevertheless, the breed composition of this herd was typical of a dairy herd in New Zealand that will have cows mated to beef bulls and the calves reared for processing.

### Weaning weight measurement

While all calves were intended to be weaned at a liveweight of 100kg, there was a difference in weaning weight between dam breed groups. Calves born to Friesian dams were heavier at weaning than those born to Friesian-cross and Friesian-Jersey dams. As calves were not weighed daily, it would be expected that some might be lighter or heavier than 100kg at weaning, although the range in weaning weights was considerably large, with a difference of 79kg between the lightest (85kg) and heaviest (164kg) calf at weaning.

### Investigation of meat quality

Literature on performance characteristics of beef cattle often include meat quality characteristics as these are important to gauge product value and potential consumer acceptance of the meat. Due to resource and time constraints, meat quality testing on samples from these cattle was unfeasible, therefore it is unknown how dam breed affects meat quality of beef-cross-dairy-breed cattle in a pastoral based system. The low ossification scores of these animals, however, could be an indicator of good eating quality as an increase in physiological maturity is congruent with an increase in collagen crosslinking within muscle tissue and reduced eating quality of the meat (Bonny et al., 2016). The lack of difference among dam breed groups for ossification score and pH could indicate similar eating quality among dam breed groups as both variables are correlated with meat quality. The greater marbling score in Jersey progeny could indicate greater tenderness in meat from the Jersey progeny compared to other dam breed groups. Straightbred Jersey steers produce more tender meat compared to Friesian steers because of having the ability to deposit greater amounts of intramuscular fat (Purchas & Barton 1976). However, Coleman et al. (2016) found no difference in meat quality characteristics between progeny of Angus-Friesian, Angus-Friesian-Jersey and Angus-Jersey dams.

### 3.4.5 Conclusions and Implications

Progeny from Friesian dams had better overall growth performance than progeny from other dam breed groups, taking less time to reach weaning and having heavier birth, yearling and slaughter weights compared to other dam breed groups. While growth rates were similar among dam breed groups up until yearling age, Friesian progeny had faster growth rates than Friesian-Jersey progeny from yearling to slaughter. Carcass characteristics were less affected by dam breed than growth traits, with carcass weight, fat colour and ossification score being the only carcass characteristics influenced by dam breed. Carcass weight and fat colour, however, are particularly important characteristics to beef producers as they determine the return to the farmer. The greater carcass weight of progeny from Friesian dams equates to a return that is $32, $63 and $53 greater than progeny from Friesian-cross, Friesian-Jersey, and Jersey-cross dams, respectively (Table 10). The frequency of excessively yellow fat results in a 4.7, 2.5, 1.5 and 0.7% decrease in return from downgrading to M grade for progeny from Jersey cross, Friesian-Jersey, Friesian cross and Friesian dams, respectively (Table 10).

The increase in Jersey and Friesian-Jersey genetics in the dairy herd will result in an increasing proportion of Jersey genetics in surplus dairy calves retained for beef finishing. These calves will have slower growth rates, taking more time to reach a set weaning weight and having lighter finishing and carcass weights than calves from cows with a greater proportion of Friesian genetics. The incidence of excessively yellow fat, and the potential loss in returns from downgrading to M grade, will also increase as a result of increasing proportions of Jersey genetics. These factors are reflected in the lower sale price of surplus calves with Jersey genetics compared to Friesian calves (Cook, 2014).

# Chapter 4. Carcass characteristics and meat quality of 11-month-old Stabilizer-Friesian-Jersey heifers and steers

## 4.1 Introduction

While there is already an established supply chain of surplus calves from the New Zealand dairy industry to the beef industry for beef finishing, surplus bobby calves are still underutilised. It is estimated that the remaining surplus calves from the dairy industry typically slaughtered before a week of age could be worth $1 billion if finished for beef (Jolly, 2016). There is also further opportunity to increase both the economic and environmental efficiency of pastoral beef production by utilising these beef-cross-dairy-breed calves in a yearling beef system, which finishes cattle at or before 12 months of age (McDermott et al., 2005; Burggraaf, 2016; Pike et al., 2019).

The use of the composite breed, Stabilizer, could be an ideal sire to use over dairy cows for an accelerated system of beef production as Stabilizer progeny have similar birthweights to, but reach weaning earlier than Angus progeny, and have similar 200 day liveweights as Simmental progeny (B+LNZ Genetics, 2020). Little is known about the carcass and meat quality of composite sired heifers and steers of dairy origin. Previous research on beef breed heifers and steers has found that carcass weight is typically greater for steers compared to heifers, and fat content is typically greater for heifers, but dressing out percentage and muscularity characteristics are similar for steers and heifers (Martin et al., 1971; Berg et al., 1979; Forrest, 1981; Crews et al., 2002; Park et al., 2002; Lage et al., 2012; Blanco et al., 2020). Meat quality characteristics are also typically similar for heifers and steers (Martin et al., 1971; Lucero-Borja et al., 2014; Blanco et al., 2020).

The majority of this literature has been based on traditional finishing systems with cattle slaughtered at 20 months of age or above. Literature that has compared heifers and steers at younger slaughter ages is based off grain-feeding systems with larger European beef breeds so is less relevant to beef finishing in a pastoral-based New Zealand system (Rahnefeld et al., 1983; Blanco et al., 2020). It has been found that yearling beef-cross-dairy-breed steers can produce highly tender beef in a pastoral based system (Pike, 2019). It is unknown whether the same differences in carcass and meat quality between heifers and steers exist under this yearling system.

Postmortem aging of meat is a well-known method of improving eating quality of meat, mainly through increasing tenderness (Lawrie, 1991; Oliete et al., 2005; Carvalho et al., 2018; Kim et al., 2019). For yearling beef-cross-dairy-breed steers, both aged and unaged meat was highly and similarly tender indicating that the meat from the young, yearling animals does not require aging to ensure tenderness (Pike, 2019).

