The harvest pathology and grading characteristics of cull dairy cows by breed, reason for leaving the herd, days in milk, and lactation number

by

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ABSTRACT

Two experiments studied the harvest pathology and grading characteristics of cull dairy cows by breed, reason for leaving the herd, days in milk, and lactation number. The first experiment compared the harvest pathology and grading characteristics of cull Holstein and Jersey cows. Cull Jersey cows were younger at harvest compared to Holsteins. Holsteins had a lower edibility frequency due to a greater liver abscess frequency when compared to Jerseys. Jersey cows had a greater frequency of livers with carotenitis cows. Holstein cows had a greater lung abnormalities. Holstein cows had larger longissimus muscle areas, heavier hot carcass weights, and lower cutability yield grades. The younger Jersey cows had a greater frequency of USDA Standard or better compared to the older Holstein cows. The sirloin had the highest frequency of bruising of the primals. Holstein cows had a greater frequency of bruises and larger bruises compared to Jersey cows. The most frequent reason for a carcass to be railed out was contamination. Septicemia was the most frequent reason for an animal to be condemned by the USDA veterinarian. In experiment two, cull Jersey cows harvest pathology and grading characteristics were matched with their on dairy record for the last year. The most frequent reason for a cow leaving the herd for culling was low production and mastitis respectively. Cows culled for digestive disorders had the greatest frequency of non-abscess abnormalities. Cows culled for respiratory disease had the greatest frequency of inflated lungs. Subcutaneous fat depth, intramuscular fat, longissimus muscle area, and hot carcass weight worked inversely to a milk lactation curve. Inflated lung frequency

increased as age increased. Hot carcass weight increased from cows on their first lactation to cows on their third lactation.

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DEDICATION

This dissertation is dedicated to my family:

To Kyla,

To Dad,

To Mom,

To Avery,

To Adam,

To Adrian,

To Papa Avery,

To Grandma Joy,

To Grandma Pat,

To Grandpa Weldon,

To Grandma Phillis,

You all have played a huge role in the man that I have become and I cannot be any more appreciative of that. You all have been my biggest supporters through the easy times and the hard times. I could write a book on how much all of you mean to me. To summarize it, thank you for always having my back and I love everyone of one of you.

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CHAPTER 1

INTRODUCTION

Culling dairy cows is necessary to improve production efficiency, reduce diseases, and ensure humane endings for the animals. Dairy cull cows are an important part of the beef production stream, accounting for 9.6% of the daily harvest (USDA, 2018). Reasons for culling include low production, mastitis, lameness, reproduction, respiratory, udder confirmation, digestive disorders and transition diseases. Holstein (HOL) and Jersey (JER) (Bascom and Young, 1998; Hadley et al., 2006). Holstein cows make up 92 to 94% of the dairy cow population whereas Jerseys make up 6 to 7% (CDCB, 2017; HOL ASSOC, 2017). Liver abnormalities for cull cows ranged from 44 to 64 % with abscesses being the most common liver abnormality (Rezac et al., 2014; Harris et al., 2017). Pneumonia lesions were visually observed in 23.8% to 33.8% of dairy cull cows (Rezac et al., 2014; Harris et al., 2017). Cull cows are not ribbed at beef processors and generally classified on body conformation to estimate lean trimmings for ground products (Hilton et al., 1996; Gill, 1998). Limited research has been reported comparing gross carcass pathology, yield and quality outcomes between the two primary dairy breeds. The objective of this study was to compare post-mortem characteristics of Holstein (HOL) and Jersey (JER) cows.

Bascom and Young (1998) and Hadley at el. (2006) discussed culling patterns which included culling for low production, mastitis, lameness as well as other reasons. With on farm herd database systems like Dairycomp 305 (Valley Agriculture Software, Tulare, CA), birth date, days in milk (DIM), lactation number, animal event data, production and culling patterns can be much easier surveyed. No research has been done to associate culling patterns with harvest pathology; however, it was suggested by Rezac et al. (2014) to get a better understanding of different parameters and their effects on lung lesions and liver abscess frequency. Though it is commonly understood that after peak milk production nutrients are partitioned more towards the body instead of milk production, no research has been done to associate carcass fat and muscle with days in milk. The new USDA maturity standards (established Dec 2017) would allow cull animals with a verified documented age or dentition that identifies an animal as less than 30 months of age with less than D^{00} maturity to qualify for young beef grades (USDA – AMS, 2017). Historically, dairy cull cows had a skeletal maturity bias against them since they ossified more rapidly than male animals due to increased estrogen production (Lawrence et al., 2001). The objective of this study was to associate culling patterns, DIM, and lactation number with harvest pathology and carcass grading attributes of Jersey cull dairy cows.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Dairy industry overview

Milk is classified into grades A and B (USDA - AMS, 2018). Grade A milk is defined as the fluid grade milk which must be produced under sanitary conditions that meet federal standards (USDA - AMS, 2018). Grade A milk can be used for any manufactured dairy product. Grade B milk is defined as manufactured grade milk that must be produced under conditions which meet state and local standards (USDA - AMS, 2018). Grade B milk can only be used for manufactured milk products because the standards are less sanitary than those of fluid grade milk. The major difference between grade A and B milk are the sanitary practices at the dairy with most dairies in the United States classifying for grade A milk (USDA - AMS, 2018).

In 1937, the Federal Milk Marketing Orders were authorized by the Agricultural Marketing Agreement Act of 1937, allowing the Secretary of Agriculture to establish a minimum milk price based on what the milk will be used for (USDA - AMS, 1937). Milk prices should be uniform except for adjustments for volume, market, production differentials, grade, and location (USDA - AMS, 1937). Seasonal adjustments may also be made and a fund began to encourage seasonal adjustments in the production of milk (USDA - AMS, 1937). Handlers became responsible for market information, weight verification, milk sampling, milk testing, and making appropriate deductions (USDA - AMS, 1937). Grade A milk was divided into four separate classes (USDA - AMS, 1937;

USDA - AMS, 2018). Class I milk is used for beverages, including eggnog and ultra-high temperature milk (USDA - AMS, 1937; USDA - AMS, 2017). Class II milk is used for soft products including cottage cheese, frozen desserts, sour cream, half and half, or any product containing artificial fat or fat substitutes that resemble fluid cream (USDA - AMS, 1937; USDA - AMS, 2017). Class III milk is used in the manufacturing of spreadable and hard cheese types that may be shredded, grated, or crumbled (USDA - AMS, 1937; USDA - AMS, 2017). Class IV milk is used to produce butter and any milk product in dry form (USDA - AMS, 1937; USDA - AMS, 2017). A producer will determine which class of milk to target generally based on geographic location of local milk processors.

2.1.1. Production outcomes

In 2017, total milk production was 215 billion pounds in the United States (USDA – ERS[d], 2018). The different classes of milk will call for different types of markets throughout the United States. A specific region may be classified as a cheese market which suggestg the market for the region is class III milk (USDA - AMS, 1937). Producers may be paid for premiums, such in the case of cheese, for higher milk fat and protein percentages as compared to other markets (USDA - AMS, 1937; Elbehri et al, 1993). The different milk markets yield multiple different milk products. Fluid milk is the predominant market whereas, cheese, ice cream, yogurt, butter and nonfat dry milk follow respectively (USDA – ERS[f], 2017).

In 2016, 49.7 million pounds of fluid milk was sold (USDA – ERS[a], 2017). Fluid beverage milk in order of per capita availability (lbs) included reduced fat milk (76.7), whole milk (45.7), skim milk (17.7), flavored milk (13.9), buttermilk (1.6), and eggnog

(0.04) (USDA – ERS[b], 2017). Only class one milk can be used for fluid beverage consumption (USDA - AMS, 1937)

In 2016, 13.96 million pounds of soft dairy products were produced in the United States (USDA – ERS[e], 2017). Soft dairy products included in descending order of per capita availability (lbs): ice cream (18.9), non-frozen yogurt (14.7), sour cream (4.1), cottage cheese (2.1), water and juice ices (1.5), frozen yogurt (1.3), and sherbet (0.9) (USDA – ERS[b], 2017; USDA – ERS[c], 2017). All soft dairy products are considered a class two market; thus, class one and two milk can be used for soft dairy product production (USDA - AMS, 1937)

In 2016, 11.8 million pounds of cheese was produced in the United States (USDA – ERS[f], 2017). American cheese is the predominant cheese produced, narrowly surpassing 40% of total cheese production. Though more pounds of fluid milk are sold, cheese production facilities receive more pounds of milk and produce less pounds of product due to the loss of water in cheese production (USDA – ERS[f], 2017; USDA 2018) Class one, two and three milk can be used for cheese production (USDA - AMS, 1937). In 2015, the per capita annual consumption of cheese was 35.1 pounds (USDA – ERS[c], 2017).

In 2016, 1.8 million pounds of butter was produced in the United States (USDA – ERS[f], 2017). Butter is classified as class four under the milk marketing order (USDA - AMS, 1937) All classes of milk that are grade A are eligible to be used for butter production. In 2015, the per capita annual consumption of butter was 5.6 pounds (USDA – ERS[c], 2017).

In 2016, 1.75 million pounds of dried milk products were produced in the United States (USDA – ERS[f], 2017). Dried milk products include in descending order (lbs): non-fat dried milk (3.3), dried buttermilk (0.3), and dried whole milk (0.3) (USDA – ERS[c], 2017). Similar to cheese, water is lost from the production of dried milk. Thus, more pounds of milk may go into non-fat dry milk production but less output is produced (USDA – ERS[f], 2017; USDA 2018). All classes of milk are eligible to be used for non-fat dry milk production (USDA - AMS, 1937).

2.1.2. Dominant breeds and uses

Like the beef industry, there are a variety of dairy cattle breeds. A breed's genetics have been selected over time for its milk components, pounds of milk production as well as other various selection traits like polled, strength, and hind leg structure. Cross-breeding has become more popular as time has passed. (McAllister, 2002; CDCB, 2017) Producers are trying to combine the benefits of two or more breeds and put them in one cow. The United States has over 9 million cows (USDA – ERS[d], 2017). Of those cattle, the predominant purebred breeds are Holstein and Jersey (CDCB, 2017). Other U.S. breeds include, Ayshire, Brown Swiss, Guernsey, and Milking Shorthorn. (CDCB, 2017)

The Holstein breed originated in the Netherlands over two thousand years ago (HOL ASSOC, 2018). The breed was developed from crossing black Batavians and white Friesians to produce the now Holstein-Friesian breed (HOL ASSOC, 2018). Holsteins were first imported into America in the mid eighteen fifties (HOL ASSOC, 2018). Purebred Holsteins are easy to identify due to their unique black and white flecked phenotype (HOL ASSOC, 2017). Of all the dairy cows in the United States, it's estimated between 92 to 94 % are of Holstein-Friesian genotype (CDCB, 2017; HOL ASSOC, 2017). A purebred Holstein cow is the only genotype to hold the world record for milk production since keeping began (HOL ASSOC, 2017). Thus, it is easy to see why producers choose Holstein influenced cattle over 90 % of the time. According to the Holstein Association, the average Holstein will produce 23,000 pounds of milk during a 305 d lactation (HOL ASSOC, 2017). Though Holsteins generally have a lower percentage of milk components, the increased total milk production will net a similar or higher output of total protein and fat pounds (Heins et al., 2008; Bjelland et atl., 2011).

The Jersey breed was developed on Jersey island of England (Porter et al., 1965). Jerseys are hypothesized to be the combination of dark cattle from Brittany and red or brindle cattle from Normandy. It is not known when exactly the first Jersey breed was imported to North America because Jersey cattle have a similar look compared to Alderney and Guernsey cattle; however, it is estimated they came in the early eighteen hundreds (Porter et al., 1965). Jersey cattle are the second most popular breed of cattle in the United States (CDCB, 2017). Jersey animal's high milk component genotype make them an excellent complement for the Holstein high milk yield genotype and is why most crossbreeding producers choose Holstein x Jersey crosses (McAllister, 2002). Jerseys are recognized to produce the highest percentage of milk solids and fat percentage as a composition of whole milk of the major dairy breeds (Porter et al., 1965). Jerseys are identified as easier to re-breed and this is likely due to them having higher body fat throughout life (Washburn et al., 2002; Bjelland et al., 2011).

The Brown Swiss breed, also known as Brown Schwyzer, originated in Switzerland (Porter et al., 1965). Brown Swiss are the third most popular breed according to the CDCB (2017). The first Brown Swiss cattle were brought to North America by

Henry M. Clark in 1869 (Porter et al., 1965). Unlike other dairy cattle breeds, Brown Swiss were used for milk production, meat production and as draft animals (Porter et al., 1965). The large stature is of no surprise because it was a draft animal and when selection for milk production started, a larger animal ate more and thus would produce more milk (Porter et al., 1965; Tyler and Ensminger, 2006). Brown Swiss are known for their durability and hardiness as compared to other breeds (Porter et al., 1965). Brown Swiss are the latest maturing breed of the popular breeds in the United States (Porter et al., 1965).

The Guernsey breed originated on the Guernsey island of England and was developed from the crossing of Froment du Leon and Norman Brindle cattle (Porter et al., 1965). According to the Council of Dairy Cattle Breeding (CDCB), Guernsey cattle are the fourth most popular purebred breed in the United States (2017). Similar to Jerseys, it is unknown when the first Guernsey cattle were brought to North America but it is estimated to be the mid eighteen hundreds (Porter et al., 1965). Guernsey cattle are similar to Jersey cattle in having high milk components with Guernsey having the highest percentage of protein in whole milk (Porter et al., 1965). Guernsey cattle are the earliest maturing of the breeds used in America (Porter et al., 1965)

The Ayrshire breed originated in southwestern Scotland and were first introduced to North America in 1822 (Porter et al., 1965). The Ayrshire breed is the fifth most popular breed in the United States (CDCB, 2017) Ayrshire cattle are known for the durability of their feet and legs (Porter et al., 1965).

The Milking Shorthorn breed are descendants of the beef Shorthorn breed of Northern England and Scotland (Porter et al., 1965). The beef and dairy Shorthorn breeds started separating from each other when Thomas Bates and other Shorthorn breeders started selecting for high milk producing cows (Porter et al., 1965). Their goal was to create a dual purpose breed that could produce large quantities of milk and present a carcass with favorable confirmation (Porter et al., 1965). The breed is the least popular of the major breeds in the United States likely to the low milk production (Porter et al., 1965; CDCB, 2017).

2.2 Dairy cow life cycle

A dairy female is the key commodity in the dairy industry. Thus, the animal should be properly managed from birth until culling to increase the animal's production life and wellbeing. A dairy producer has choices when it comes to finding replacements for his herd. Ideally, a producer would be able to raise and use his own heifers to replace his cull animals, known as closed herd. Another common practice is to utilize contract growers which will grow and breed heifers until they are close to calving. A producer also has the option to sell the heifers and buy replacements when he needs more lactating cows.

