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The Effects of Foot and Udder Scoring on Cow and Calf Performance

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Abstract

Foot soundness and udder conformation are essential for longevity in beef cattle. The objective of this study was to investigate the effects of foot angle (FA), claw set (CS), teat size (TS) and udder suspension (US) scores on cowherd performance. Data were analyzed for 1,685 observations on Angus-based cows over a four-year period. At weaning FA, CS, TS, and US were evaluated. Scores are based on nine-point scales. A score of one indicates straight pasterns, divergent toes, enlarged bottle shaped teats, and absence of a median suspensory ligament; nine indicates weak pasterns, curled toes, small symmetrical teats, and a tight udder attachment. Cows that exhibited FA and CS scores from four to six were considered acceptable. Cows that exhibited scores outside this range were considered undesirable. Cattle with US and TS scores ranging between four and eight were evaluated. All cows were evaluated for age and performance traits including pre-breeding weight (PBW), pre-breeding body condition score (PBCS), pregnancy rate, calf birthweight (BW), calf weaning weight (WW), calf adjusted weaning weight (AWW), cow body weight at weaning (CWW), weaning body condition score (WBCS), and adjusted weaning performance (AWP). Data were analyzed using the GLIMMIX procedure of SAS. Significance was declared at $P \leq 0.05$. Acceptable cows had a WBCS 10.14% greater ($P < 0.01$) compared to undesirable cows. Acceptable cows possessed an average WBCS of 4.83 compared to 4.34 in undesirable cows. Acceptable cows were 9.50% younger ($P = 0.05$) than undesirable cows. The mean age for acceptable cows was 4.67 compared to 5.16 in undesirable cows. There were no US differences ($P \geq 0.24$) for WBCS. There were no TS differences ($P \geq 0.13$) for CWW, WBCS, WW, AWW, and AWP. Cattle with US scores of 4 were on average the oldest ($P < 0.01$) at 7.75 years of age. Cattle with TS scores of 8 were on average the youngest ($P < 0.01$) at 3.20 years of

age. Cattle with US scores of 4 weaned the heaviest calves ($P < 0.01$) at 246.92 kg. These results could help predict cow performance based on FA, CS, TS, and US.

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Introduction

Proper foot and udder structure is thought to be essential for optimum performance, animal health, and longevity in beef cattle. The objective of this research was to determine its effects on performance in the beef research herd housed at the Savoy research unit near Fayetteville, Arkansas.

Chapter 1 Literature Review

Scoring Beef Cattle

Selection for type traits in beef cattle by visual appraisal is one of the means by which producers can improve future calf crops (Daniel and Kriese-Anderson., 2013). McDaniel, (1997) noted that genotype effects conformation through metabolic and structural pathways. Metabolic effects are challenging to quantify, but structural and conformational differences can be observed and measured with a trained eye (McDaniel, 1997). McDaniel (1997) even remarks that until more is understood about the genetic component that underlies an animal's metabolic processes, improvements in visually observed traits associated with productivity such as soundness, growth, and capacity are best improved through selection for type traits that will withstand the rigors of production or enhance profitability.

In addition to selection for type traits which hold value across all facets of the industry and management systems, producers must also be aware of specific traits which allow cattle to be better adapted to their environment. Decker and Parish (2017) state "Cattle that are well suited for their environment or more profitable. Not only are well adapted cattle more productive, but they also require fewer inputs and interventions." These statements support the reasoning that cattle whose genetics are more suited to their surroundings perform at an optimum level, and selection for the phenotypic expression of these traits increases their ability to thrive regardless of the challenges their environment presents (Decker and Parish, 2017).

The way traits are evaluated and objectively measured become the central idea of the numerous scoring systems utilized in the beef industry today. Scoring systems have been created to objectively measure traits of economic importance as simple quantitative data often fails to tell the whole story as explained by Gadberry (2010) as he states, "changes in body condition, rather than live weights or shifts in weight, are a more reliable guide for evaluating the nutritional status of a cow." Because of gut fill, pregnancy, or mature cow size, Gadberry (2010) rightly observes that cattle of similar live weights could be in distinctly different condition when compared to each other; furthering the need for objective scoring measures for qualitative visual type traits with application in production settings.