The primary objective of this study was to investigate the effect of sex on carcass and meat quality characteristics of 11-month-old Stabilizer-Friesian-Jersey heifers and steers in a pastoral based system. A second objective was to investigate the effect of aging on meat quality characteristics of 11-month-old Stabilizer-Friesian-Jersey heifers and steers to validate previous findings that identified a minimal effect of aging on tenderness for meat from yearling cattle. It is hypothesised that steers will have greater carcass weights and heavier femurs compared to heifers, but other carcass characteristics will be similar between the sexes. Meat quality characteristics are expected to be similar between heifers and steers. It is hypothesised that aged and unaged meat will be highly tender and have similar meat quality characteristics.

# 4.2 Materials and Methods

## 4.2.1 Animals and management

This experiment involved 24 dairy-cross-Stabilizer$^{TM}$ cattle (12 heifers and 12 steers) born in the spring of 2018 and artificially reared at Top Notch Calves in Tirau, Waikato. All cattle were sired by a team of Stabilizer$^{TM}$ bulls from Focus Genetics. Dams were primarily first-calving two-year-old Friesian-Jersey crossbred heifers. The Stabilizer$^{TM}$ is a four-breed composite comprising 25% each of the Angus, Hereford, Simmental and Gelbvieh breeds. Male calves were castrated at 4 months of age. Calves were moved from Top Notch Calves to Cheltenham downs in Manawatu at approximately 100kg liveweight at around 3 months of age and grazed under commercial management in one mob until 11 months of age. At 11 months of age, on the 12th July 2019, these cattle were transported to Venison Packers in Fielding and slaughtered according to standard commercial procedure.

### 4.2.2 Measurement of carcass characteristics

6 weeks prior to slaughter, the unfasted liveweights of all cattle were recorded and the area of the *Longissimus thoracis* muscle (EMA), and fat depth at the P8 rump and rib sites were measured using ultrasound. The rib fat depth is measured between the 12th and 13th rib over the eye muscle (Kirton, 1989). The P8 rump site is located over the gluteus muscle at an intersection between the line from the pin bone parallel to the shine, and a perpendicular line down the third sacral crest.

Prior to being loaded on the truck for slaughter, all cattle were weighed. Immediately after dressing, the carcasses were halved and the length of each side measured as a line from the distal end of the tarsal bones to the midpoint of the cranial edge of the first rib (Purchas et al., 1992). The lengths of both halves was averaged to give the carcass length of each animal. Each half was also weighed and the sum of the two weights gave the hot carcass weight for each animal. The DO% was calculated as the ratio of hot carcass weight to preslaughter liveweight measured before transport to the abattoir and expressed as a percentage. Subcutaneous fat colour was visually assessed after halving against a colour standard ranging from 1 (white) to 8 (deep yellow).

Muscularity index expresses muscularity as the ratio of muscle depth to the length of an adjacent bone. The sum of the weights of the five main muscles surrounding the femur (those in the topside, silverside and knuckle) and femur length was used in the following formula to calculate muscularity of each animal (Purchas et al., 1991; Purchas et al., 2002):

$$Muscularity = \frac{\left(\sqrt{\frac{Combined\ muscle\ weights\ (g)}{Femur\ length\ (cm)}}\right)}{Femur\ length\ (cm)}$$

Muscle to bone ratio (M:B) was also calculated from the sum of the weights of the same muscles and the femur weight using the following formula:

$$M{:}B = \frac{Combined\ muscle\ weights\ (g)}{Femur\ weight\ (g)}$$

## 4.2.3 Measurement of meat quality characteristics

**Sample Preparation**

After the carcass characteristics were measured, the *Longissimus lumborum* muscle (striploin) from the left side of the carcass was collected at boning-out, halved and vacuum packed for meat quality testing. One half was immediately frozen at -20˚C while the other half was aged for 21 days at 1°C, resulting in two striploins for analysis per animal; one aged and one unaged. Meat quality assessment occurred over 4 days and for each day a random allocation of both aged and unaged samples were tested. The striploins were thawed at 1°C for 24 hours prior to testing.

The striploins were weighed within the packaging, then removed from the packaging and both the striploin and packaging were blotted dry with a paper towel and weighed to determine thaw loss. Before the striploins were cut, the area of the muscle was traced on the unaged samples. A 20mm steak was cut from the end of the striploin sample to test pH. A second 20mm steak was then cut, and the cut end was exposed to air for at least 30 minutes to measure lean meat colour. Two 25mm steaks were then cut and placed flat alongside each other into a plastic bag for cooking to determine cooking loss and Warner Bratzler shear force. A final 40mm steak was then cut to use for the determination of drip loss and myofibrillar fragmentation index. After testing for pH and meat colour, the 20mm steaks were trimmed of fat and connective tissue, minced finely and sealed in a plastic bag and frozen for subsequent analysis of intramuscular fat (IMF) content.