2.2.1 Heifer calf raising

Heifer management starts at birth when the animal is first born. A heifer calf has 75% chance of being born without assistance, and are 4.2 times more likely to survive the first 21 days of life than heifers born with assistance (Wells et al., 1996; Urie et al., 2018). The naval is disinfected on 79% of heifers as observed by Urie et al. (2018). More than half of the heifers managed in the US will receive colostrum from the mother while the remainder will receive it from a colostrum pool or another cow (Urie et al., 2018). At this point, a heifer can be moved to a contract raiser.

The heifer will then be moved to a housing system where she will be housed individually on 87% of farms (Urie et al., 2018). Fifty-two percent of the heifers surveyed by Urie et al. (2018) were dehorned at an average of 28 days of age of which 27% received an analgesic or anesthetic to counteract the pain. The most common milk diets for the heifer are waste milk, milk replacer or a combination of the two (Urie et al., 2018). The most common practices for feeding are bottle, bucket or pail, milk bar, or robotic (Urie et al., 2018). On average, the heifer will receive liquid feed until 63 days of age at which point she will be weaned (Urie et al., 2018). A heifer calf will first be offered calf starter at 5 days of age, water at 7 days of age, and hay at 27 days of age (Urie et al., 2018). Of the dairies surveyed by Urie et al. (2018), 65% of them received some sort of vaccination. Heifers in the United States have an 88% chance to become morbid while in the preweaning stage of life; however, of those morbid heifers, only 5% of the total population died (Urie et al., 2018). Digestive and respiratory distress are the two primary causes of morbidity and mortality (Urie et al., 2018).

After weaning, heifers are put into group housing with other heifers of similar age (USDA APHIS, 2016). Heifers are bred as close to puberty as possible to get to freshening faster and to lower feed cost (Tozer and Heinrichs, 2001). It is common to administer vaccines again to weaned and springer heifers (USDA APHIS, 2016). When close to calving, the heifer may be moved up to a calving pen or barn to facilitate closer supervision of the animal.

The few weeks before calving to the few weeks after calving is known as the transition period (Tyler and Ensminger, 2006). The transitioning cow or heifer should not be over conditioned as this causes the animal to be more susceptible to transition diseases including fatty liver syndrome, milk fever, and dystocia (Tyler and Ensminger, 2006). The goal as a producer is to keep the cow at a lower body condition score to keep her feed intake high and to also monitor her post parturition to make sure no more than a 1 point reduction in body condition score occurs (Tyler and Ensminger, 2006).

2.2.2 Production management

The goal for cow when she hits production is be as productive for as many lactations as she can. As discussed earlier, when a cow first freshens she will be allowed to spend up to 24 hours with that calf to allow her to pass immunoglobulins through her colostrum (Urie et al., 2018). After parturition the cow is in a negative energy balance, the goal for management is to place a diet in front of her that will help get her out of that negative energy balance (Tyler and Ensminger, 2006). High producing dairy cows have a greater difficulty leaving negative energy balance and thus use their energy stores to meet their genetic potential (Tyler and Ensminger, 2006). This is often why cows that are over conditioned in early lactation are culled for low milk production (Tyler and Ensminger, 2006).

Optimizing rumen function in the animal is a key component for keeping the animal productive throughout multiple lactations (Tyler and Ensminger, 2006). The rumen should be managed to be as close to acidosis without acidosis occurring in a negative energy balanced diet to produce as much energy as possible; however, acidosis does occur in multiple situations if not managed properly (Tyler and Ensminger, 2006). In a positive energy balanced cow, the rumen should be optimized by using fiscally efficient ingredients to optimize milk output (Tyler and Ensminger, 2006).

When a positive energy balance occurs, the optimal time for breeding ensues (Tyler and Ensminger, 2006). In positive energy balanced cows, the amount of milk produced starts to drop and various methods such as increasing milking frequency, the use of light on photoperiod effects and the use of bovine somatotropin to keep high milk production can be used (Tyler and Ensminger, 2006). Increasing milking frequency can result in more pounds of milk produced per day (Tyler and Ensminger, 2006). The use of lighting to simulate days with more light can increase a cow's production (Tyler and Ensminger, 2006). The controversial bovine somatotropin can be used to increase milk production at the cost of increased risk of infertility, ketosis, and fatty liver (Tyler and Ensminger, 2006).

Historically, a cow would ideally be re-bred at 60 days in milk so that she can be moved to the dry period when her inputs become more then her outputs (Tyler and Ensminger, 2006). However, with the increase of high producing cows it is now not uncommon for an animal to be rebred close to 100 days in milk and still be profitable when she is allocated to the dry pen (Tyler and Ensminger, 2006).

Dry period cows are managed to eat as inexpensive as possible (Tyler and Ensminger, 2006). The dry cow also needs to be watched to make sure she doesn't become over conditioned while in the dry period (Tyler and Ensminger, 2006). The dry period is important for animals that have previously dealt with mastitis to repair alveolar tissue (Tyler and Ensminger, 2006).

2.2.3 Reasons for Culling

Culling can be defined as the animal leaving the herd to be sold to another dairy for production, receive a salvage value for the cow at a sale barn, sent to a harvest facility for a humane ending, and death (Fetrow et al., 2006). A cow is culled for economical or biological reasons (Fetrow et al., 2006). Economic reasons are low production for a cow when she can be replaced with a more productive cow (Fetrow et al., 2006). Biological reasons are an issue with a cow that would cause her to be culled for a reason other than or associated with low production (Fetrow et al., 2006). Cull rates range around 35.4 % for the upper Midwest and Northeast regions (Hadley et al., 2006). However, different regions have higher culling rates than those in the Midwest and Northeast regions (Tyler and Ensminger, 2006). The 2016 National Beef Quality Audit (NBQA) observed more single defects and less multiple defects as compared to previous audits suggesting producers are culling cows before a second defect onsets (Harris et al., 2017[a])

Cows that are voluntarily culled for low production make up about 12.8-14% of the reason why an animal is culled (Bascom and Young, 1998; Hadley et al., 2006). A cow culled for low production is worth less than a heifer that is replacing her (Fetrow et al., 2006). Depending on the quantity of replacement heifers available, a producer may choose to cull as many low producing cows as they have replacements (Tozer and Heinrichs, 2001).

Cows that are involuntarily culled for mastitis make up about 12.1-15% of the reason why an animal is culled (Bascom and Young, 1998; Hadley et al., 2006). "Mastitis is an infectious inflammation or irritation in the udder that interferes with the normal flow of milk and/or quality" (Tyler and Ensminger, 2006). Mastitis is the most costly disease to dairy producers. (Tyler and Ensminger, 2006). Because mastitis can be contagious, it is important to sanitize the milking equipment between milking groups (Tyler and Ensminger, 2006). Mastitis is a treatable disease and one case of mastitis will not often cause the cow to be culled; however, if the cow contracts the disease multiple times within a short period of time she will be considered for culling and replaced with a younger healthier heifer (Tyler and Ensminger, 2006).

Cows that are involuntarily culled for lameness make up about 6-30 % of the reason why an animal is culled (Bascom and Young, 1998; Hadley et al., 2006). Lameness can be identified as when a cow refrains from putting weight on a certain limb of the body (O'Callaghan et al., 2003). Lameness can be hard to identify early when it's contracted because of the cow's stoical, nature which can lead to the case getting worse (O'Callaghan et al., 2003). A common practice to identify lameness is mobility scoring (Green et al., 2002; O'Callaghan et al., 2003). Cows that become lame are less productive than cows that are sound (Green et al., 2002). It is important to maintain routine hoof care, keep the cows comfortable, and try to have the cows on concrete for as little time as possible to avoid culling a cow for lameness (Green et al., 2002; O'Callaghan et al., 2003; Cook and Nordllund, 2009).

Cows that are involuntarily culled for reproduction make up about 18.9-24% of the reason why a dairy cow is culled (Bascom and Young, 1998; Hadley et al., 2006). Reproduction issues includes infertility and abortion issues for dairy cows. Infertility has been of major concern as producers have selected for high milk producing cows while inadverntenly selecting lower fertility females (Lucy, 2001; VanRaden et al., 2004; Hare et al., 2006; Norman et al., 2009). Over time we have seen a decrease in fertility breeding value; however, in recent years with more selection on fertility based traits we are seeing an increase in fertility breeding value (Norman et al., 2009). If a cow becomes infertile, she has little value to the producer because she cannot reset her milk lactation curve.

Similarly, cows that abort during the dry period are of little use to the producer if they do not produce milk.

Digestive disorders are an uncommon reason to cull dairy cows. Authors most commonly classify digestive disorders into the other category when discussing why dairy cows are culled. Digestive disorders that are prone to getting an animal culled include subacute acidosis and diarrhea. Both diseases can be hard to identify and cause a drop in milk production which make animals that contracted them likely to get culled for low milk production (Bareille et al., 2002)

Other reasons for culling include transition period diseases, respiratory diseases, Johne's disease, poor udder conformation, and undesirable animal disposition (Bascom and Young, 1998; Hadley et al., 2006). The most common transition disease are metritis, ketosis, fatty liver syndrome, displaced abomasum, and milk fever (Tyler and Ensminger, 2006). Pneumonia and bovine respiratory disease are the most common respiratory diseases in cattle (Tyler and Ensminger, 2006). Johne's disease negatively effects milk production and salvage value and is caused by *Mycobacterium paratuberculosis* (Ott et al., 1999). If the udder becomes too low hanging due to a weak suspensory ligament or a dry quarter is found, a cow will be culled for udder conformation (Tyler and Ensminger, 2006). A cow that kicks at the milker or is troublesome to get into the milk parlor may be culled for the safety of the dairy employees (Tyler and Ensminger, 2006).

2.3 Harvest Pathology of Cull Cows

After cows are culled from the production herd, they deserve a humane death and producers will receive a salvage value once they are sent to a harvest facility. In 2017, dairy cows made up 9.4% of all animals slaughtered in the United States (USDA –

NASS, 2018). Cull dairy cows are important for the beef supply chain. Multiple attributes can be evaluated at harvest to objectively quantify for the animal's health and wellbeing.

2.3.1 Bruises

Bruises negatively influence animal welfare and meat quality of animals at harvest (Strappini et al., 2009). Bruises are defined as an injury that causes a blood vessel to rupture and pool blood and serum in the area (Hoffman et al., 1998). A carcass that is bruised must be trimmed, resulting in a loss for both the dairy producer and the beef processor (Strappini et al., 2009). The 2016 NBQA reported that 64.1% of all cows had a bruise and of those dairy cows 40% had a major or critical bruise (Harris et al., 2017[a]). In a survey study done in the Great Lakes region, cull dairy cows had a prevalence of 54.1% of bruises (Rezac et al. 2014). The most common bruise location reported was on the round and sirloin, specifically the dorsal aspect of those primals (Rezac et al., 2014; Harris et al., 2017[a]).

2.3.2 Cancer eye

Bovine ocular neoplasia has become less of an issue thanks to breeding selection (Gardiner et al., 1972). Cancer eye is the most common form of cancer in cattle (Gardiner et al., 1972). In the 2016 NBQA, less than 1% of cull animals had cancer eye (Harris et al., 2017[a]).

2.3.3 Gastrointestinal tract abnormalities

One of the most prevalent gastrointestinal tract abnormalities is acidosis. Acidosis is defined as a pH drop in the rumen that causes volatile fatty acids and lactic acid to be absorbed into the blood stream (Church, 1988). Both rumen papillae and liver abscess frequency can be used to identify an animal that has contracted acidosis (Church, 1988;

Rezac et al., 2014). Acidosis effects both the producer and the beef processor. The producer realizes its effect through decreased feed efficiency and decreased milk production (Rezac et al., 2014). The beef processor realizes feels the effect through lost by-product income and reduced kill floor efficenceis(Church, 1988). Rezac et al. (2014) scored rumen epithelium post mortem to identify acidosis incidence and observed that 35.2% of the cull cows had an abnormal epithelium score.

A common gastrointestinal tract problem in cattle is bloat. Bloat is defined as an excess of gas in the reticulo-rumen compartment of the stomach that causes distention because the animal is not able to relieve the pressure via eructation (Church, 1988). Bloat occurs in dairy animals if a legume is fed in excess (Church, 1988). To prevent bloat, a producer can feed poloxalene, a defoamer. (Church, 1988).

Another gastrointestinal tract abnormality that's common in the transition period is displaced abomasum. A displaced abomasum is defined as the twisting or repositioning of the abomasum to the point it slows stomach content flow allowing gas build up to occur (Tyler and Ensminger, 2006). It can be labor intensive to treat displaced abomasum and maybe easier to cull the cow rather than treating her (Tyler and Ensminger, 2006).

Hardware disease or traumatic reticuloperitonitis is also a common disease in mature dairy cows. Hardware disease is defined as a foreign object that is ingested, trapped in the rumen, and pierces a hole into the reticulum wall causing bacteria to get into the heart (Jubb et al., 1993) In most cases, the foreign object is a metal material that was collected when the feed was harvested (Jubb et al., 1993). Hardware disease can lead to more serious conditions like peritonitis or pericarditis (Jubb et al., 1993).

2.3.4 Kidney abnormalities

Harris et al. (2017[b]) reported that 10 % of cows had kidney abnormalities at harvest in the 2016 NBQA. The two primary kidney diseases of concern are nephritis and renal cyst. Other kidney abnormalities include discoloration and renal atrophy.

Nephritis can be identified as a kidney with white spots which is the most common kidney disease for cattle and is an infection caused by bacteria (Yener and Keles, 2001; Uzal et al., 2002). Yener and Keles (2001) believe the presence of *Leptospira interrogans* are correlated with nephritis; however, other observations disagree (Uzal et al., 2002).

Renal Cyst can be identified as a kidney with water sacs attached (Jubb et al., 1993). Like other cysts, a renal cyst is a fluid filled sac attached to the kidney (Jubb et al., 1993). “There are three mechanisms for renal cyst: obstructive lesions, a change in tubular basement membrane, and abnormal growth of tubular epithelial cells” (Jubb et al., 1993).

2.3.5 Lameness

Lameness is of major concern for animal welfare in dairy animals at slaughter. Dairy cows in the NBQA for 2016 had the lowest percentage (76) of a sound mobility score compared to beef cows (87.1), bulls (82.9), and dairy bulls (76.9) (Harris et al., 2017[a]). However, dairy cows have made improvements on lameness compared to previous beef quality audits (Harris et al., 2017[a]).

2.3.6 Liver abnormalities

The liver is of great value to the beef processor. Depending on the weight of the liver, a cow’s liver is worth up to 5 dollars. However, liver abnormalities that cause a liver to be inedible can cost the packers thousands of dollars a day. Liver condemnations range from 44 to 64% (Rezac et al., 2014; Harris et al., 2017). Liver abnormalities commonly observed at cow slaughter plants include abscesses, flukes, telangiectasis, carotenitis, cirrhosis, and sawdust.