Commonly Used Scoring Systems in Beef Production

As purebred breed associations have expanded their databases in the pursuit of more accurate genetic records, many have devised scoring systems for type traits they wish to improve. Extension and beef improvement organizations have also devised some of the more commonly used scoring systems in beef cattle production today. The following is an overview of the various scoring systems most commonly used to assign value to the qualitative data observed in type traits thought to have economic relevance.

Body Condition Score

Changes in body condition of cattle in production effects numerous traits relating efficiency and profitability including length of post-partum interval, lactation performance, health of new born calf, and calving difficulties for extremely fat first calf heifers. He also notes the impacts of body condition at breeding affecting services per conception and percentage of open cows. The economic implications of poor body condition are the need for increased supplementation in critical periods of production when resources are scarce (Gadberry, 2010).

Body Condition Score (BCS) can be defined as “Numbers used to suggest the relative fatness or body composition of the cow,” (Gadberry, 2010). He explains further that the BCS system is one of the most producer-friendly, being easy to learn, practical in settings where recording weights is difficult or impossible, and reliable when performed by the same person within the same herd over an extended period of time. The majority of published studies use a one to nine-point scale where a score of one indicates emaciated cattle whose shoulders, ribs, and pin bones are easy to see with extremely minimal expression of fat and muscling, and a nine indicates extremely fat cattle whose bone structures are not visible, tail heads are surrounded by fat, and they may even express reduced locomotive capabilities. A score ranging from five to seven is accepted by the industry as ideal, cattle in this range are moderately to abundantly fat on either side of the tail head, ribs mostly covered and not visible unless shrunk, and full quarters.

Body condition scores provide relevant information for ranchers to make decisions for their herd at numerous stages of the production cycle. Pryce et al. (1999) observed that thinner cows had longer calving intervals. Gadberry, (2010) observed that at calving, cattle with a BCS below the desirable threshold, had the lowest pregnancy rates. At breeding, cattle with a BCS below 5 recorded extremely low pregnancy rates. Pryce et al. (1999) also observed effects of BCS during early lactation, “It is likely that cows are mobilizing body tissue to sustain milk production… Cows in negative energy balance, particularly in early lactation, may be yielding milk at the expense of reproduction.” These conclusions offer a plethora of practical applications for the producer. Cows can be sorted off condition and moved to separate pastures with different nutritional management programs to optimize performance, while reducing input costs on easier doing cattle. The economic ramifications are clear; cows whose BCS was raised from three to five became $161 more profitable each year, and cows whose BCS was raised from just four to five where $93 more profitable each year. Gadberry (2010) concludes, "nutritional and reproductive decisions, so important to profitability, are made with more precision and accuracy when a body condition scoring system is routinely used,". A description of the BCS system can be found in Table 1.1.

Hair Shedding Scores

Decker and Parish (2017) acknowledge the need for heat tolerance in cattle produced in the southern tier of the United States where heat indices can soar during summer month. Aside from the injection of Bos indicus genetics into the cow herd, it is suggested to select for Bos taurus cattle with a greater propensity to shed their winter hair coat earlier and more thoroughly in the spring.

The hair shedding score system used by Decker and Parish ranges from one to five, where a score of one indicates a completely "slick" hair coat and a score of five indicates the retention of a full winter hair coat. Mid-May was deemed the optimum time to collect hair coat scores in the Southeastern United States where its application is most useful, however; the hotter and more humid the climate, the earlier scores should be taken. The popularity of hair shedding scores is likely to rise, as the data is easy to record, observe, and quantify.

The benefits of hair coat shedding in commercial cow-calf systems located in hot and humid environments are clear: calves out of cows that shed their winter coats earlier weaned heavier calves, however; no effects on calf performance in operations located in temperate environments were observed.

Sheath Score

There are examples of how scoring systems have become adequate predictors of longevity in not only breeding females, but bulls as well. "Bulls with a lazy prepuce or a very pendulous sheath are at a greater risk for [injuries]" Waldrip, (2017). The International Brangus Breeders Association, (2008) utilizes a five-point scoring system where a score of one indicates extremely clean "Angus-like" sheaths, and five represents extremely pendulous sheaths with large, loose prepucial openings. Producers must take care to observe the frequency of the prepuce's protrusion, as this greatly enhances the risk of infection and injury, resulting in a reduction of the bull's useful life and loss on investment (Waldrip, 2017).