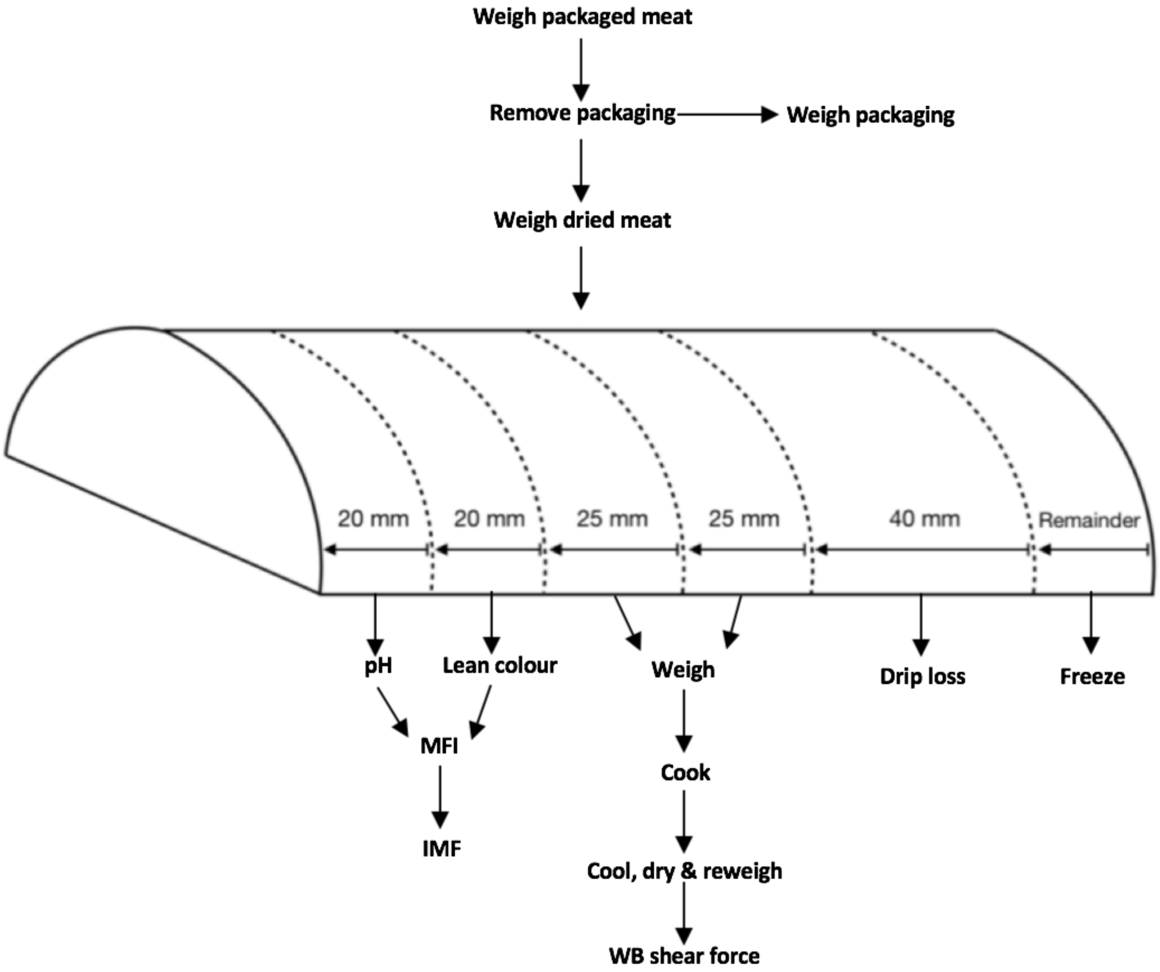


**Figure 5** – Diagram of partitioning of the striploin for subsequent meat quality analysis.

### Ultimate pH

Ultimate pH was measured using a handheld pH spear (Eutech Instruments). The spear was inserted at three measurement points across the surface of the cut steak, at approximately equal increments from the medial to lateral end of the steak. These three measurements were then averaged to give the ultimate pH of the striploin.

### Lean meat colour

Lean meat colour was measured using a hand held colorimeter (chromameter CR-400, Konica Minolta) which was calibrated to a standard white reflective plate supplied by the manufacturer. The lense of the chromameter was placed on a clear plastic petri dish over the steak in order to protect the lense. The Commission Internationale de I'Eclairage (CIE) L* (lightness), a* (redness) and b* (yellowness) values were recorded. As with pH, lean meat colour was measured at three points across the steak, medial to lateral, and the three points were averaged to determine colour values for each sample.

### *Longissimus* muscle area

The area of the unaged samples was traced before the steaks were cut for testing. Trace paper was placed over the caudal end of the striploin and the area was traced using a pencil. The area of the tracing was then measured using a planimeter (Placom KP-90N, Tokyo, Japan).

### Tenderness

The two 25mm steaks in the plastic bag were immersed in a water bath at 70 $^{oC}$ to cook for 90 minutes. After cooking, the steaks were cooled to room temperature over a one hour period and then chilled at 1$^{o}$C for a minimum of four hours. After chilling, 13mm cylindrical cores were cut from each steak for Warner-Bratzler shear force using a cork borer (Purchas et al., 1989). The cores were cut following the direction of the muscle fibres. One cut was made on each core using a V-blade which cut through the core perpendicular to the direction of the muscle fibres and the peak load (kgF) was recorded. Peak load is the maximum shear value recorded (Purchas & Aungsupakorn, 1993). For each striploin, 6 replicate cores were measured and these replicates averaged to get the shear force value for the sample.

Myofibrillar fragmentation index (MFI) was measured using a standardised homogenisation followed by filtration. Approximately 5g of the meat was finely diced, weighed (w1) and homogenised with 50ml of physiological saline (0.85% NaCl) for two periods of 30 seconds using a standing homogenizer (Ultra-Turrax, 18mm shaft). The homogenate was then allowed to pass through a 231 µm stainless steel filter under gravity. The filters were weighed before the homogenate was passed through (w2), after which they were stored at 30 °C for 40 hours and reweighed after drying (w3). These weights were then used to determine the percentage of muscle fibres that passed through by calculating MFI using the following equation:

$$MFI\ \% = 100 - \left[\frac{\left((w3 - w2) \times 100\right)}{w1}\right]$$

**Water holding capacity**

The percentage of thaw loss (the liquid lost during thawing after freezing) was calculated using the weight of the striploin in its packaging and the weights of the dried striploin and packaging using the following equation:

$$Thaw\ loss\ \% = \frac{initial\ weight - \ (vacuum\ pack\ weight + meat\ weight)}{(initial\ weight - vacuum\ pack\ weight)} \times 100$$

The two 25mm steaks were weighed before cooking, and patted dry using a paper towel after cooking and reweighed. Cooking loss (the liquid lost during cooking) was calculated with the weight of the steaks before and after cooking using the following equation:

$$Cooking\ loss\ \% = \frac{Weight\ before\ cooking - Weight\ after\ cooking}{Weight\ before\ cooking} \times 100$$

A 40mm x 40mm x 40mm cube of meat was cut from the 40mm steak and suspended on a metal hook inside a plastic bag at 1°C for 48 hours to determining drip loss. After 24 and 48 hours, the cube was blotted dry with a paper towel and reweighed. Drip loss was calculated with the weight of the meat cube before and after suspension using the following equation:

$$Drip\ loss\ \% = \frac{Weight\ before\ suspension - Weight\ after\ suspension}{Weight\ before\ suspension} \times 100$$

**Intramuscular fat content**

After assessment of pH and lean meat colour, the leftover steaks were trimmed of subcutaneous fat and finely minced (Kenwood Meat Grinder MG450) using a 3mm hole screen. Approximately 5g of minced meat from each sample was packaged in a zip lock bag and frozen for analysis of fat content in the Nutrition Laboratory at Massey University using an ether extraction method (AOAC 960.39).