The most common liver abnormality in cull cows is liver abscesses which occurs in 20.7 to 32.2% of cull animals (Rezac et al., 2014; Harris et al., 2017). A liver abscess is formed when bacteria like *Fusobacterium necrophorum* in the blood come into the liver via the hepatic artery, hepatic portal, or umbilical veins; when an object penetrates the reticulum wall; and when forms of peritonitis occur (Jubb et al., 1993). Though liver abscesses are primarily associated with ruminal acidosis, liver abscesses are starting to be recognized as a multifactorial disease (Dore et al., 2007; Rezac et al.; 2014).

A commonly identified liver abnormality is distoma or more generally known as liver flukes. Liver flukes occur in about 3.2 to 6.4% of cull animals (Rezac et al., 2014; Harris et al., 2017). The common cattle liver fluke species is *Fasciola hepatica* which are leaf shaped, around 2.5 centimeters long, located in the bile ducts, hermaphroditic, and prefer warm moist environments (Jubb et al., 1993). The liver fluke enters the body through ingestion, the fluke will pass through the intestinal wall, peritoneal cavity and penetrate the liver through its capsule (Jubb et al., 1993).

Another liver abnormality observed at cull animal harvest facilities is telangiectasis. Telangiectasis occurs in cull animals at a frequency of 1 to 6.5% (Rezac et al., 2014; Harris et al., 2017). Jubb et al. (1993) defined telangiectasis as “a cavernous ectasia of groups of sinusoids”. Telangiectasis can be identified as circular shaped dark reddish colored spots on the liver (Jubb et al., 1993). Telangiectasis cannot be identified in the living animal as it has no major effect on the animals performance (Jubb et al., 1993).

A less common liver abnormality is carotenitis (Smith, 1940). Carotenitis has also been termed hepatic fatty cirrhosis. Little research has been done to identify what causes hepatic fatty cirrhosis or its effects on animal performance.

Focal hepatitis is a liver abnormality commonly known as sawdust. The pathology of sawdust is not known but is hypothesized to be caused by organisms from the digestive system making it to the liver (Jubb et al., 1993). Though unproven, it has been hypothesized that focal hepatitis can lead to telangiectasis (Jubb et al., 1993).

2.3.7 Lung abnormalities

One of the most well-known diseases in cattle is bovine respiratory disease (BRD). It is a problem that most producers have dealt with when producing beef and dairy animals. Stanton et al. (2012) reported that performance decreased or tended to decrease in heifers with BRD versus heifers without BRD through the first lactation.

Lung consolidation or lung lesions is the most common lung abnormality observed when evaluating harvest pathology for BRD. Harris et al. (2017) in the 2016 NBQA observed that 23% of audited carcasses exhibited lung condemnation, with mild pneumonia making up 4.2% of the carcasses audited, moderate pneumonia making up 2.3% of the carcasses audited, and severe pneumonia making up 1.2% of the carcasses auditied. Rezac et al. (2014) observed 33.8% of lungs had lung lesions with mild lung lesions representing 23.5% and severe lung lesions accounting for 10.3%.

A less commonly identified lung abnormality is fibrin tags. Tennant et al.(2014) defined fibrin tags as “interlobular adhesions between lobes.” No research has been reported in cull cows to evaluate fibrin tags. Tennant et al. (2014) observed 42% of observed feedlot cattle had fibrin tags; however, no performance difference were observed for cattle with fibrin tags versus those without them.

2.4 USDA beef grading

Grading in beef cattle has become an important part of marketing beef from harvest to retail. Beef is graded for two factors: quality and yield. Quality grading is used to classify into general palatability categories to identify tenderness, juiciness, and flavor (USDA – FSIS, 2014; USDA – AMS, 2017). Yield grading is the evaluation of a carcass to estimate the percentage of closely trimmed retail cuts (USDA – FSIS, 2014; USDA – AMS, 2017).

The U.S. standards for beef was first documented in 1916 (USDA – AMS, 2017). They were then used as a national service to uniformly identify carcasses in 1917 (USDA – AMS, 2017). Although the main purpose for the grading standards was for meat marketing, the practical use became apparent when selecting beef for the United States in World War I (USDA – AMS, 2017). In 1927, voluntary beef grading and stamping began (USDA – AMS, 2017). In July 1939, the standards were amended to provide a uniform standard for young beef and cows (USDA – AMS, 2017). The amendment changed Medium, Common, and Low cutter to Commercial, Utility, and Canner (USDA – AMS, 2017). In 1941, an amendment identified the quality grades as Prime, Choice, Good, Commercial, Utility, Cutter and Canner (USDA – AMS, 2017). In 1950, Prime and Choice were combined to form Prime; Good became Choice, and Commercial was divided into Good for the top half and Commercial for the lower half (USDA – AMS, 2017). In 1956, Commercial was divided into Standard and Commercial by maturity

(USDA – AMS, 2017). In 1965, it became required to rib an animal between the 12th and 13th rib for it to be graded (USDA – AMS, 2017). Yield grading also began in 1965 (USDA – AMS, 2017). In 1987, USDA Good was renamed to USDA Select (USDA – AMS, 2017). In 2017, maturity standards were changed to allow dentition or proof of age to be used to determine maturity (USDA – AMS, 2017).

2.4.1 Quality grading

Once confirmation was eliminated from quality grading in 1975, two factors have been used to classify beef carcasses for quality: maturity and marbling (USDA – AMS, 2017). To determine the quality grade, a carcass must be divided into two sides down the spine and ribbed between the 12th and 13th rib revealing a smooth cut surface (USDA – AMS, 2017).

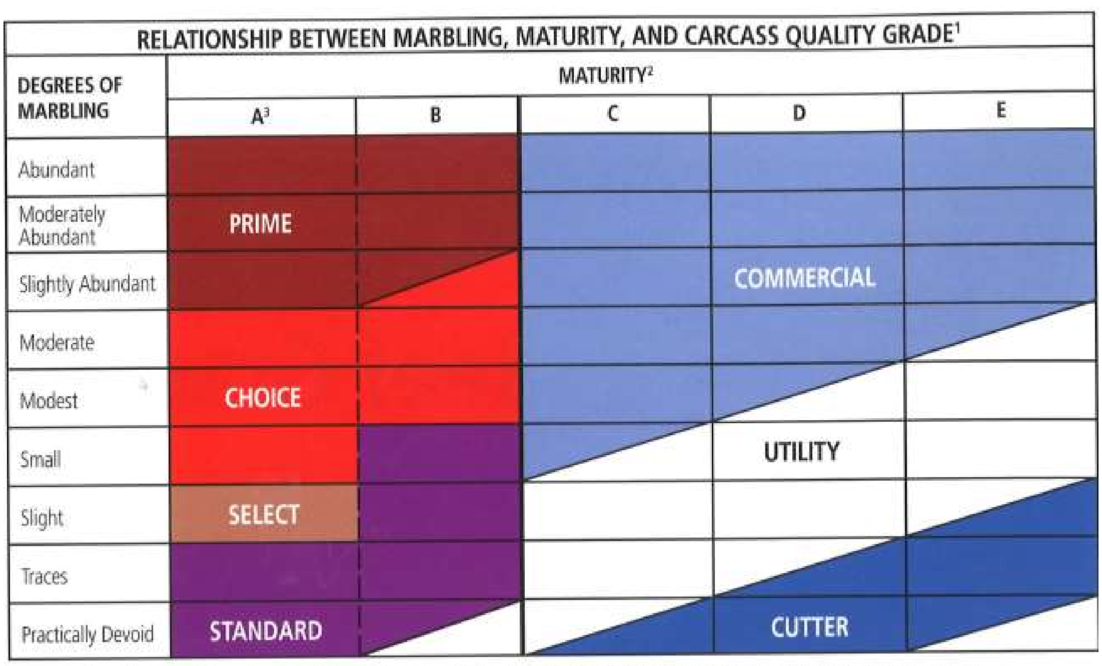
Maturity is classified into 5 categories: A, B, C, D, and E (USDA – AMS, 2017). Maturity standards A and B are considered as young animals and qualify for the young beef grades Prime, Choice, Select, and Standard (USDA – AMS, 2017). Maturity standards C, D, and E are considered for old animals and qualify for the old beef grades Commercial, Utility, Cutter and Canner (USDA – AMS, 2017). Maturity can be determined using 3 different methods: the traditional method (skeletal ossification with lean color), dentition combined with skeletal ossification and lean color, and documentation combined with skeletal ossification and lean color (USDA – AMS, 2017).

The traditional method asses skeletal ossification of the the sacral vertebrae, lumbar vertebrae, and thoracic vertebrae in combination with lean maturity which is an evaluation of muscle color (AMSA, 2001). An A-maturity carcass may have separation between sacral vertebrae, little to almost all ossification of the lumbar vertebrae, and little to no ossification of the thoracic vertebrae with a light grayish red lean color (AMSA, 2001). A B-maturity carcass has sacral vertebrae completely fused, almost complete ossification of the lumbar vertebrae, and some to partially ossified thoracic vertebrae with a light red to slightly dark red lean color (AMSA, 2001). A C-maturity carcass exhibits fused sacral vertebrae, completely ossified lumbar vertebrae, and partially ossification of thoracic vertebrae with slightly dark red to moderately dark red lean color (AMSA, 2001) A D-maturity carcass exhibits fused sacral vertebrae, completely ossified lumbar vertebrae, and mostly ossified thoracic leaving cartilage outlines visible on the thoracic vertebrae buttons with moderately dark red to dark red lean color (AMSA, 2001). An E-maturity carcass shows complete ossification in the sacral, lumbar and thoracic vertebrae with a dark red to very dark red lean color (AMSA, 2001).

Dentition is monitored by the Food Safety Inspection Service (USDA – AMS, 2017). All animals that are at or above 30 months of age must be marked with purple ink along the spinal column (USDA – AMS, 2017). As long as the animal is less than 30 months of age and does not exhibit D or E skeletal maturity, the animal will be considered A-maturity (USDA – AMS, 2017).

Documentation can also be used to assign maturity classifications to animals (USDA – AMS, 2017). The age has to be documented and verified through a USDA approved program (USDA – AMS, 2017). Similar to dentition, as long as the animal is less than 30 months of age and does not exhibit D or E skeletal maturity, the animal will be considered A-maturity (USDA – AMS, 2017).

After the animal has been classified as young or old, marbling is evaluated to determine the quality grade. There are 9 marbling classifications with each classification having 0 to 99 degrees. From most marbling to least, the classifications are: abundant, moderately abundant, slightly abundant, moderate, modest, small, slight, traces and practically devoid (USDA – AMS, 2017). Prime is from young beef that meets the marbling requirements for abundant, moderately abundant, and slightly abundant (USDA – AMS, 2017). Choice is from young beef that meets the marbling requirements for moderate, modest and small (USDA – AMS, 2017). Select is from A-maturity beef that meets the marbling requirements for slight (USDA – AMS, 2017). Standard is from young beef that has the lowest degrees of marbling: traces and practically devoid (USDA – AMS, 2017). The old cow grades involve combining maturity score and the degrees of marbling to meet Commercial, Utility, Cutter and Canner standards (USDA – AMS, 2017). The following figure taken from the AMSA meat evaluation handbook (2001) can be used to determine carcass quality grade given specific marbling and maturity scores.



[1]Assumes that firmness of lean is completely developed with the degree of marbling and that the carcass is not a "dark cutter."
[2]Maturity increases from the left to right (A through E).
[3]The A maturity portion of the figure is the only portion applicable to bullock carcasses.

Source: AMSA. 2001. Meat evaluation handbook. 1st ed. American Meat Science Association, Savoy, IL.

2.4.2 Yield grading

Beef yield grading uses subcutaneous fat, percentage of kidney, pelvic and heart fat (KPH), ribeye muscle cross-section area, and hot carcass weight (HCW) (USDA – AMS, 2017). The beef yield grade equation is "=2.50+ (2.50 x adjusted fat thickness, inches) + (0.20 x KPH) + (0.0038 x HCW, pounds) – (0.32 x ribeye area, square inches)" (USDA – AMS, 2017). Subcutaneous fat is measured perpendicular to the outside cut surface of the ribeye (USDA – AMS, 2017). The measurement can be adjusted if subcutaneous fat is greater or lesser over other major primals from the rib (USDA – AMS, 2017). The fat subjectively measured in KPH is recorded as a percentage of hot carcass weight (USDA – AMS, 2017). The area of the ribeye can be determined subjectively or with a ribeye grid (USDA – AMS, 2017).

A Yield Grade 1 carcass will have a thin layer of fat over the outside surface with muscle being visible throughout the carcass (USDA – AMS, 2017). A Yield Grade 2 carcass will have fat over a majority of the carcass with lean visible over the round shoulders and neck (USDA – AMS, 2017). A Yield Grade 3 carcass will exhibit fat throughout the carcass with lean only being exposed over the neck and parts of the round (USDA – AMS, 2017). A Yield Grade 4 carcass will be completely covered with fat with little lean showing (USDA – AMS, 2017). A Yield Grade 5 carcass will have more fat than a Yield Grade 4 or with less muscle (USDA – AMS, 2017).

2.4.3 Cow grading expectations

Cull cows are usually not ribbed at beef processors as they are more used for ground beef (Hilton et al., 1996). Cull cows are all generally expected to be classified as old beef and the need for quality grading is not necessary. Harris et al. (2017) observed in the 2016 NBQA that dairy cows averaged an overall maturity of C^{80},which is considered quite young. Harris et al. (2017) did not report how many cows were in each classification, which could have been useful to determine if some of the cull cows could qualify for young beef. When comparing to previous NBQA, dairy cull cows are getting younger, which suggest higher turnover rates (Harris et al., 2017[a]). Harris et al. (2017[a]) reported that cull dairy cows averaged a marbling score of Slight^{80}.

Because of dairy cull cows high energy output for milk production, subcutaneous fat is observed in lesser amounts compared to female beef type animals (Harris et al., 2017). Harris et al. (2017) observed the following average yield grade carcass characteristics in the 2016 NBQA: 0.4 cm of subcutaneous fat opposite the ribeye, 303.4 kg hot carcass weight, 78.8 cm^2 ribeye area, and 1.8% kidney, pelvic, and heart fat. The final yield grade for dairy cull cows was 2.8 in the 2016 NBQA (Harris et al., 2017).

2.5 Utilization and value of cull cows

As previously mentioned; cull cows generally are not ribbed and classified based on carcass conformation and subcutaneous fat levels (Hilton et al., 1996; Gill, 1998). To increase a cull cows value, feeding her a high energy diet before slaughter can be beneficial (Schnell et al., 1997; Gill, 1998; Stelzleni et al., 2007; Allen et al., 2009). Schnell et al. (1997) observed that as days on a high energy concentrate diet increased, fat became whiter, live weight increased, hot carcass weight increased, average daily gain increased, yield grade increased, and steak tenderness increased for 56 days on feed versus no days on feed. Stelzeni et al. (2007) observed cull cows fed a high energy diet before slaughter showed greater carcass and muscle quality. Allen et al. (2009) observed ractopamine hydrochloride had no effect on cull dairy cows but feeding a high concentrate diet 90 days before slaughter improved carcass quality, value and sensory characteristics. Cull cows are typically categorized into one of five grades: Canner, Cutter, Boning Utility, Breaking Utility, and Commercial (Gill, 1998).