Frame Score

Evaluating the size of cattle has varied over the years given the availability and changes in technology. Height and length were the traditional methods of size estimation before scales became commonplace. Hammack and Gill (2009) stress the need for a scoring system that more adequately translates the quantitative data of hip height and weight for practical applications. At seven months old cattle are almost 80% of mature height, while only being around 40% of mature weight; maturity is the trait relative to height and weight that effect frame score.

The Beef Improvement Federation (BIF) has issued a method of frame scoring beef cattle that is based off of hip height, which can be defined as the topline most directly above the hips or hook bones. Measuring sticks with cross-arm bubble-levels with 90-degree angle measures ensure accuracy of measurements.

Feeder cattle grading falls under the umbrella of frame scoring, Hammack and Gill, (2009) state, where frame size, thickness, and "thriftiness" (which can be described as look of health), should be used to predict at what weight steers are ready to be harvested. "Medium frame steers are projected to finish at 1,100 to 1,250 pounds. Small frames are projected to finish below that range and large frames above." The authors then outline the numerous studies on frame size and mature cow size to conclude that the frame score system is a more accurate predictor of weight at slaughter, onset of puberty, and maturity pattern rather than actual body size which can best be quantified by weight in relation to body condition.

Feet and Leg Scoring

The Holstein Association USA, Inc. (2018) has utilized a scoring system for feet and legs for greater part of the 20th century. When evaluating dairy cattle, five major categories take precedent: front end and capacity, dairy strength, rump, udder, and feet and legs which accounts for 20% of the 100 points possible (Holstein USA, 2018). Feet and rear legs comprise the F&L scoring system. The rear view of rear legs assigns point values from 1 to 5 for cattle that hock in and toe out, and assigns point values between 45 and 50 for square hocked, wide set feet that all point in a forward facing direction. Side view of rear legs assigns point values from 1 to 5 on post legged, straight hocked cattle, 25 points for moderate set to the hock and rear leg, and 45 to 50 points for cattle who are extremely sickle hocked. Locomotion is scored based on the utilization of feet and legs including length of stride and direction of legs, where 1 to 15 points describes cattle with "severe abduction with short stride and skating motion" (Holstein USA, 2018), 20 to 35 points are given to cattle exhibiting moderate deviation of limbs from the midline of the body, and 40 to 50 points are assigned to cattle with a long appropriate stride and little to no abduction from the midline of the body. Feet are scored based on the angle of the toe and depth of heel, where 1 to 5 points is given to extremely shallow heeled cattle with very small toe angles, 25 points are given to the intermediate optimum of deep heeled cattle with large toe angles and symmetrical claws, and 45 to 50 points are given to cattle who are extremely upright on the most extreme toe angles. Hocks and bone structure must be clean, flat, and lacking any swelling or coarseness, with pasterns being short, stable and flexible (Holstein USA, 2018).

The Australian Angus Association and Australian Brahman Breeders Association have adapted and utilized the common feet and leg scoring systems used in the dairy industry. The genetic parameters for feet and leg traits have been determined by their associations and are in use among producers on the continent. Jeyaruban et al. (2012) analyzed the genetic parameters and breeding values for front feet angle, rear feet angle, front feet claw set, rear feat claw set, rear leg hind view, and rear leg side view, which were scored on nine-point scales and treated as intermediate optimum traits, where five and six were ideal. The ABBA scores front legs as normal, knock kneed, or bow legged. "The front legs of the bull should be straight when viewed from the front. On a structurally sound animal, a vertical line may be drawn from the point of the shoulder to the middle claw," ABBA (2014). Shoulders are rated A, B, and C where A is ideal, B is straight, and C is too much angle, the idea is that half the animal's weight is supported by the knee, and any structural discrepancies here will result in un-sound livestock (ABBA, 2014).

Jeyaruban et al., (2012) found moderate to high heritabilities of these traits, suggesting that evaluation for feet and leg scores could be a means of genetic improvement. The cost of treatment to injuries, increased days open, decreased expression of estrus, longer calving intervals, involuntary culling, among others were commonly observed issues associated with un-sound feet and legs by Boettcher et al., (1998).