### 4.2.4 Statistical analysis

Means for pH, lean meat colour and shear force were calculated and used for statistical analysis. Data was analysed in SAS version 9.4 (SAS institute). Carcass characteristics and meat quality characteristics were analysed using a general linear model that included the fixed effect of sex. Aging was also included as a fixed effect for meat quality characteristics. Carcass weight was fitted as a covariate for eye muscle area, rib fat depth and P8 fat depth. Ultimate pH was fitted as a covariate for all meat quality characteristics. Subcutaneous fat colour was not analysed in SAS as there was little variation between animals, with most animals scoring 2, and few scoring 1.5.

## 4.3 Results

### 4.3.1 Ultrasound traits

Heifers and steers had a similar 10 month liveweight at the time of ultrasound (P>0.05, Table 11). Fat depth at the P8 site was similar for heifers and steers (P>0.05, Table 11). There was no variation in fat depth at the rib between heifers and steers (PValue = 1). Eye muscle area was greater in steers than in heifers (P<0.05, Table 11). When adjusted for carcass weight, however, there was no difference in eye muscle area between heifers and steers (P>0.05, Table 11).

**Table 11** – Ultrasound traits for Stabilizer-Friesian-Jersey heifers and steers at 10 months old. Values are least squared means, including the standard error of the mean.

| Trait | Heifers | Steers | SEM | P-value |
|---|---|---|---|---|
| Liveweight | 248.3 | 258.1 | 3.96 | 0.096 |
| Fat depth (P8) | 2.42 | 2.33 | 0.17 | 0.731 |
| Fat depth (rib) | 2 | 2 | 0.12 | 1.000 |
| EMA | 46.6$^{a}$ | 49.8$^{b}$ | 1.07 | **0.0437** |
| EMA (at equal CW) | 47.4 | 49.0 | 1.03 | 0.292 |
| $^{a\text{-}b}$Values with different superscript are significantly different from one another. | | | | |

## 4.3.2 Carcass characteristics

While liveweight at slaughter was similar for heifers and steers, carcass weight and dressing out percentage was greater in steers than in heifers ($P< 0.05$, Table 12). Carcass length was similar for heifers and steers ($P>0.05$, Table 12). Muscularity characteristics were similar for heifers and steers; eye muscle area, knuckle weight, silverside weight, topside weight and muscularity index did not differ between heifers and steers ($P>0.05$, Table 12). Muscle to bone ratio was greater in heifers than in steers ($P< 0.05$, Table 12). While femur length was similar for heifers and steers $P>0.05$, Table 12), femur weight was greater in steers ($P<0.05$, Table 12). Intramuscular fat content was similar for heifers and steers ($P>0.05$, Table 12).

**Table 12** – Carcass characteristics of Stabilizer-Friesian-Jersey heifers and steers slaughtered at 11 months. Values are least squared means, including the standard error of the mean.

| Trait | Heifers | Steers | SEM | P-value |
|---|---|---|---|---|
| Liveweight (kg) | 314.3 | 323.42 | 5.22 | 0.228 |
| Carcass weight (kg) | 148.2$^{a}$ | 157.1$^{b}$ | 2.78 | **0.034** |
| Dressing out % | 47.1$^{a}$ | 48.6$^{b}$ | 0.004 | **0.013** |
| Carcass length (mm) | 1873 | 1891 | 12.51 | 0.311 |
| Eye muscle area | 55.1 | 53.21 | 3.51 | 0.556 |

| | | | | |
|---|---|---|---|---|
| Eye muscle area (at equal CW) | 57.31 | 49.50 | 3.29 | 0.109 |
| Femur length (mm) | 352.25 | 359.42 | 2.9 | 0.109 |
| Femur weight (kg) | 1.71$^{a}$ | 1.95$^{b}$ | 0.58 | **0.009** |
| Knuckle weight (kg) | 2.85 | 2.84 | 0.11 | 0.963 |
| Silverside weight (kg) | 4.15 | 4.28 | 0.12 | 0.453 |
| Topside weight (kg) | 4.51 | 4.72 | 0.12 | 0.209 |
| Muscularity index | 0.55 | 0.55 | 0.01 | 0.690 |
| Muscle to bone ratio | 7.76$^{a}$ | 7.09$^{b}$ | 0.15 | **0.005** |
| Intramuscular fat % | 1.4 | 1.1 | 0.13 | 0.051 |

$^{a\text{-}b}$Values with different superscript are significantly different from one another.

## 4.3.3 Meat quality characteristics

### Ultimate pH

Ultimate pH of lean meat was the same for heifers and steers (P>0.05, Table 13). Ultimate pH of lean meat was also the same for aged and unaged samples (P>0.05, Table 13).

### Lean meat and fat colour

Lean meat lightness, redness, and yellowness was the same for heifers and steers when measured using the chromameter (P>0.05, Table 13). Aged samples were lighter, redder and yellower than unaged samples (P<0.05, Table 13). Subjectively assessed fat colour was not statistically analysed as almost all animals scored a fat colour score of 2.

### Tenderness

Myofibrillar fragmentation index was the same for heifers and steers (P>0.05, Table 13). and for aged and unaged samples (P>0.05, Table 13). Shear force values did not differ between heifers and steers (P>0.05, Table 13). Shear force values were greater for unaged samples compared to aged samples (P<0.05, Table 13).

**Water holding capacity**

Thaw loss and drip loss, after both 24 and 48 hours, was the same for heifers and steers (P>0.05, Table 13). Cooking loss, however, was greater in heifers than in steers (P<0.05, Table 13). Thaw loss was the same for unaged and aged samples (P>0.05, Table 13). Cooking loss was greater in aged samples compared to unaged samples, while drip loss, after both 24 and 48 hours, was greater in unaged samples compared to aged samples (P<0.05, Table 13).