2.5.1 Canner

A Canner graded animal will have the lowest market value and dressing percentage ranging from 40% to 46% (Gill, 1998). A Canner will have the highest percentage of lean content in the trimmings ranging from 90% to 92% (Gill, 1998). A Canner grade animal can be identified live as an animal ranging between a 1 and 3 beef BCS (Body Condition Score) score (Gill, 1998).

2.5.2 Cutter

The second lowest value cull cow grade is Cutter (Gill, 1998). The dressing percentage for a Cutter graded cow will range between 45% to 49% (Gill, 1998).The lean trimming percentage for Cutter cows will be slightly less than Canner ranging from 88% to 90% Gill, 1998). A Cutter cow can be identified live with a beef BCS score ranging from 4 to 5 (Gill, 1998).

2.5.3 Boning Utility

The Boning Utility grade is the third highest value grade (Gill, 1998). Due to the greater quality of muscles versus cutter and canner, the tenderloin, rib, and loin are kept (Gill, 1998). A Boning Utility carcass will dress between 50% and 52% (Gill, 1998). The lean content of trimmings will range between 78% to 83% (Gill, 1998). It can be hard to identify boning utility animals via BCS scoring as Boning Utility animals, Breaking Utility animals, and Commercial graded animals share similar BCS scores (Gill, 1998).

2.5.4 Breaking Utility

Breaking Utility graded animals are tied for the highest value cull cows with Commercial graded cows (Gill, 1998). Breaking Utility animals have more intramuscular fat than any lesser grades (Gill, 1998). The middle meats will be pulled on these and sold as boneless cuts rather than lean trim (Gill, 1998). It is close to impossible to identify the animals before slaughter (Gill, 1998).

2.5.5 Commercial

Commercial cows are generally the youngest animals in old beef (Gill, 1998; USDA – AMS, 2017) The primal cuts are pulled from commercial carcasses to sell to restaurants wanting a discounted price from young beef (Gill, 1998).

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Chapter 3

Comparison of carcass characteristics between cull Holstein and Jersey cows

3.1. Abstract

The objective of this study was to compare post-mortem characteristics of Holstein (HOL; n=734) and Jersey cull cows (JER; n=1,234). Cull cows were evaluated after immobilization/exsanguination for dairy body condition score, hock score, tongue and head condemnations, permanent incisor count, bruising, liver abnormalities, lung abnormalities, viscera condemnation, rail out trim weight, USDA condemnation reason, hot carcass weight, 12th rib subcutaneous fat depth, longissimus muscle area, calculated yield grade, marbling score, lean maturity, skeletal maturity, and quality grade. Interval scale variables were non-normal and did not become normal with log, square or square root transformations. Thus, each interval scale variable was analyzed using both mixed and non-parametric models and the most conservative *P*-value was used. Ordinal and nominal data were analyzed using Mann-Whitney U and Glimmix tests respectively. No difference ($P \geq 0.13$) was observed for rates of tongue (6.73%), head (5.43%), or viscera (20.81%) condemnations between dairy breeds. Liver (55.06% vs 45.09%) and lung (82.12% vs 71.34%) abnormalities occurred at a greater ($P \leq 0.04$) frequency in HOL than JER, respectively. Holstein cows tended to have a greater ($P = 0.08$) body condition score (3 or greater; 21.4% vs 7.6%), more ($P = 0.09$) 12th rib subcutaneous fat (0.27 vs 0.21 cm), and lesser cutability ($P < 0.01$) yield grades (3.13 vs 2.44) than JER. Holstein cows exhibited more ($P \leq 0.04$) permanent incisors (7.1 vs 5.6), larger longissimus

muscle area (47.0 vs 44.1 cm^2), heavier hot carcass weights (285.2 vs 193.7 kg), and more advanced skeletal maturity (D^{74} vs D^{33}) than JER. Jersey cows exhibited darker (P < 0.01) lean color than HOL. Holstein cows had a greater (P < 0.01; 73% vs 60%) frequency of ideal hocks than JER. Final quality grades differed ($P \leq 0.02$; USDA Standard or better 30.38% JER vs 23.15% HOL) because JER cow carcasses were younger than HOL. The sirloin was the primary location for bruises. Contamination on carcasses was the primary reason for further trim. Septicemia was the most frequent reason for USDA condemnation.

3.2. Introduction

Culling dairy cows is necessary to improve production efficiency, reduce diseases, and ensure humane endings for the animals. Dairy cull cows are an important part of the beef production stream, accounting for 9.6% of the daily harvest (USDA, 2018). Reasons for culling include low production, mastitis, lameness, reproduction, respiratory, udder confirmation, digestive disorders and transition diseases (Bascom and Young, 1998; Hadley et al., 2006). Holstein cows make up 92 to 94% of the dairy cow population whereas Jerseys make up 6 to 7% (CDCB, 2017; HOL ASSOC, 2017). Liver abnormalities for cull cows ranged from 44 to 64 % with abscesses being the most common liver abnormality (Rezac et al., 2014; Harris et al., 2017). Pneumonia lesions were visually observed in 23.8% to 33.8% of dairy cull cows (Rezac et al., 2014; Harris et al., 2017). Cull cows are not ribbed at beef processors and generally classified on body conformation to estimate lean trimmings for ground products (Hilton et al., 1996; Gill, 1998). Limited research has been reported comparing gross carcass pathology, yield and quality outcomes between the two primary dairy breeds. The objective of this study was to compare post-mortem characteristics of Holstein (HOL) and Jersey (JER) cows.

3.3. Materials and methods

Institutional Animal Care and Use Committee approval was not acquired for this study because live animals were not involved. Data collection began immediately post-mortem. Dairy cull cows (n = 1,234 JER; n = 734 HOL) were harvested in the southern high plains region over a 13 week period. The animals originated from the Texas Panhandle and Eastern New Mexico. A trained team of undergraduate and graduate students from West Texas A&M University collected data at each station. Data collectors observing subjective variables remained consistent throughout the study.

The animals were received by the beef processor and the USDA veterinarian conducted ante-mortem inspection. After immobilization and exsanguination, an individual carcass tag was assigned to the animal and correlated with an ear tag number to track the animal through the harvest and grade floors. The carcasses were evaluated for dairy body condition score, hock score, tongue, head, and viscera condemnations, permanent incisor count, liver and lung abnormalities, hot carcass weight, 12th rib subcutaneous fat depth, longissimus muscle area, calculated yield grade, marbling score, lean maturity, skeletal maturity, and calculated maturity

3.3.1 Hide-on evaluation

Animals were evaluated for dairy body condition score (BCS) after exsanguination prior to any hide being removed. A single evaluator used the Elanco Body Condition Scoring in Dairy Cattle (1996) to assess dairy BCS (Fig 3.1). The Dairy BCS system used was based on a 5-point scale in 0.25 increments with 1 being emaciated and 5 being obese (Wildman et al., 1982; Ferguson et al., 1994; Elanco, 1996).

Animals were evaluated for hock score after exsanguination prior to any hide being removed. A single evaluator used the Hock Assessment Chart for Cattle from Cornell Cooperative Extension (Fig 2). The system is a 3 score system which evaluates hock swelling and hair coat. The scores are defined as 1 = no swelling or hair missing, 2 = no swelling and bald area on hock, and 3 = swelling is evident or there is a lesion through the hide.

3.3.2 Head chain evaluation

Head and tongue condemnations as well as permanent incisor count were recorded after USDA inspection on the head chain. Head and tongue were passed or stamped condemned by the online USDA inspector and was recorded. Permanent incisor count was recorded as describe by Lawrence et al. (Fig 3.3).

3.3.3 Carcass bruising

Bruising was recorded after head removal and before any trimming of the carcass had occurred. Bruising location was recorded by primal and an estimated diameter of the bruise was recorded.

3.3.4 Gut table evaluation

The livers were evaluated on the gut table after evisceration and USDA inspection. A liver scoring system was used as published by Brown and Lawrence (2010). Edible livers had no abnormalities and marked as normal. Abscessed livers were broken down into 6 categories with A- = 1 or 2 small abscesses, A = 1 or 2 large abscesses or multiple small abscesses, A+ = multiple large abscesses, A+ adhesion =

abscessed liver adhered to the diaphragm, A+ open = open abscess, and A+ adhesion / A+ open = open abscess on an adhered liver. Telangiectasis, liver flukes, cirrhosis, carotenitis, and sawdust were other abnormalities identified.

The lungs were evaluated and palpated at the gut table after evisceration and USDA inspection. The lung lesion scoring system used was similar to that published by Tennant et al. (2014). A normal lung had no abnormality. Lung consolidation: 1 = 5% to 15%, 2 = 15% to 50%, and 3 = >50%. Fibrin tags between lung lobes were assigned a score based on severity: minor = a few threadlike fibrin tags that are easy to break and separate lobes during palpation, and major = many thick fibrin tags that are challenging to break and separate lobes during palpation. Lungs that remained inflated after evisceration were recorded.

Pluck, viscera, and kidney condemnation frequency as well as pregnancy was recorded at the gut table after evisceration and USDA inspection.

3.3.5 Rail out bay and veterinarian rail

Carcasses that were railed out for further trim were identified and cause for further trim was recorded. Lean, fat, and bone trimmed of the carcass was weighed and recorded.

Animals that were condemned by the USDA veterinarian were recorded. A reason for condemnation was recorded from the USDA veterinarian.

3.3.6 Cooler floor assessment

USDA quality (marbling and physiological maturity) and yield grade (12th rib back fat depth, hot carcass weight, and ribeye area) attributes were collected in the cooler after the carcasses had chilled for 20 hours (USDA – AMS, 2017). Kidney, pelvic, and heart fat (KPH) was removed on the harvest floor; therefore, the average KPH (2.0%) reported by Lowe (2007) was used for cull dairy cattle.

3.3.7 Statistical Analysis

Interval scale variables were non-normal and did not become normal with log, square or square root transformations. Thus, each interval scale variable was analyzed using both Mixed and non-parametric models and the most conservative *P*-value is reported. Ordinal and nominal data were analyzed using Mann-Whitney U and Glimmix tests respectively. Dairy of origin and harvest date were used as random effects.

3.4. Results and discussion

3.4.1 Hide-on evaluation

Holstein cows had a greater ($P < 0.01$; 21.5%) frequency of body condition scores ≥ 3.0 than Jersey cows (7.6%) while Jersey cows had a greater ($P < 0.01$; 35.6%) frequency of body condition scores ≤ 2.5 compared to Holstein cows (22.5%). Heins et al. (2008) observed HOL and JER crosses had a greater BCS than purebred Holstein which is in contrast to our observations. The animal's physiological state can play a huge role in body condition score. Animals 70 days in milk will have a different body condition score than cows 400 days in milk. The Holsteins may have been culled in an anabolic physiological state as opposed to the Jerseys in catabolic state. Body condition score is affected by many things and this sample of the cull cow population may not represent the full population. More research needs to be done to compare Holstein and Jersey cows at different physiological states for body condition score.

Holstein cows had a greater ($P < 0.01$; 73.6%) percentage of normal hocks compared to JER cows (61.5%) (Table 3.1). Jersey cows had a greater ($P < 0.01$; 37.2%)

number 2 hock score then HOL (24.2%). The difference in hocks scores is likely due to more of the sample Jersey dairies using free stall barns rather than open lot dairies as compared to Holsteins. Adams et al. (2016) observed that cows on an open lot dairy had a greater frequency of normal hock scores than cows kept in a free stall barn.

3.4.2 Head and tongue observations

No difference ($P \geq 0.18$) was detected for percentage edible head and tongue between the two breeds (Table 3.2). The percentage for head and tongue edibility was similar to those in the 2016 NBQA (Harris et al., 2017).

Jersey cows were notably younger ($P < 0.01$) as determined by dentition then HOL cows. Of the JER cows collected, 21.3 % were less than 30 months of age as compared to only 7.0% of HOL cows (Table 3.2). With the new USDA maturity standards (established December 2017), animals under the age of 30 moths are allowed to be considered for young beef grades as long as the average of their lean and skeletal maturity is not greater than a C^{100} (USDA – AMS, 2017). Cull cows under 30 months of age are eligible for marketing opportunities as young beef compared to the traditional method of classifying by confirmation and fat cover. Cows culled from a dairy that keeps good records could market their cull cows as age and source verified.

3.4.3 Gut table evaluation

Holstein cows (45.3%) had fewer ($P < 0.01$) edible livers as compared to JER (55.2%) (Table 3.3) which was similar to those reported by Rezac et al. (2014) and Harris et al. (2017), 44.9% and 54.4% respectively. Holstein cows (32.1%) had a greater ($P < 0.01$) liver abscess rate than JER (21.1%). Different management practices between the source dairies could be the cause of the greater liver scores in HOL as compared to JER.

Harris et al. (2017) reported 20.7% liver abscess rate which was similar to our JER liver abscess rate. Rezac et al. (2014) reported a liver abscess rate of 32.3% rate which was similar to our HOL abscess rate. For individual liver abscess scores, no difference ($P \geq$ 0.28) was observed between the two breeds for A- and A+open. Holsteins tended (P = 0.06; P = 0.08) to exhibit a greater frequency of A and A+adhesion / A+open scores than JER. Jerseys had lesser ($P \leq 0.02$) frequencies for A+ and A+adhesion scores than HOL. A reason for the Holstein cows to have more frequent large abscesses than Jerseys could not be identified.

Holstein (22.7%) and JER (23.7%) had similar (P = 0.25) non-abscess liver abnormality frequencies. No difference ($P \geq 0.90$) was observed for sawdust and telangiectasis between the two breeds. Jersey cows had a greater ($P \leq 0.03$) percentage of carotenitis and contaminated livers than HOL. Contaminated livers are generally cause by personnel at the harvest facility during evisceration, so the difference could be due to the larger visceral cavity of HOL allowed more working space during evisceration to prevent contamination than in JER. Tian et al. (2009) observed that cattle, like JER, missing the β, β-carotene-9', 10'dioxygenase gene would present yellower fat than cows without it; thus, the greater frequency of carotenitis could be caused by JER inability to metabolize β-carotene in the liver. Holsteins had a greater (P ≤ 0.03) frequency of cirrhosis and liver flukes than JER. Holsteins notably had a greater percentage of liver flukes than JER. Flukes are generally contracted from forage or water sources that were grown in a humid environment. With more background data of the Holstein cows, we possibly could have identified the reason for the greater liver fluke frequency in Holsteins. We cannot identify a reason for why Holstein cows had a greater percentage of Cirrhosis livers than Jerseys.