**Table 13** - Meat quality characteristics of Stabilizer-Friesian-Jersey heifers and steers slaughtered at 11 months. Values are least squared means, including the standard error of the mean.

| Trait | Heifers | Steers | SEM | P-Value sex effect | Aged | Unaged | SEM | P-Value aging effect | pH covariate | P-Value pH |
|---|---|---|---|---|---|---|---|---|---|---|
| pH | 5.57 | 5.59 | 0.01 | 0.286 | 5.60 | 5.56 | 0.01 | 0.124 | - | - |
| Thaw loss % | 3.22 | 3.58 | 0.29 | 0.339 | 3.24 | 3.56 | 0.31 | 0.488 | 10.52 ± 2.8 | **0.001** |
| Cooking loss % | 37.79$^{a}$ | 35.56$^{b}$ | 0.68 | **0.033** | 46.81$^{a}$ | 26.55$^{b}$ | 0.68 | **<0.001** | 15.46 ± 7.2 | **0.043** |
| Drip loss (24h) | 3.66 | 3.79 | 0.31 | 0.759 | 2.29$^{a}$ | 5.16$^{b}$ | 0.40 | **<0.001** | 12.23 ± 3.0 | **0.001** |
| Drip loss (48h) | 4.83 | 5.1 | 0.37 | 0.598 | 3.27$^{a}$ | 6.66$^{b}$ | 0.48 | **<0.001** | 14.62 ± 3.5 | **0.001** |
| L* | 35.71 | 35.84 | 0.33 | 0.787 | 37.01$^{a}$ | 34.53$^{b}$ | 0.33 | **<0.001** | 3.29 ± 3.5 | 0.358 |
| a* | 15.91 | 15.72 | 0.20 | 0.517 | 16.55$^{a}$ | 15.09$^{b}$ | 0.21 | **<0.001** | 1.24 ± 2.1 | 0.557 |
| b* | 8.53 | 8.66 | 0.17 | 0.579 | 9.17$^{a}$ | 8.02$^{b}$ | 0.17 | **<0.001** | 2.40 ± 1.8 | 0.184 |
| Myofibrillar fragmentation index | 97.30 | 97.32 | 0.73 | 0.871 | 98.49 | 96.13 | 1.45 | 0.119 | 1.90 ± 1.2 | 0.133 |
| Shear force (kg) | 4.94 | 4.94 | 0.16 | 0.248 | 4.65$^{a}$ | 5.51$^{b}$ | 0.17 | **0.001** | 0.48 ± 1.7 | 0.780 |

$^{a\text{-}b}$Values with different superscript are significantly different from one another.

## 4.4 Discussion

### 4.4.1 Ultrasound traits

At 10 months of age, there was no difference in ultrasound fat depth at either the P8 or rib sites between heifers and steers, which is consistent with Blanco et al. (2020), who compared 14-month-old Pirenaica heifers and steers. Previous literature on animals 20 months or older has found heifers to have greater subcutaneous fat depths than steers (Forrest, 1981; Carvalho et al., 2018). As cattle reach maturity the amount of fat as a proportion of gain increases and the amount of muscle decreases (Berg & Butterfield, 1976). Heifers reach maturity earlier than steers, resulting in greater subcutaneous fat depths in heifers compared to steers (Berg & Butterfield, 1976). However, at younger ages this difference may not be seen as heifers have yet to reach a stage of increased fat deposition (Keane, 2011). Both sexes had less than 3mm of fat deposited at both sites, which is consistent with other studies involving yearling beef-cross-dairy-breed cattle in a pastoral based yearling finishing system (Pike et al., 2019).

Steers had a greater eye muscle area than heifers when unadjusted for liveweight weight, but this difference became insignificant when considering the heifers and steers at equal live weight. Typically, adjustment for live weight or carcass weight results in similar eye muscle areas in heifers and steers (Rahnefeld et al., 1983; Lage et al., 2012; Li et al., 2014; Augusto et al., 2019). This indicates that eye muscle area is directly related to the size of the animals and not to differences in the way that muscle is distributed over the body as the animal grows (Berg & Butterfield, 1976).

### 4.4.2 Carcass characteristics

Although heifers and steers were the same liveweight, carcass weight was greater in steers than in heifers. This agrees with a multitude of literature comparing carcass weights of steers and heifers slaughtered at both the same age and at similar liveweights (Reiling et al., 1992; Steen, 1995; Lage et al., 2012; Blanco et al., 2020). There was no difference in carcass length between heifers and steers, which agrees with previous literature (Purchas et al., 2003; Lage et al., 2012; Li et al., 2014; Blanco et al., 2020).

As a consequence of having greater carcass weights but similar liveweights, steers also had a greater dressing out percentage compared to heifers. Previous literature on heifers and steers has found conflicting results on whether a sex effect on dressing out percentage exists when compared at the same slaughter age (Forrest, 1981; Rahnefeld et al., 1983; Lage et al., 2012; Carvalho et al., 2018; Augusto et al., 2019; Blanco et al., 2020). In studies where a sex difference was found, excess non-carcass fat deposition in heifers explained sex differences in dressing out percentage of older animals, but would not apply here as low levels of fat are deposited before 12 months of age, however weight differences in developing reproductive tracts may contribute to differences in dressing out (Keane, 2011).

While femur length was similar for heifers and steers, femur weight was greater in steers than in heifers (P>0.05, Table 4.3.2). This finding agrees with both Purchas et al. (2002) and Jones et al. (1978), who found femur weight to be greater in steers compared to heifers. The greater femur weight of steers relative to heifers, despite no difference in femur length, could be attributed to male cattle typically having thicker bones than females (Purchas et al., 2002; Wilson et al., 1977). This reflects the inhibiting effects of oestrogen on appositional bone growth, with heifers having greater levels of oestrogen, and therefore more slender bones than steers (Gibson et al., 2021). The genetics for a greater mature size and therefore a greater frame size will also promote a greater circumference of long bones of steers compared to heifers (Gibson et al., 2021).

In general, muscularity characteristics were similar for heifers and steers. There was no difference in the weights of knuckle, silverside or topside between heifers and steers and even without adjustment for carcass weight, there was no difference in eye muscle area between heifers and steers. This agrees with other studies comparing weights of primal cuts of heifers and steers (Jeremiah et al., 1997; Choi et al., 2002; Paulino et al., 2008; Li et al., 2014), although some studies have found differences in weights of primal cuts from the shoulder and the flank in heifers and steers (May et al., 1992; Knapp et al., 1989). Muscularity index was the same for heifers and steers, while muscle to bone ratio was greater in heifers, which is consistent with previous literature and can be attributed to the lighter femur weight of the heifers compared to the steers (Purchas et al., 2002; Blanco et al., 2020).

## 4.4.3 Meat quality characteristics

### 4.4.3.1 Effect of sex

**Ultimate pH**

No difference in ultimate pH was found between steers and heifers. This agrees with Carvalho et al., (2018). Other studies have found  steers to have a greater ultimate pH compared to heifers (Martin et al., 1971; Lucero-Borja et al., 2014). In all these studies, including the current study, pH was within the acceptable range for meat quality, meaning any difference between the sexes in pH would have had little effect on other measures of meat quality such as colour or tenderness (Purchas, 1990).

**Lean meat colour**

No difference in lean meat colour was found between steers and heifers. This agrees with both Park et al. (2002) and Blanco et al. (2020). In older animals, meat may be lighter in heifers than in steers, which is often attributed to increased intramuscular fat deposition in heifers compared to steers at a given age (Martin et al., 1971). As intramuscular fat is the last fat depot to be deposited in growing cattle, the yearling heifers in this study would have minimal deposition of intramuscular fat, explaining why no difference in lightness was observed between the sexes. The similarity in redness of the meat of heifers and steers can be attributed to heifers and steers having similar concentrations of myoglobin (Destefanis et al., 2003). Steers and heifers also have similar temperaments during lairage, being less prone to the detrimental effects of pre-slaughter stress or excitement on lean meat colour sometimes observed in bulls (Destefanis et al., 2003).

### Tenderness

Shear force was the same between steers and heifers. Previous literature has also found no difference in tenderness between steers and heifers, both with and without postmortem aging (Martin et al., 1971; Lucero-Borja et al., 2014; Augusto et al., 2019; Blanco et al., 2020). This could be attributed to the heifers and steers being slaughtered at the same age, as castrated males and females tend to have similar concentrations of connective tissue and insoluble collagen when compared at the same age (Bures & Barton, 2012; Augusto et al., 2019). Although tenderness was only measured objectively in this study, previous literature has found no difference between steers and heifers when subjectively measuring tenderness with taste panels (Martin et al., 1971; Lucero-Borja et al., 2014; Blanco et al., 2020).

### Water holding capacity

Both thaw loss and drip loss were similar for heifers and steers. This has been observed in other studies with cattle (Li et al., 2014; Augusto et al., 2019). No difference in pH is likely to have contributed to equal water holding capacity for the steers and heifers (Augusto et al., 2019). Ultimate pH of meat affects the water binding properties of muscle proteins, while carcass fat acts as a physical barrier to water loss (Augusto et al., 2019). Despite this, cooking loss was greater in heifers than steers. While Carvalho et al. (2018) found a greater cooking loss in the semitendinosus muscle of heifers compared to steers, cooking loss in the longissimus thoracis and triceps brachii were similar for both sexes. Previous literature has also found no difference in cooking loss in the longissimus muscle of heifers and steers (Jeremiah et al., 1996; Augusto et al., 2019). As pH was similar for heifers and steers, the reason for a higher cooking loss in heifers is unknown.

### Intramuscular fat content

There was no difference in the intramuscular fat content of heifers and steers. Numerically, fat content was similar to that of beef-cross-dairy-breed heifers and steers slaughtered at 18 and between 8 to 12 months, respectively (Coleman, 2016; Pike, 2019). The lack of a sex effect on intramuscular fat content is inconsistent with previous literature comparing heifers and steers at younger ages, which found heifers to have a greater intramuscular fat content than steers (Carvalho et al., 2018; Blanco et al., 2020). This could be partly attributed to these studies feeding concentrate based diets, as high starch concentrate-based diets increase IMF deposition by inducing upregulation of adipogenic pathways, which could allow for an observable difference between steers and heifers (Park et al., 2018). However, Carvalho et al. (2018) did state that the difference in fat content between heifers and steers may have been too small to be noticeable by consumers.

## 4.4.3.2 Effect of postmortem aging

### Ultimate pH

Ultimate pH was similar for aged and unaged samples. This agrees with Oliete et al. (2005), although other literature observed an increase in meat pH as aging time increased (Carvalho et al., 2018; Pike, 2019; Kim et al., 2020). As with heifer and steer samples, both aged and unaged samples were within the normal pH range so other meat quality characteristics would be unaffected by pH, regardless of whether meat was aged or unaged (Purchas, 1990).

### Lean meat colour

Aged samples were lighter than unaged samples. This is consistent with previous literature and has been attributed to changes in the structure of myofibrillar proteins, causing a change in absorption, transmission and reflection of light on the surface of the meat (Oliete et al., 2005; Onopiuk et al., 2016; Carvalho et al., 2018; Kim et al., 2019). Aged samples were redder than unaged samples, which agrees with previous research (Oliete et al., 2005; Onopiuk et al., 2016; Carvalho et al., 2018; Kim et al., 2019; Pike, 2019). The redness of meat is mainly affected by myoglobin content and form (Lawrie, 1991). Oxygen concentration on the surface of muscle increases as meat ages due to a lack of respiration from mitochondria, resulting in an increased formation of oxymyoglobin, giving a redder appearance to the meat (Lawrie, 1991; Oliete et al., 2005). The increase in yellowness with ageing also agrees with previous research (Oliete et al., 2005; Onopiuk et al., 2016; Carvalho et al., 2018; Kim et al., 2020). While this is difficult to explain, it is possibly a consequence of an increase hue angle due to formation of metmyoglobin (Zhang et al., 2018).

### Tenderness

Samples that were aged postmortem had lower shear force values than unaged samples. Postmortem aging is an established method of increasing tenderness of beef through the autolysis of muscle by which proteases, namely calpains and cathepsins, degrade myofibril proteins and their associated proteins (Oliete et al., 2005; Carvalho et al., 2018). Increased tenderness through aging is attributed to the partial degradation of collagen (Oliete et al., 2005). Although statistically significant, the difference in shear force between aged and unaged samples was numerically small. Both aged and unaged samples had shear force values well below 8kgF, which is recognised by New Zealand consumers as tender (Bickerstaffe et al., 2001). This calls to question the necessity of aging meat of yearling cattle, as the difference in tenderness may be too small to be noticed by consumers. No increase in myofibrillar fragmentation index was observed with aging, which typically is an indicator of proteolytic activity (Oliete et al., 2005). This suggests that the meat from yearling cattle is easily fragmented regardless of aging, so the aging of meat is less vital for ensuring tenderness with yearling beef.