Jersey cows (29.8%) had a greater ($P < 0.01$) percentage of normal lungs compared to HOL (17.9%) (Table 3.3). Holstein cows (48.0%) had a greater ($P = 0.01$) percentage of lungs with consolidation than JER (40.1%). No difference ($P \geq 0.15$) was observed for consolidation scores 1 and 2 between the two breeds; however, HOL had a greater ($P = 0.03$) percentage of consolidation score 3 lungs than JER. There is no explanation for the difference in consolidation score lung 3 between breeds other than HOL cows were older and had more days to contract a severe bovine respiratory disease. Rezac et al. (2014) observed 35% of lungs surveyed in the Great Lakes Region had lung consolidation. Holsteins had a greater ($P < 0.01$) percentage of lungs with fibrin tags than JER due to a greater ($P < 0.01$) frequency of minor fibrin tags; however, no difference ($P = 0.11$) was observed for extensive fibrin tags. Holsteins had a greater ($P < 0.01$) frequency of inflated lungs as compared to JER. As animals get older, inflated lung frequency increases (non-tabular data; permanent incisor count of inflated lungs vs deflated lungs; 7.25 vs 6.18 respectively), thus the HOL cows being older at harvest could explain the difference in inflated lungs.

No difference ($P \geq 0.13$) was observed between the two breeds for pregnancy rate (HOL, 23.6%; JER, 26.4%) kidney condemnation (HOL, 29.7%; JER, 26.6%), pluck condemnation (HOL, 21.9%; JER, 21.7%), and gastrointestinal tract condemnation (HOL, 21.5%; JER, 22.3%) (Table 3.3). The pregnancy rate we observed is greater than the 17.4% reported by Harris et al. (2017). Harris et al. (2017) observed 10.5% kidney condemnation for all cull animals which is lower than what we observed. The most common reasons for kidneys to get condemned are from infection lesions or cyst on the kidney. Harris et al. (2017) did report similar condemned rates for the pluck (22.3%) and gastrointestinal tract (20.0%).

3.4.4 Carcass Grading attributes

Jersey cows had a greater ($P < 0.01$) cutability than HOL (Table 3.4). Holstein cows (0.3 cm) tended ($P = 0.08$) to have more subcutaneous fat than JER (0.2 cm). Holstein cows (47.1 cm^2) had a larger ($P < 0.01$) longissimus muscle area than JER (44.0 cm^2). Jersey cows (193.7 kg) had a lighter ($P < 0.01$) hot carcass weight than HOL (285.2 kg). Jersey cows (2.4) had a lesser ($P < 0.01$) final yield grade than HOL (3.1). Smith and Baldwin (1973) observed that HOL cows had a greater hot carcass weight than JER. Harris et al. (2017) reported 2.8 for the average final yield grade, 0.4 cm of subcutaneous fat, 303.4 kg of hot carcass weight, and 64.6 cm^2 longissimus muscle area which compared to our data we observed a smaller longissimus muscle area, less subcutaneous fat, and lighter hot carcass weights. Though HOL had a larger ribeye than JER, their heavier hot carcass weight caused their yield grade to be greater than the JER.

No difference ($P = 0.55$) was observed between JER and HOL for marbling score (Table 3.4). Jersey cows exhibited younger ($P = 0.04$) skeletal maturity than HOL (D^{33} vs D^{74}); however, lean maturity and overall maturity were not different ($P \geq 0.14$) between the two breeds. Jersey cows (30.38%) had a greater ($P < 0.01$) percentage of standard or better than HOL (23.15%). With the new use of dentition as a maturity indicator, the younger JER qualified for young beef at a greater frequency than the older HOL. It is notable that a majority of the animals that qualified for young beef fall in the lowest valued young beef quality grade (USDA Standard). However, feeding of high concentrated diets for 50 to 90 days has been observed to increase marbling scores

(Stelzleni et al., 2007; Allen et al., 2009). If a beef processor had the opportunity to market young cull cows, it could become economically feasible to feed high concentrate diets to animals with 2 permanent incisors or less.

3.4.5 Carcass bruising

The most frequent location for bruising for both HOL (58.4%) and JER (43.9%) cows was the sirloin (Table 3.5). For HOL, bruising of the ribs (33.0%) was the second most bruised primal followed by the round (22.8%), chuck (17.0%), loin (6.9%), neck (2.1%), brisket (1.9%), and flank (1.6%). For JER, bruising of the ribs (25.1%) was the second most bruised primal followed by the chuck (17.1%) round (11.4%), loin (4.7%), neck (1.2%), brisket (0.5%), and flank (0.5%). Bruising on the ribs was numerically one of the largest of the primals for both breeds. Similarly, Rezac et al. (2014) reported that 54.1% of cull cow carcasses had a bruise with the primary location for a bruise being the hip. Jersey cows numerically had a lesser frequency of bruising as well as smaller diameter of bruises.

3.4.6. Rail out bay

For both HOL and JER, the primary reason to be railed out was contamination (4.4%; 3.2%) followed by USDA vet retained (2.7%; 3.2%), bruise (1.2%; 1.7%), miss-split carcass (0.8%; 1.0%), and abscess (0.3%; 0.2%) (Table 3.6). For JER, carcasses railed out for abscesses (36.9 kg) had the largest trim loss followed by miss-split (23.0 kg), bruise (19.0 kg), USDA vet rail retained and passed (15.7 kg), and contamination (10.1 kg). For HOL, carcasses railed out for bruises (28.8 kg), USDA vet rail retained and passed (23.9 kg), abscess (19.6 kg), contamination (16.6 kg), and miss-split carcasses (6.4 kg).

3.4.7 USDA condemned

Jersey cattle had a numerically larger (2.3%) condemned frequency than HOL (1.6%)(Table 3.7). The major reasons for condemnation for JER were septicemia and peritonitis. For HOL, the major reasons for condemnation were septicemia and lymphoma. Rezac et al. (2014) reported lymphoma and septicemia were the primary reason for condemnation of cull cows in the great lakes region.

3.5. Conclusions

For the sample population, JER were younger compared to HOL. Being younger, the Jersey cows had a greater chance of qualifying for young beef quality grades than HOL. Jersey cull cows had fewer abnormalities when observing the livers and lungs as compared to HOL. This could also be due to age as HOL had more days of age to contract an illness or other abnormality than JER. Jersey cull cows were greater cutability primarily due to smaller hot carcass weights than HOL.

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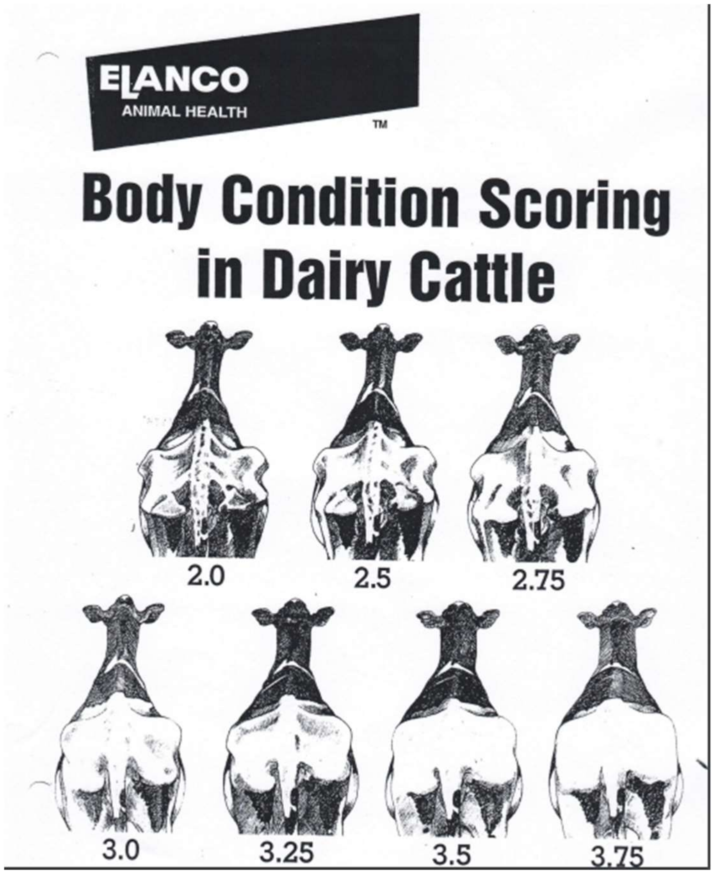

Figure 3.1 Elanco body condition scoring in dairy cattle
Source: Elanco Animal Health. 1996. Body condition scoring in dairy cattle. Elanco Animal Health Bulletin. AI 8478. Elanco Animal Health, Greenfield, IN.

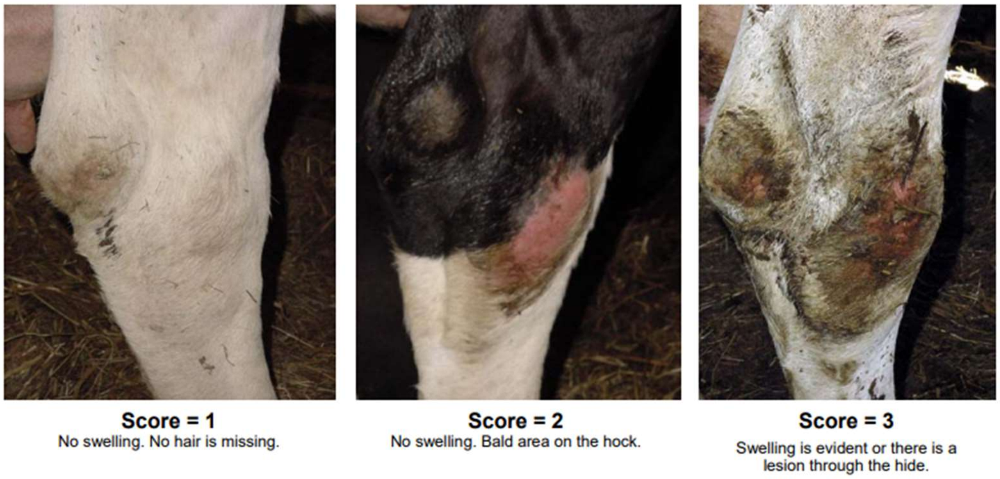

Figure 3.2 Hock Score assessment
Source: Cornell Cooperative Extension. 2004. Hock assessment chart for cattle. Accessed: Aug. 20, 2016. https://ahdc.vet.cornell.edu/programs/NYSCHAP/docs/HockScoringChart-NYSCHAP-4-04.pdf.

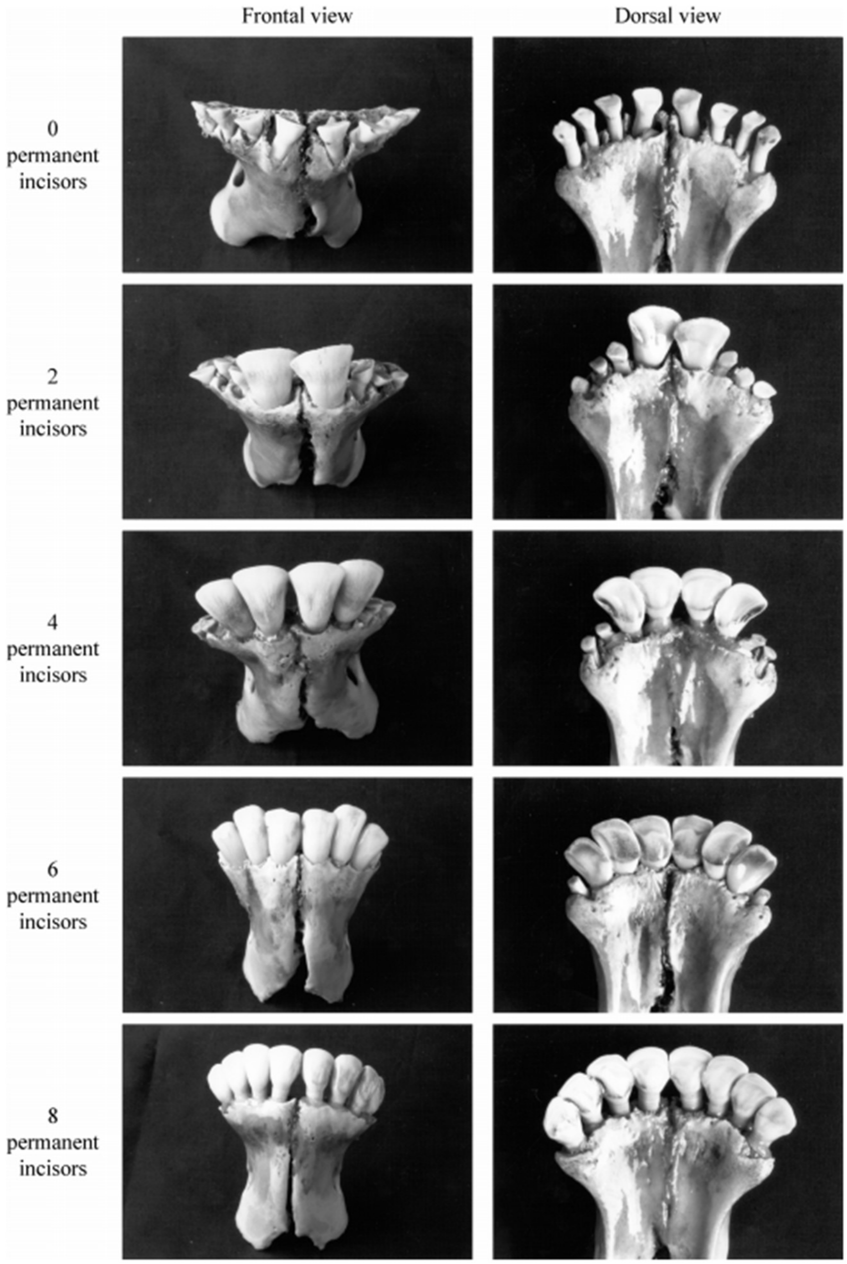

Figure 3.3 Permanent incisor count

Lawrence et al. (2001)

Table 3.1 Comparison of hide-on animal characteristics between cull Holstein and Jersey cows

Hide on attributes	Holstein	Jersey	*P* - value
n	734	1,234	
Body condition score[1],%			
≤ 2.5	22.5	35.6	<0.01
2.75	56.0	56.8	0.46
≥ 3.0	21.5	7.6	<0.01
Hock Score[2], %			
1	73.6	61.5	<0.01
2	24.2	37.2	<0.01
3	2.2	1.3	0.41

[1] Cows were scored on a 5 point scale with 1 being emaciated and 5 being obese and score given in 0.25 increments

[2]Hock score: 1 = no swelling or hair missing, 2 = no swelling and bald area on hock, and 3 = swelling is evident or there is a lesion through the hide

Table 3.2 Comparison of head and tongue characteristics between cull Holstein and Jersey cows

	Holstein	Jersey	*P* - value
n	734	1,234	
Edible heads, %	95.5	94.0	0.18
Edible tongues, %	93.0	93.4	0.74
Permanent Incisor Count[1]			
0-2	7.0	21.3	<0.01
3-6	14.2	30.2	<0.01
7-8	78.8	48.5	<0.01