### Water holding capacity

Aging increased water holding capacity through a decrease in drip loss. This is consistent with previous literature, and can be attributed to structural changes that occur in cytoskeletal proteins during proteolysis  (Hughes et al., 2014; Pike, 2019). A different relationship between aging and cooking loss was observed, as cooking loss was greater in aged samples than in unaged samples. This is consistent with previous literature, and as with drip loss, can be attributed to structural changes occurring in proteins during proteolysis (Hughes et al., 2014; Onopiuk et al., 2016). The degradation of cytoskeletal and myofibrillar proteins during aging weakens the protein structure, reducing the ability of the meat to trap and retain water during cooking (Hughes et al., 2014).

### 4.4.4 Limitations

**Comparison to traditional finishing ages**

In an ideal experiment, controls are used to minimize the effects of variables other than those being investigated. Groups of Stabilizer-Kiwicross heifers and steers slaughtered at the typical age of 24 months were intended to be used as controls for this study to compare carcass and meat quality of yearling steers and heifers to traditionally slaughtered steers and heifers. Due to errors during processing of the animals, these samples were unattainable so a comparison to older steers and heifers could not be made.

**Slaughter ages of heifers and steers**

Under normal commercial practices in New Zealand, heifers are slaughtered earlier than steers. In this study, steers and heifers were slaughtered at the same age, regardless of level of finish. This allowed for investigation of just the effect of sex on carcass and meat quality of heifers and steers, without being confounded by slaughter age. Running heifers and steers in one mob further removed any confounding variables such as preferential feeding or variations in management.

**Measurement of carcass characteristics**

Fat depth was measured using ultrasound one month prior to slaughter and was not taken after processing. Ideally, carcass fat depth would have been measured at the processors as the fat content of the animals may have increased in the interim between taking ultrasounds and slaughter. Typically, empty body weight after fasting is used to calculate dressing out percentage in scientific literature. In this study, truck liveweight straight after drafting out the animals on-farm was used to calculate dressing out percentage so dressing out percentage may have been underestimated due to gut fill of the animals.

### 4.4.4 Conclusions and Implications

Stabilizer-Friesian-Jersey heifers and steers had similar fat depths at 10 months of age. As fat depths at both the P8 and rib sites were less than 3mm, presuming fat depths had not increased in the month before slaughter, neither the steers nor heifers would have made P grade if graded at slaughter. Both sexes would be classified as L in the current carcass grading system and would be classified as manufacturing beef, receiving a lower return on a cents/kg basis (NZMCA, 2004). Although carcass weights of the steers were greater than those of heifers, both sexes produced light carcasses compared to cattle slaughtered at traditional ages, which would further reduce returns as both sexes would be classed as underweight under the current payment schedule. The small size of the yearling carcasses also makes them less practical to process at beef cattle abattoirs. The animals in this study were processed at a venison abattoir as this was more suitable for the smaller sized carcasses. As New Zealand farmers are paid on a kg hot carcass weight basis, yearling Stabilizer-Friesian-Jersey steers would likely be more profitable than heifers as they produced heavier carcasses at the same age. Dressing out percentage was also greater in the steers than the heifers, further increasing their profitability over heifers as they produced more carcass at an equivalent liveweight. However, steers may have consumed more feed than heifers and the purchase price of steers also has the potential to be higher than heifers, which would reduce the profitability of steers. While saleable meat yield was not measured, the weight of the primal cuts taken in this experiment indicate that muscularity characteristics of yearling Stabilizer-Kiwicross heifers and steers are similar and it can be inferred that yield would also be similar between the sexes.

At 11 months of age, the Stabilizer-Friesian-Jersey heifers and steers produced highly tender and lean meat. Given that tenderness is an important sensory characteristic of meat to consumers, and some consumers are willing to pay a premium if tenderness is guaranteed (Reddy et al., 2015; Holloway & Wu, 2019), New Zealand yearling beef could be targeted to certain markets for a premium. Most meat quality characteristics did not differ between the sexes meaning the eating quality of the heifer and steer meat is likely to be similar. As a result, meat from beef-cross-dairy-breed yearling heifers and steers could be classed together as one product.

Tenderness and drip loss were improved with aging. Aged meat would be classed by New Zealand consumers as very tender, requiring less than 5kgF shear force while unaged meat would be classed as tender, requiring more than 5kgF but less than 8kgF shear force (Bickerstaffe et al., 2001). However, the difference between aged and unaged samples was numerically small and may be unnoticeable to consumers (0.86kgF). Perhaps a shorter aging time, such as 7 days as opposed to 21, would be sufficient for yearling beef. A shorter aging time would also allow aged yearling beef products to get to markets that have a shorter shipping time, such as the burgeoning South East Asia market (Waldron et al., 2018).

# Chapter 5. General Discussion

## 5.1 Implications

While sire breed is often of interest when investigating breed effects on performance of finishing cattle, dam breed also affects both growth and carcass characteristics of beef-cross-dairy-breed heifers and steers. An increase in Jersey genetics of the dam decreases the return from beef-cross-dairy-breed progeny through decreased growth rates and carcass weights, and increased incidences of excessively yellow fat. The effect of Jersey genetics on growth is noticeable even in Friesian-Jersey dams. As a result, there was little difference in return from progeny of Jersey-cross and Friesian-Jersey dam. The slightly greater return from progeny of Friesian-Jersey dams was a result of a lesser frequency of excessively yellow fat.

The lack of difference in carcass and meat quality characteristics between yearling Stabilizer-Friesian-Jersey heifers and steers indicates that while return may be slightly greater for steer carcasses, both could be classed as the same product. However, the only current economically viable beef finishing system utilising heifers and steers of dairy origin in New Zealand is to finish them at the traditional slaughter age of between 24 to 32 months, as were the animals in chapter 3. This is mainly a consequence of the current beef grading system in New Zealand, which would undervalue the lighter carcasses from yearling heifers and steers, regardless of meat quality (Hunt, 2019).

The effect of dam breed on heifers and steers in a yearling finishing system was not investigated, however the lack of difference in growth rates before 12 months of age between dam breeds in chapter 3 suggests that dam breed would not affect growth performance of yearling heifers and steers from birth to slaughter. Excessive yellowness of subcutaneous fat in cattle with Jersey genetics is typically not observed until after 12 months of age (Morgan et al., 1969). This suggests that dam breed effects on yellowness of fat would also be inconsequential in a yearling beef finishing system. The results from Pike (2019) also indicate that slaughter age (of between 8 and 12 months) has little effect on finishing performance of yearling beef-cross-dairy-breed cattle, meaning calves of dairy origin could be utilised for yearling finishing systems and classed as one product, regardless of slaughter age, sex or dam breed. If yearling finishing systems were to become viable in New Zealand, it could increase retention of calves with a greater proportion of Jersey genetics which would otherwise be less desirable for retention in a traditional 24 month finishing system as they may have similar performance in a yearling system to calves with a greater proportion of Friesian genetics.

## 5.2 Future research

### Development of a yearling grading system in New Zealand

Yearling steers and heifers would be classed as manufacturing beef under the current grading system, making it an economically unviable system as carcasses would receive less return on a cents/kg basis (Hunt, 2019). A new grading system for young cattle would be required for yearling beef cattle to be a viable class of cattle for processing. This need is further increased by the highly tender beef produced by yearling cattle as it seems illogical to class beef with such great eating quality as manufacturing beef. Results from this study, as well as those from Pike (2019) could be used to develop a new carcass grading system for yearling beef.

### Viability of finishing systems across New Zealand

The animals in chapter 3 were finished in the Waikato region while those in chapter 4 were finished in the Manawatu region. The majority of previous research on the performance of cattle of dairy origin in New Zealand has also been undertaken in either of these regions (Morris et al., 1987; Barton & Pleasants, 1997; Purchas & Morris, 2007; Hickson et al., 2014; Coleman, 2016; Pike et al., 2019). Beef finishing occurs throughout New Zealand, and while these two regions differ in both climate, soil type and pasture growth, there are even greater differences between these and other regions (Li et al., 2011). For example, annual rainfall is almost three times greater in the Waikato region than inland South Island, and herbage accumulation is also greater in the Waikato region than inland South Island (Li et al., 2011). Future research is needed on the performance of cattle of dairy origin across different regions of New Zealand. Southland, in particular, has an increasing number of dairy farms resulting in an increased number of beef-cross-dairy-breed calves being finished in Southland (Geenty & Morris, 2017).

### Finishing performance of straight-bred dairy cattle

It is common practice to use beef sires over dairy cows after accounting for replacements to add value to surplus calves. The majority of underutilised bobby calves in New Zealand, however, are smaller dairy breed male calves, typically Jersey and Friesian-Jersey calves. Further research is required on the performance of these animals in a beef finishing system, particularly in an accelerated yearling system of beef production as it is currently unknown how straight-bred dairy calves perform in a yearling finishing system in New Zealand compared to beef-cross-dairy-breed calves.

### Meat quality from other parts of the carcass

Only the striploin was used for assessment of meat quality in chapter 4. The longissimus muscle is typically used to assess meat quality as using a standard muscle allows for comparisons across literature, it is also one of the most important muscles of the beef carcass, comprising a number of more expensive primal cuts. The highly tender meat from the longissimus muscle of yearling cattle could indicate that other muscles of the carcass could also have good eating quality. While previous literature has also included assessment of meat quality of other muscles such as the semitendinosus and psoas major, it would be interesting to assess the meat quality of less valuable parts of the carcass that are typically made into stewing and manufacturing beef. If a greater percentage of the carcass of yearling beef animals has good eating quality (table beef), the value of the carcass/kg would increase. This would further increase the economic viability of accelerated beef finishing systems in New Zealand.

## 5.3 Conclusions

Dam breed affected all growth traits measured in this study, with progeny of Friesian dams consistently having greater growth performance than progeny from other dam breed groups.

Progeny of Friesian dams were heavier at birth, took less time to reach a set weaning weight, and were heavier as yearlings and at slaughter. Between weighing as yearlings and slaughter, progeny of Friesian dams also had greater growth rates than progeny of Friesian-Jersey dams.
Dam breed had a lesser effect on carcass characteristics than on growth, with carcass weight, fat colour and ossification score being the only characteristics affected by dam breed. The greater growth performance in progeny of Friesian dams translated into a greater carcass weight in progeny of Friesian dams than progeny of the other dam breed groups. Progeny of Jersey-cross dams had yellower fat and a greater incidence of excessively yellow fat than progeny of all other dam breed groups. It is this greater incidence of excessively yellow fat, as well as the lower carcass weights, that result in the lowest returns for progeny of Jersey-cross dams than for any other dam breed group. An increase in Jersey genetics in the national dairy herd will result in a greater proportion of Jersey genetics of surplus calves available for beef finishing, which are slower growing, produce lighter carcasses and are at higher risk of having excessively yellow fat than those which have a greater proportion of Friesian genetics. If a market could be created for yellow fat, however, there would be greater potential for Jersey-cross calves to be finished for beef.

Carcass weight was greater for Stabilizer-Friesian-Jersey steers than for heifers at 11 months of age, which also resulted in a greater dressing out percentage for steers, although both sexes produced light carcasses relative to cattle slaughtered between 18 and 36 months of age. Sex did not affect fat depth, and both sexes had less than 3mm of fat at the P8 and rib sites so would be graded L and classified as manufacturing beef. It is for this reason, along with the low returns from having lighter carcasses, that a yearling beef finishing system is currently unviable in New Zealand under the current carcass grading system. Muscle to bone ratio was greater in heifers, although sex did not affect muscularity index, suggesting yield would be similar between the sexes.

Sex had little effect on meat quality characteristics, and both heifers and steers produced highly and similarly tender meat. This suggests that yearling beef from heifers in steers could be classified together as one product and targeted to certain markets for a premium. While aging increased meat tenderness, unaged meat was still highly tender, suggesting that aging is unnecessary to provide a tender product.

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