[1]<30 month animals had less than 3 permanent incisors

Table 3.3 Comparison of viscera abnormalities between cull Holstein and Jersey cows

	Holstein	Jersey	*P* - value
n	734	1234	
Liver evaluation			
Abscess, %	32.1	21.1	<0.01
A-	8.8	7.3	0.28
A	6.0	3.9	0.06
A+	6.1	2.9	<0.01
A+Adhesion	8.0	4.9	0.02
A+Open	1.3	1.3	0.92
A+Adhesion / A + Open	1.8	0.8	0.08
Condemned other than abscess,%	22.7	23.7	0.25
Carotenitis	3.0	7.9	<0.01
Cirrhosis	2.1	0.7	0.03
Contamination	4.1	6.9	0.03
Flukes	11.1	5.7	<0.01
Sawdust	0.2	0.2	0.99
Telangiectasis	2.2	2.3	0.90
Edible, %	45.3	55.2	<0.01
Lung evaluation			
Normal,%	18.0	29.8	<0.01
Consolidated,%			
Normal	52.0	59.6	0.01
1	24.1	23.3	0.72
2	12.2	9.3	0.15
3	8.8	5.7	0.03
Fibrin tags,%			
Normal	67.7	77.1	<0.01
Minor	20.2	13.5	<0.01
Extensive	12.2	9.3	0.11
Inflated lungs,%	30.5	20.9	<0.01
Pregnant,%	23.6	26.4	0.17
Kidney condemnation,%	29.7	26.6	0.13
Pluck condemnation,%	21.9	21.7	0.91
Gastrointestinal tract condemnation,%	21.5	22.3	0.51

Table 3.4 Comparison of USDA quality and yield characteristics between cull Holstein and Jersey cows

Carcass attributes	Holstein	Jersey	SEM	*P* - value
n	734	1,234		
Yield				
Adjusted back fat thickness, cm	0.3	0.2	0.05	0.08
Longissimus muscle area, cm^2	47.1	44.0	1.04	<0.01
Hot carcass weight, kg	285.2	193.7	7.60	<0.01
Final yield grade	3.1	2.4	0.11	<0.01
Quality				
Marbling score	Traces^{71}	Traces^{63}		0.55
Lean maturity	C^{16}	C^{22}		0.46
Skeletal maturity	D^{74}	D^{33}		0.04
Overall maturity	C^{92}	C^{74}		0.14
USDA Standard or better, %	23.2	30.4		<0.01
USDA Standard	18.2	20.5		0.40
USDA Select	3.7	7.2		<0.01
USDA Choice	1.3	2.7		0.08

Table 3.5 Comparison of bruising frequency and diameter of primals between cull Holstein and Jersey cows

	Holstein		Jersey	
Location	Frequency, %	Diameter[1], cm	Frequency, %	Diameter[1], cm
Round	22.8	6.9	11.4	5.1
Sirloin	58.4	7.4	43.9	6.1
Flank	1.6	9.4	0.5	5.6
Loin	6.9	7.6	4.7	6.9
Rib	33.0	8.9	25.1	8.1
Chuck	17.0	6.6	17.1	5.6
Brisket	1.9	4.3	0.5	4.1
Neck	2.1	5.3	1.2	5.3

[1]Average diameter was taken only from cattle with the location bruise

Table 3.6 Comparison of rail out reason frequency and trim weight between cull Holstein and Jersey cows

	Holstein		Jersey	
Reason railed out	Frequency, %	Trim weight[1], kg	Frequency,%	Trim weight[1], kg
Abscess	0.3	19.6	0.2	36.9
Bruise	1.2	28.8	1.7	19.0
Contamination	4.4	16.6	3.2	10.1
Miss-split	0.8	6.4	1.0	23.0
USDA Vet Rail[2]	2.7	23.9	3.2	15.7
Not available	0.8	5.6	0.7	10.6

[1]Trim was only weighed on cattle that were railed out
[2]Trim was weighed on cattle that passed USDA veterinarian inspection but not cattle that were condemned

Table 3.7 Count of USDA condemned carcasses between Holstein and Jersey cows

USDA condemned reason	Holstein, count	Jersey, count
Cancer Eye	1	0
Emaciated	0	1
Fistula	0	1
Kiss test	1	1
Lymphoma	3	0
Mastitis	0	2
Peritonitis	0	5
Pericarditis	2	1
Pneumonia	0	3
Septicemia	4	12
Toxemia	1	1
Not available	0	1
Condemned, %	1.6	2.3

Chapter 4

The association of culling decisions, days in milk, and lactation number with harvest pathology and carcass grading characteristics of Jersey cows.

4.1. Abstract

The objective of this study was to associate culling patterns, days in milk (DIM), and lactation number with harvest pathology and carcass grading attributes of Jersey cull dairy cows. Jersey cull cows (n=874) sourced from the Texas panhandle were evaluated after immobilization/exsanguination for permanent incisor count, liver abnormalities, lung abnormalities, hot carcass weight, 12th rib subcutaneous fat depth, longissimus muscle area, calculated yield grade, marbling score, lean maturity, skeletal maturity, and calculated maturity score. Interval scale variables were non-normal and did not become normal with log, square or square root transformations. Thus, each interval scale variable was analyzed using both mixed and non-parametric models and the most conservative *P*-value was used. Ordinal and nominal data were analyzed using Mann-Whitney U and Glimmix tests respectively. Cows were culled for low production, mastitis, lameness, digestive disorders, reproductive issues, respiratory diseases, udder conformation, and temperament respectively. Non-abscess liver abnormalities differed ($P = 0.01$) among reasons culled with digestive disorders having the greatest frequency. Cows culled for respiratory diseases had 100% abnormal lung frequency. Of the cows culled for reproduction issues, 28.8% were pregnant at harvest. Cows culled for low production and reproduction had greater ($P < 0.01$) carcass muscle and fat components compared to cows

culled for different reasons. Nearly 29% of cows were culled before 101 days in milk. Cows culled in the transition period had a greater (*P* < 0.01) non-abscess liver abnormality frequency than any other period during lactation. After peak milk production, carcass component redeposition works inversely of a milk lactation curve. Nearly 60% of cows were culled in their first and second lactation. As the cows lactation number increased, inflated lung frequency increased (*P* < 0.01). Cows hot carcass weights increased (*P* < 0.01) linearly until their third lactation before plateauing off. The average cow in her first lactation would meet the requirements to receive a young beef grade.

4.2. Introduction

Dairy cull cows account for 9.6% of the total daily beef harvest in the United States (USDA-NASS, 2018). Culling dairy cows is necessary to improve herd production, manage contagious diseases, and warrant humane endings for the animals. Bascom and Young (1998) and Hadley at el. (2006) discussed culling patterns which included culling for low production, mastitis, lameness as well as other reasons. With on farm herd database systems like Dairycomp 305 (Valley Agriculture Software, Tulare, CA), birth date, days in milk (DIM), lactation number, animal event data, production and culling patterns are much easier surveyed. Published literature is lacking that associates culling patterns with harvest pathology; however, it was suggested by Rezac et al. (2014) to get a better understanding of different parameters and their effects on lung lesions and liver abscess frequency. Though it is commonly understood that after peak milk production nutrients are partitioned more towards the body instead of milk production, no research has been done to associate carcass fat and muscle with days in milk. The new

USDA maturity standards (established Dec 2017) would allow cull animals with a verified documented age or dentition identifying an animal as less than 30 months of age and less than D^{00} maturity to qualify for young beef grades (USDA – AMS, 2017). Historically, dairy cull cows had a skeletal maturity bias against them since they ossified more rapidly than male animals due to increased estrogen production (Lawrence et al., 2001). The objective of this study was to associate culling patterns, DIM, and lactation number with harvest pathology and carcass grading attributes of Jersey cull dairy cows.

4.3. Materials and methods

Institutional Animal Care and Use Committee approval was not acquired for this study because the animals used were going to be harvested regardless of data collection. Post-mortem data was collected first, immediately after exsanguination and then ear tag data was used to collect data from the dairy herd database.Cull Jersey cows (n=874) were harvested in the southern high plains region over a 13 week period. The animals originated from the Texas Panhandle. A trained team of undergraduate and graduate students from West Texas A&M University collected data at each station. Data collectors observing subjective variables remained consistent throughout the study.

The Jersey cows were received by the beef processor and passed ante-mortem inspection from the veterinarian. After immobilization and exsanguination, a carcass identification tag was given to the animal and correlated with the animal’s ear tag. The carcasses were evaluated for permanent incisor count, liver and lung abnormalities, hot carcass weight, 12th rib subcutaneous fat depth, longissimus muscle area, calculated yield grade, marbling score, and overall maturity. After all animals had been collected for post mortem characteristics, ear tag data were correlated with the dairy herd data for the last year.

4.3.1 Dentition

A permanent incisor (0-8) count was recorded post head removal and USDA inspection on the head chain (Fig 4.1).

4.3.2 Gut table evaluation

Livers were evaluated on the gut table after evisceration and USDA inspection. A liver scoring system was used as published by Brown and Lawrence (2010). Edible livers had no abnormalities and were marked as normal. Abscessed livers were broken down into 6 categories with A- = 1 or 2 small abscesses, A = 1 or 2 large abscesses or multiple small abscesses, A+ = multiple large abscesses, A+ adhesion = abscessed liver adhered to the diaphragm, A+ open = open abscess, and A+ adhesion / A+ open = open abscess on an adhered liver. Telangiectasis, liver flukes, cirrhosis, carotenitis, and sawdust were other abnormalities identified. Animals with a fetus were recorded by estimated trimester after the carcass was eviscerated.

Lungs were evaluated and palpated at the gut table after evisceration and USDA inspection. The lung lesion scoring system used was similar to that published by Tennant et al. (2014). A normal lung had no abnormality. Lung consolidation: 1 = 5% to 15%, 2 = 15% to 50%, and 3 = >50%. Fibrin tags between lung lobes were assigned a score based on severity: minor = a few threadlike fibrin tags that were easy to break and separate lobes during palpation, and major = many thick fibrin tags that were challenging to break and separate lobes during palpation. Lungs that remained inflated after evisceration were recorded.

4.3.3 Cooler floor assessment

USDA quality (marbling and physiological maturity) and yield grade (12th rib subcutaneous fat depth, hot carcass weight, and ribeye area) attributes were collected in the cooler after the carcasses had chilled for 20 hours (USDA – AMS, 2017). Kidney, pelvic, and heart fat (KPH) was removed on the harvest floor; therefore, the average KPH (2.0%) was used from Lowe (2007).

4.3.4 Dairy herd data

After all post mortem data had been collected, the corresponding ear tag data was matched from the dairy herd database. Reason for culling, DIM, and lactation number was the primary data used from the dairy herd database.

4.3.5 Statistical analysis

Interval scale variables were non-normal and did not become normal with log, square or square root transformations. Thus, each interval scale variable was analyzed using both Mixed and non-parametric models and the most conservative *P*-value is reported. Ordinal and nominal data were analyzed using Mann-Whitney U and Glimmix tests respectively. Dairy of origin and harvest date were used as random effects.

4.4. Results and discussion

4.4.1 Culling patterns

The primary two reasons for culling were low production (LPD; 31.6%) and mastitis (MA; 29.5%) (Table 4.1). Jersey cows were also culled for lameness, which includes injury (LI; 14.9%), digestive disorders (DIG; 12.5%), reproductive reasons (REP; 6.1%), respiratory (RES; 2.3%) and other reasons which including poor udder confirmation and kicking (OTH; 3.2%).

Cows culled for DIG (6.6) had a greater (*P* ≤ 0.04) permanent incisor count than cows culled for LPD (5.7), MA (5.3), or OTH (5.3). Cows culled for LI (6.0) and REP (6.4) were older (*P* ≤ 0.02) than cows culled for MA. No difference was observed between RES, REP, and MA for permanent incisor count. Cows that were culled for MA and OTH were statistically or numerically younger than cows culled for other reason. The younger animals culled for mastitis could signify that the source dairy producers were focusing on eliminating mastitis from their herd.

No difference (*P* ≥ 0.13) was observed for edible liver and abscessed liver frequency; however, cows culled for RES diseases did have a numerically greater abscess frequency which could be caused by the animal's immune system being weakened due to the animal already fighting an infection in the lungs and opportunistic pathogens inhibiting the liver. Non-abscess abnormality (NAA) livers were different (*P* = 0.01) for reason culled. Cows culled for DIG (40.0%) had a greater frequency of NAA than cows culled for MA (26.3%), REP (24.0%) and LPD (20.2%). Cows culled for LI (32.6%) had a greater (*P* = 0.01) frequency of NAA than cows culled for LPD. No difference (*P* ≥ 0.12) was observed between cows culled for DIG, LI, RES (25.0%) and OTH (25.0%) for NAA. No difference (*P* ≥ 0.11) was observed between cows culled for MA, RES, OTH, REP, and LPD for NAA. Similar to cows culled for RES issues having a high liver abscess frequency, a chronically stressed animal may be more susceptible to NAA due to a weakened immune system.

No difference (*P* ≥ 0.05) occurred for normal lung frequency, consolidated lung frequency, or fibrin tag frequency; however, it should be noted that cows culled for RES issues all had abnormal lungs and had a numerically greater frequency of consolidation and fibrin tags than cows culled for any other reason. Cows culled for RES diseases were a small part of the population and had they made up a larger part of the population, we may have observed statistically different frequencies instead of just numerically different. Cows culled with RES diseases (55%) had a greater ($P \leq 0.01$) percentage of inflated lungs (lungs did not deflate at slaughter) compared to cows culled for OTH (21.4%), MA (20.9%), DIG (18.9%), REP (14.3%), and LI (14.0%). Jersey cows culled for low LPD had a greater frequency of inflated lungs than cow culled for MA, DIG, REP, and LI. The cause for inflated lungs at slaughter has yet to be identified. With 55% of the cows culled for RES having inflated lungs, it can be hypothesized that respiratory diseases may have an influence on inflated lungs.

The frequency of carcasses with fetuses tended ($P = 0.06$) to be different between cows culled for different reasons. It should be noted that cows culled for REP were 28.8% pregnant at harvest. Producers may want to perform a secondary pregnancy check to confirm a cow is open before culling her for REP issues.

Jersey cows culled for LPD had a greater ($P < 0.01$) adjusted back fat thickness (ABFT; 0.3cm) than cows culled for DIG (0.2 cm), LI (0.2 cm), MA (0.2 cm), or RES (0.2 cm) reasons. Cows culled for REP (0.3 cm) had a greater ($P \leq 0.02$) ABFT than cows culled for DIG, LI, MA, and RES. No difference was observed between cows culled for LPD and REP. No difference was observed between cows culled for REP and OTH. No difference was observed between cows culled for DIG, LI, MA, RES, and OTH. Cows culled for LPD and REP physically are not putting their diet and body resources toward production or reproducing respectively and instead storing energy via fat cells subcutaneously.

Cows culled for LPD (46.8 cm^2) had larger ($P < 0.01$) longissimus muscle area (LMA) than cows culled for MA (43.6 cm^2), LI (42.4 cm^2), DIG (41.6 cm^2), OTH (41.1 cm^2), and RES (38.1 cm^2); however, cows culled for LPD had a similar LMA compared to cows culled for REP (45.7 cm^2). Cows culled for REP had a larger LMA than cows culled for LI, DIG, OTH, and RES; however, they were similar to cows culled for MA. Cows culled for MA exhibited a larger LMA than cows culled for RES issues; however, they were similar to cows culled for LI, DIG and OTH. No difference was observed for LMA between cows culled for DIG, OTH, and RES. Similar to ABFT, cows culled for LPD and REP are directing their resources more towards muscle growth than milk production and reproducing respectively.

Cows culled for LPD (208.7 kg) and REP (203.3 kg) had heavier ($P < 0.01$) hot carcass weights than those culled for LI (182.3 kg), MA (181.5 kg), RES (169.7 kg), and digest (164.4 kg); however, cows culled for LPD and REP were similar to cows culled for OTH (199.3 kg). Cows culled for OTH had a greater hot carcass weight than cows culled for DIG and REST. No difference was observed for hot carcass weights between cows culled for DIG and REST. Similar to ABFT and LMA, cows culled for production and reproduction are putting fat and muscle onto their carcass instead of using diet and body resources for milk production and reproduction. Cows culled for DIG and RES had significantly or numerically lighter hot carcass weights than the other reasons for culling due to the animal not likely being able to absorb nutrients from the diet or the body's resources are being used to fight infection respectively.

Cows culled for OTH (2.7 FYG) had a lesser ($P < 0.01$) cutability than cows culled for LI (2.4 FYG), MA (2.3 FYG), and DIG (2.3 FYG); however, cows culled for

OTH were similar to cows culled for RES (2.5 FYG), LPD (2.5 FYG), and REP (2.5 FYG). No difference was observed between cows culled for RES, LPD, REP, LI, MA, and DIG. Due to ABFT having a major impact on FYG, the cows culled for reasons that had a lesser ABFT had greater cutabilities.

Cows culled for LPD (28.4) had greater ($P < 0.01$) marbling scores than cows culled for MA (25.5), DIG (23.7), LI (22.1), and RES (20.8); however, cows culled for LPD had similar marbling scores compared to cows culled for REP (27.6) and OTH (27.2). Cows culled for REP had greater marbling scores than cows culled for DIG, LI, and RES; however; cows culled for REP had similar marbling scores to those culled for OTH and MA. Cows culled for OTH and MA had greater marbling scores than cows culled for LI and RES; however, cows culled for OTH and MA were similar to cows culled for DIG. No difference was observed for marbling score between cows culled for DIG, LI, and RES. Similar to ABFT, cows that aren't putting their diet and body resources towards fighting infection, disease, reproduction, or towards milk production (LPD, REP) had greater marbling scores. Cows culled for DIG (418.1) and REP (412.0) had greater ($P < 0.01$) maturity scores than cows culled for LPD (373.8) and MA (369.7); however, cows culled for DIG and REP had similar maturity scores compared to RES (403.3), LI (391.3), and OTH (377.1). No difference was observed for maturity score between cows culled for LPD, MA, RES, LI, and OTH. Similar to permanent incisor count, maturity score highlights that younger cows are being culled for mastitis more than other culling reasons.

4.4.2 Days in milk at culling

Cows were classified by days in milk (DIM) into groups with less than 51 days associated with the transition period, 51 to 100 associated with the breed back period, and then every 100 days of DIM thereafter (Table 4.2). The DIM group with the highest frequency was < 50 (26.1%), followed by 101-200 (19.8%), 201-300 (18.8%), 50-100 (13.0%), 301-400 (12.2%), and > 400 (10.1 %) respectively.

Cows culled before 101 days in milk had fewer ($P < 0.01$) permanent incisors than cows culled after 100 days in milk. Cows culled 101 to 200 DIM had fewer permanent incisor than cows culled after 300 DIM but were similar to cows culled between 201 and 300 DIM. Cows culled 201 to 300 DIM had fewer permanent incisors than cows culled after 400 DIM but were similar to cows culled 301 and 400 DIM. Permanent incisor count increased ($P < 0.01$) linearly with days in milk. Permanent incisor count increases as DIM increases which signifies that younger cows are being culled at the beginning of their lactation as opposed to older cows being culled at the end of their lactation.

Cows culled < 51 DIM had a greater ($P \leq 0.02$) inedible liver frequency than cows culled after 50 DIM due to a greater ($P \leq 0.01$) percentage of NAA than cows post 50 DIM. Days in milk had no ($P = 0.41$) effect on liver abscess frequency. As defined earlier, cows in the < 51 DIM group are identified as the transition group. The physiological stresses caused from cows going from dry to lactating can cause many metabolic disorders which effect the liver causing it to be inedible such as fatty liver syndrome.

Days in milk had no ($P \geq 0.14$) effect on normal lung frequency, lung consolidation frequency, fibrin tag frequency, or inflated lung frequency.

Cows culled 51-100 DIM had a lesser ($P < 0.01$) frequency of pregnancy compared to cow's culled < 51 DIM and > 100 DIM. Cows culled at 101-200 DIM and > 400 DIM had a lesser frequency of pregnancy than cows culled < 51 DIM and cows culled 201 to 400 DIM. Cows culled <51 DIM should have the lowest frequency of pregnancy; however, numerically they had one of the greatest frequencies of pregnancy. We concluded that those cows were not likely pregnant at harvest but involution of the uterus from parturition had not occurred and was misidentified as a uterus with a fetus present. It takes 25 days for uterus involution and an infection of the uterus causes delay of involution (Fonseca et al., 1983; Sheldon et al., 2006)

Cows culled >400 DIM had a greater ($P < 0.01$) ABFT than cows culled less than earlier DIM groups. Cows culled 301 to 400 DIM had a greater ABFT than cows culled less than 301 DIM. Cows culled < 51 DIM had a greater ABFT than cows culled 101 to 300 DIM but were similar to cows culled 51 to 100 DIM. Days in milk and ABFT had both a linear and quadratic effect. Inverse to a lactation curve, subcutaneous fat drops until after peak production in which diet and body resources are being put back into subcutaneous fat instead of milk production (Figure 4.2).

Cows culled > 300 DIM had a larger ($P < 0.01$) LMA than cows culled < 301 DIM. Cows culled 101 to 300 DIM had larger LMA than cows culled < 50 DIM but did not differ from cows that were culled 51-100 DIM. Cows culled 51 to 100 DIM tended to have larger LMA than cows culled < 50 DIM. Days in milk and LMA had a linear effect. Cows toward the end of their lactation are using less of their diet and body resources towards milk production, thus these resources can be used towards muscle growth (Figure 4.2).

Cows culled >400 DIM had heavier (*P* < 0.01) hot carcass weights than cows in lower DIM groups. Cows culled 301 to 400 DIM had heavier (*P* < 0.01) hot carcass weight than cows < 301 DIM. Hot carcass weight and DIM had a linear and a quadratic effect. Cows later in their lactation are using their diet resources more towards increasing carcass components instead of milk production (Figure 4.2).

Cows culled > 400 DIM had lower (*P* < 0.01) cutability compared to cows culled < 400 DIM. Cows culled 301 to 400 DIM and < 50 DIM were lesser cutability compared to cows culled 101-300 DIM but were similar to cows culled 51 to 100 DIM. Final yield grade and days in milk had both a linear and quadratic effect.The heavier and fatter cows later in their lactations are lesser cutability than the lighter and leaner cows in their earlier lactation.

Cows culled > 400 DIM had a greater (*P* < 0.01) marbling score than cows <400 DIM. Cows culled 301 to 400 DIM and < 51 DIM had greater marbling scores than cows culled 51-300 DIM. Cows culled 51 to 100 DIM had greater marbling scores than cows culled 101 to 300 DIM. Cows culled 101 to 200 DIM had greater marbling scores than cows culled 201 to 300 DIM. Marbling score and DIM had both a linear and a quadratic effect. Similar to ABFT, marbling scores work inversely of milk production curves for DIM (Figure 4.2).

Cows culled 101-200 DIM and > 300 DIM had greater (*P* < 0.01) maturity scores than cows culled 1-100 DIM but were similar to cows culled 201 to 300 DIM. Maturity score and DIM had a linear effect. Maturity score adds another metric to identify that younger cows are culled in the beginning of their lactation as opposed to older cows being culled in the later part of their lactation.

4.4.3 Lactation number at culling

Of cows culled from the herd, 34.9% of them will be in their first lactation (Table 4.3), 24.4% in their second lactation, 18.3% in their third lactation, 13.6% in their fourth lactation, and 8.8% in their fifth lactation or greater (FOH). For first and second lactation animals, the primary reason for leaving the herd is low milk production and then mastitis. For third and fourth lactation animals, the primary reason for leaving the herd is mastitis and then low milk production. For cows culled in their fifth or greater lactation, mastitis and then lameness were the primary reasons for an animal to be culled.

Cows culled in their first lactation had the fewest ($P < 0.01$) number of permanent incisors, followed by cows in their second lactation while cows in their third, fourth or FOH lactations all had a similar permanent incisor counts. Lactation number and permanent incisor count had both a linear and a quadratic effect. As expected, as a cow goes into more lactations her permanent incisor count will increase.

Cows culled in their first lactation had a greater ($P < 0.01$) edible liver frequency than cows culled in their fourth or FOH lactation but were similar to cows in their second or third. Cows in their second and third lactation had a greater edible liver frequency than cows culled in their fourth lactation but were similar to cows culled in their FOH. Cows in their first lactation had less ($P < 0.01$) NAA compared to cows in their third, fourth, and FOH lactations and tended to have less NAA compared to cows in their second lactation. Cows in their second, third, fourth and FOH lactation all had similar NAA frequencies. As the cows got older, they had greater risk to get a NAA which explains why older cows had a greater frequency of NAA compared to younger cows. No difference was observed between lactation number and liver abscess frequency.

A cow's lactation number had no effect ($P \geq 0.14$) on normal lung frequency, lung consolidation frequency, and fibrin tag frequency. Cows in their first lactation did have a lesser ($P < 0.01$) frequency of inflated lungs compared to cows in their second, third, fourth, and FOH lactations. Cows in their second lactation had a lesser frequency of inflated lungs compared to cows in their third, fourth, and FOH lactations. No difference was observed between cows fourth and FOH lactations on inflated lung frequency. As cows got older, inflated lung frequency increased.

No difference ($P = 0.23$) was observed in pregnancy frequency between cows culled in different lactation numbers.

No difference ($P \geq 0.33$) was observed between lactation numbers for ABFT and LMA. Cows in their third and fourth lactation had heavier ($P < 0.01$) hot carcass weights than cows in their first and second lactation but similar hot carcass weight to cows in their FOH lactation. Cows culled in their second and FOH lactation had heavier hot carcass weights than cows culled in their first lactation. Lactation number and hot carcass weight had both linear and quadratic effects. . The heavier hot carcass weights suggest that cows continue anabolic growth through their first and second lactation before plateauing at their third lactation.

Cows in their first lactation had a greater ($P < 0.01$) cutability than cows in their third, fourth and FOH lactations but were similar to cattle in their second lactationCows culled in their second lactation had a greater cutability than cows in their fourth and FOH lactations but were similar to cows in their FOH lactation. No difference was observed between cows culled in their third, fourth, or FOH lactation for cutability. Final yield grade and lactation number had both linear and quadratic effects.

Cows in their first lactation had greater ($P < 0.02$) marbling scores than cows in their second, fourth, and FOH lactation and similar marbling scores to cows in their third lactation. No difference was observed between cows culled in their second, fourth, and FOH lactations. Cows in their first lactation still had intramuscular fat stores from being heifer and as discussed earlier intramuscular fat store depleted slowly during lactation.

Cows culled in their first lactation had younger ($P < 0.01$) maturity scores than cows in their second, third, fourth, and FOH lactation. Cows culled in their second lactation had younger maturity scores than cows culled in their third, fourth, and FOH lactation. No difference was observed between cows culled in their third, fourth, and FOH lactation. Maturity score and lactation number had both a linear and a quadratic effect. As expected, cows in earlier lactation numbers have a younger maturity scores than older lactations. It should be noted that the average cow in her first lactation would meet the standards to qualify for young beef.

4.5. Conclusions

Low milk production and mastitis were the predominant reasons why a cow was culled. Cull cows culled for LPD and REP had greater carcass components than cows culled for other reasons. Inflated lungs are caused both by age and respiratory diseases. After peak milk production, carcass components work inversely of a lactation curve. Cows continue to grow through their second lactation. A cow has close to a 60% chance of being culled before her third lactation. For the highest salvage value, a cow should be culled > 300 DIM in her third lactation for the heaviest carcass. However, with the number of > 30 month of age cows coming in, new marketing opportunities are possible for young cow carcasses to be marketed as young beef.

4.6 References

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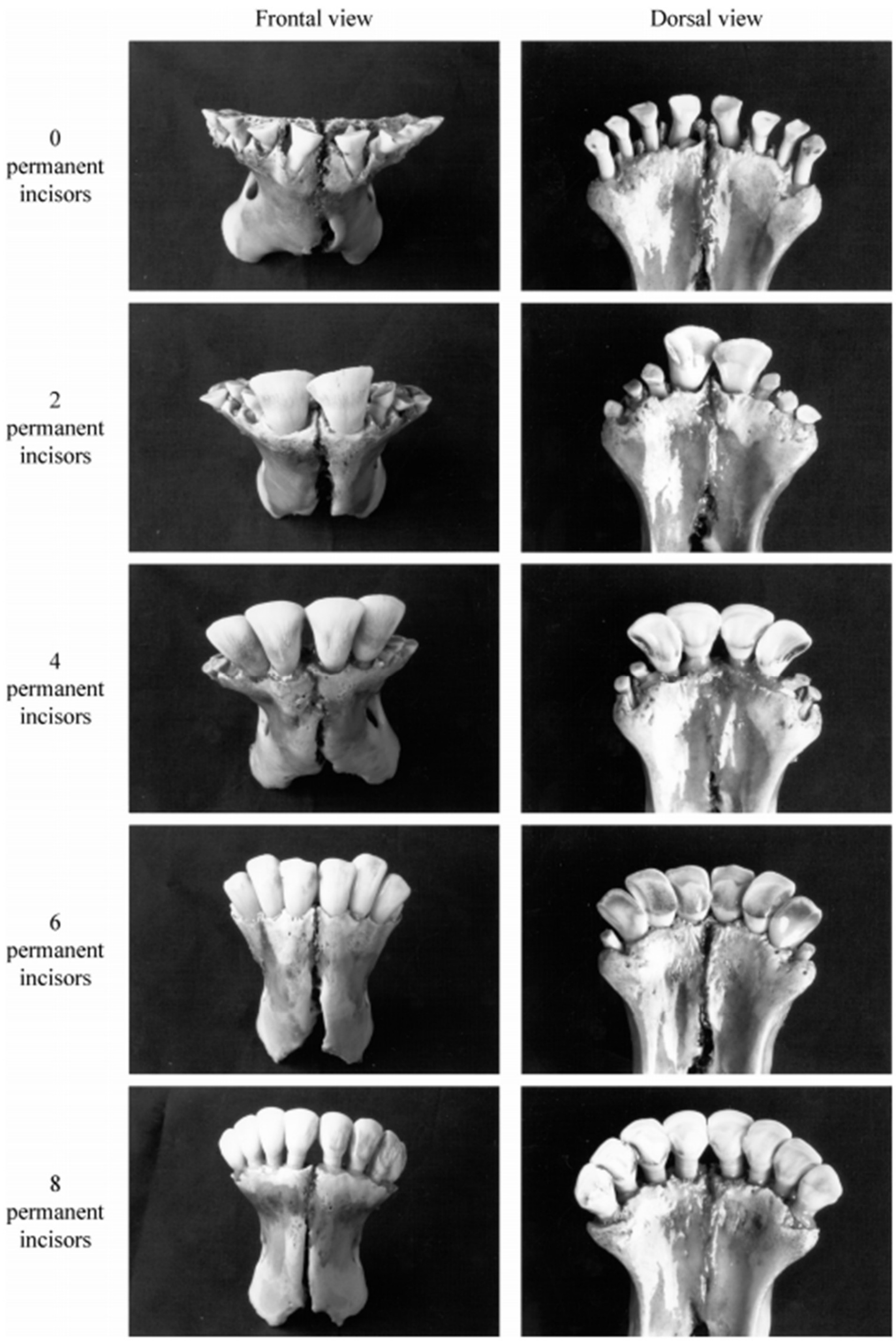

Figure 4.1 Permanent incisor count

Lawrence et al., (2001)

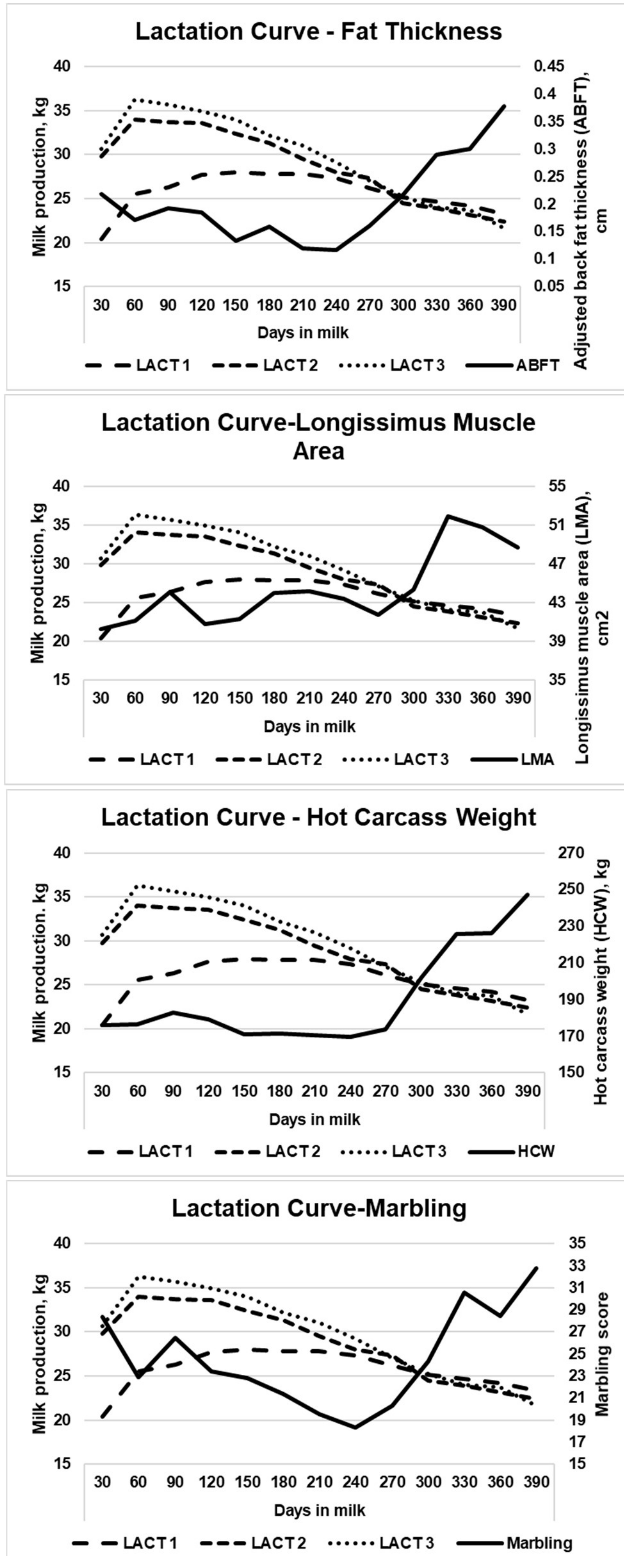

Figure 4.2 The association of grading characteristics with days in milk at harvest

Table 4.1 The association of culling decisions with harvest pathology and carcass grading characteristics of Jersey cows

	Reason culled								
	Digestive	Lameness	Mastitis	Low Production	Reproduction	Respiratory	Other[1]	SEM	*P*-value
Frequency, %	12.5	14.9	29.5	31.6	6.1	2.3	3.2		
Age									
Permanent incisor count	6.6^{a}	6.0^{ab}	5.3^{c}	5.7^{bc}	6.4^{ab}	6.2^{abc}	5.3^{bc}	0.7	<0.01
Liver evaluation									
Edible, %	44.8	54.3	57.3	57.5	58.0	40.0	46.4		0.31
Abscess, %	15.2	13.2	16.5	22.3	18.0	35.0	28.6		0.13
Non-abscess abnormality[2], %	40.0^{a}	32.6^{ab}	26.3^{bc}	20.2^{c}	24.0^{bc}	25.0^{abc}	25.0^{abc}		0.01
Lung evaluation									
Normal,%	25.8	28.5	32.3	29.9	39.0	0.0	40.0		0.22
Consolidation,%	52.4	45.7	41.3	40.2	30.6	70.0	28.6		0.05
Fibrin Tag, %	18.7	22.2	21.9	21.2	21.1	50.0	13.6		0.30
Inflated, %	18.9^{c}	14.0^{c}	20.9^{c}	21.5^{ab}	14.3^{c}	55.0^{a}	21.4^{bc}		<0.01
Fetus evaluation									
Open, %	69.7	80.0	67.6	73.7	71.2	70.0	50.0		0.06
Yield attributes									
Adjusted back fat thickness, cm	0.15^{c}	0.18^{c}	0.18^{c}	0.28^{a}	0.27^{ab}	0.15^{c}	0.20^{abc}	0.1	<0.01
Longissimus muscle area, cm^2	41.6^{cd}	42.4^{cd}	43.6^{bc}	46.8^{a}	45.7^{ab}	38.1^{d}	41.1^{cd}	0.4	<0.01
Hot carcass weight, kg	164.4^{d}	182.3^{bc}	181.5^{bc}	208.7^{a}	203.3^{a}	169.7^{cd}	199.3^{ab}	12.0	<0.01
Final yield grade[3]	2.3^{b}	2.4^{b}	2.3^{b}	2.5^{ab}	2.5^{ab}	2.5^{ab}	2.7^{a}	0.1	<0.01
Quality attributes									
Marbling score[4]	23.7^{cd}	22.1^{d}	25.5^{bc}	28.4^{a}	27.6^{ab}	20.8^{d}	27.2^{abc}	2.3	<0.01
Maturity score[5]	418.1^{a}	391.3^{ab}	369.7^{b}	373.8^{b}	412.0^{a}	403.3^{ab}	377.1^{ab}	27.5	<0.01

[abcd] Means within row lacking common superscripts differ ($P < 0.05$)
[1] Other reason culled is the combination of cows culled for udder confirmation and cows that kicked during the milking process
[2] Non-abcess abnormalities include telangiectasis, liver flukes, cirrhosis, carotenitis, contamination, and sawdust
[3] Final yield grade = 2.50+(2.5 × adjusted fat thickness in inches)+(0.2 × percent kidney, heart and pelvic fat)+(0.0038 × hot carcass weight)-(0.32 × ribeye area in square inches)
[4] Marbling Score: 10 = Pd^{00}, 20 = Tr^{00}, 30= Sl^{00}
[5] Maturity Score: 100 = A^{00}, 200 = B^{00}, 300 = C^{00}, 400 = D^{00}, 500 = E^{00}

Table 4.2 The association of day in milk with harvest pathology and carcass grading characteristics of Jersey cows

	Days in milk group									
	≤ 50	51-100	101-200	201-300	301-400	>400	SEM	*P* - value	Linear	Quadratic
Frequency, %	26.1	13.0	19.8	18.8	12.2	10.1				
Age										
Permanent incisor count	4.7^{d}	5.2^{d}	5.9^{c}	6.1^{bc}	6.6^{ab}	6.9^{a}	0.4	<0.01	<0.01	0.08
Liver evaluation										
Edible, %	44.4^{b}	56.1^{a}	58.2^{a}	57.2^{a}	66.6^{a}	53.4^{a}		0.02		
Abscess, %	16.0	21.1	20.0	18.2	14.4	25.0		0.41		
Non-abscess abnormality[1], %	39.6^{a}	22.8^{b}	21.8^{b}	24.5^{b}	19.2^{b}	21.6^{b}		<0.01		
Lung evaluation										
Normal,%	31.8	32.5	26.5	25.3	35.5	31.9		0.65		
Consolidation,%	41.1	43.4	43.8	52.5	39.1	29.6		0.14		
Fibrin tags, %	24.6	16.5	18.3	25.4	18.9	18.3		0.36		
Inflated, %	20.1	19.5	25.4	17.0	17.9	19.3		0.56		
Fetus evaluation										
Open, %	64.6^{c}	91.2^{a}	77.8^{b}	57.9^{c}	67.3^{c}	80.7^{b}		<0.01		
Yield attributes										
Adjusted back fat thickness, cm	0.21^{c}	0.19^{cd}	0.16^{d}	0.15^{d}	0.30^{b}	0.40^{a}	0.1	<0.01	<0.01	<0.01
Longissimus muscle area, cm^2	40.8^{c}	42.6^{bc}	43.0^{b}	44.7^{b}	50.7^{a}	49.4^{a}	1.9	<0.01	<0.01	0.39
Hot carcass weight, kg	176.8^{c}	179.8^{c}	173.5^{c}	179.6^{c}	231.5^{b}	249.1^{a}	7.5	<0.01	<0.01	<0.01
Final yield grade[2]	2.5^{b}	2.4^{bc}	2.3^{c}	2.2^{c}	2.5^{b}	2.8^{a}	0.1	<0.01	<0.01	<0.01
Quality attributes										
Marbling score[3]	28.2^{b}	24.9^{c}	22.6^{d}	20.0^{e}	29.3^{b}	33.1^{a}	1.2	<0.01	<0.01	<0.01
Maturity score[4]	364.7^{b}	365.5^{b}	392.5^{a}	383.2^{ab}	401.6^{a}	407.4^{a}	16.7	<0.01	<0.01	0.60

[abcd] Means within row lacking common superscripts differ ($P < 0.05$)
[1]Non-abcess abnormalities include telangiectasis, liver flukes, cirrhosis, carotenitis, contamination, and sawdust
[2]Final yield grade = 2.50+(2.5 × adjusted fat thickness in inches)+(0.2 × percent kidney, heart and pelvic fat)+(0.0038 × hot carcass weight)-(0.32 × ribeye area in square inches)
[3]Marbling Score: 10 = Pd^{00}, 20 = Tr^{00}, 30= Sl^{00}
[4]Maturity Score: 100 = A^{00}, 200 = B^{00}, 300 = C^{00}, 400 = D^{00}, 500 = E^{00}

Table 4.3 The association of lactation number with harvest pathology and carcass grading characteristics of Jersey cows

	Lactation number								
	1	2	3	4	≥ 5	SEM	P - value	Linear	Quadratic
Frequency, %	34.9	24.4	18.3	13.6	8.8				
Most common reason for culling	Prod	Prod	MA	MA	MA				
2nd most common reason for culling	MA	MA	Prod	Prod	Lame				
Age									
Permanent incisor count	2.7^{c}	6.2^{b}	7.7^{a}	7.8^{a}	8.0^{a}	0.2	<0.01	<0.01	<0.01
Liver evaluation									
Edible, %	61.3^{a}	54.3^{ab}	57.5^{ab}	41.5^{c}	44.5^{bc}		<0.01		
Abscess, %	18.9	18.8	13.8	22.9	20.8		0.59		
Non-abscess abnormality[1], %	19.9^{a}	26.9^{ab}	28.8^{b}	35.6^{b}	35.1^{b}		<0.01		
Lung evaluation									
Normal,%	41.0	21.9	29.9	17.3	27.8		0.14		
Consolidation,%	37.8	48.3	40.5	50.0	42.9		0.14		
Fibrin tags, %	22.9	26.8	20.5	17.2	13.6		0.18		
Inflated, %	9.0^{a}	17.3^{b}	26.6^{c}	37.3^{c}	32.5^{c}		<0.01		
Fetus evaluation									
Open, %	76.1	69.1	70.3	66.4	68.6		0.23		
Yield attributes									
Adjusted back fat thickness, cm	0.2	0.2	0.2	0.2	0.2	0.1	0.33	0.37	0.53
Longissimus muscle area, cm^2	43.9	44.8	44.7	43.3	44.3	2.0	0.67	0.96	0.91
Hot carcass weight, kg	175.0^{c}	189.0^{b}	207.9^{a}	202.3^{a}	198.9^{ab}	8.3	<0.01	<0.01	<0.01
Final yield grade[2]	2.3^{c}	2.4^{bc}	2.5^{a}	2.6^{a}	2.5^{ab}	0.1	<0.01	<0.01	0.03
Quality attributes									
Marbling score[3]	26.9^{a}	24.7^{b}	26.5^{ab}	24.5^{b}	24.2^{b}	1.5	0.02	0.05	0.98
Maturity score[4]	278.6^{c}	396.6^{b}	447.4^{a}	455.5^{a}	466.6^{a}	11.0	<0.01	<0.01	<0.01

[abcd] Means within row lacking common superscripts differ ($P < 0.05$)

[1]Non-abcess abnormalities include telangiectasis, liver flukes, cirrhosis, carotenitis, contamination, and sawdust

[2]Final yield grade = 2.50+(2.5 × adjusted fat thickness in inches)+(0.2 × percent kidney, heart and pelvic fat)+(0.0038 × hot carcass weight)-(0.32 × ribeye area in square inches)

[3]Marbling Score: 10 = Pd^{00}, 20 = Tr^{00}, 30= Sl^{00}

[4]Maturity Score: 100 = A^{00}, 200 = B^{00}, 300 = C^{00}, 400 = D^{00}, 500 = E^{00}