Foot Scoring

The American Angus Association (AAA) has produced the most widely accepted, frequently used foot scoring system for beef cattle in the United States today. The subject of this thesis largely centers around the application of this foot scoring method and its effects on performance in cow-calf production.

Two nine-point scales, treated as intermediate optimum traits where scores of five where deemed ideal and animals must be scored prior to trimming, around a year of age (AAA, 2015). Van Dorp et al. (2004) noted that age effects feet and leg traits as a result of heavier body weights and longer duration of usage. This supports the AAA guideline of collecting foot scores on mature cows in conjunction with mature body weight records, so scores can be adjusted accordingly.

Foot angle is the first methodology used in foot scoring, where a score of one indicates extremely straight pasterns, very short toes, and is considered unsound; a score of nine indicates a markedly shallow heel, long toes, and extremely weak pasterns, also unsound; an ideal score of five describes a 45-degree angle pastern joint, appropriate toe length and a deep heel, and is considered sound. Claw set is the second methodology used to score feet where a score of one indicates weak, open, diverging toes and is unsound; nine represents "scissor claws", curled toes, and crossing claws which renders the animal unsound; an ideal score of five represent symmetrical, evenly spaced claws and is considered sound (AAA, 2015).

Udder and Teat Scoring

Rasby (2011) notes that teat and udder conformation presents benefits as well as challenges to commercial cow-calf producers. Time constraints prevent producers from intervening in situations in which a calf cannot physically suckle and milk out quarters, that clinical mastitis results in up to 12.5% reduced weaning weight, and that poor udder conformation can result in calf sickness from teats being contaminated by debris from the surface. Selection for teat and udder traits may be considered a convenience trait, but elimination of poor teats and udders is thought to increase profitability and longevity of cow herds through increased calf performance, calf health, cow longevity, and decreased labor. This subject matter of this thesis is also largely concerned with teat and udder scores and their impacts on cow and calf performance.

Teat and udder scoring is divided into two categories. Udder suspension score refers to how close the udder is to the body wall which is reliant on the median suspensory ligament (Rasby, 2011). The BIF udder suspension score system is a nine-point scale, in which a score of nine indicates an udder that is high and tight to the body wall, above the hock joint, and possesses level quarters from the side and rear, with a prominent median suspensory ligament, this score is considered ideal; a score of one indicates a lack of a median suspensory ligament, loose, pendulous quarters, and an udder which distends below the hock joints. Teats in udder suspension score one are not perpendicular to the ground and intervention is necessary at calving to prevent mastitis, the BIF recommends culling replacements within this category.

Teat size or teat score is the other BIF scoring system related to udder quality in beef cattle. Rasby (2011) describes smaller, more symmetrical, and centrally located teats are ideal when suspended above the hocks. The BIF issues another nine-point scoring system for teats. A score of nine indicates short teats, rounded at the end, of great symmetry and central location, perpendicular to the ground, this is ideal. A teat score of one indicates thick, abnormally large, cone shaped teats, hanging loosely below the hock joint, often resulting in mastitis and requiring treatment during calving and early lactation, according the BIF, cows exhibiting these traits should also be culled. A description of Udder Suspension and Teat scoring systems can be found in Tables 1.2 and 1.3.

Importance of Longevity & Foot Structure in Beef & Dairy Cattle

Rising input costs, volatile markets, and an ever-changing environment highlight longevity as a trait of increased economic relevance to beef producers. Cost reduction is one of the easiest means by which producers can increase profit margins, and increasing longevity reduces the costs associated with developing or purchasing new replacement females (Forabasco et al., 2004). Longevity in beef cattle is defined as the measure of productive life from first calving to culling. Cattle are culled for voluntary and involuntary reasons. To be culled voluntarily would be for lack of performance or economic reasoning, such as failing to calve in regular intervals. Involuntary culling would be due to reasons beyond the producers control such as death or disease. Ducrocq et al. (1988) defines longevity corrected for *voluntary* culling as functional longevity, while actual age was defined as true longevity. USDA (2010) lists culling for physical unsoundness at 9.6%.

Foot and leg structure impacts the likelihood of a cow to be culled, according to (Forabasco et al., 2004). Industry rhetoric associates moderation of frame, and correct feet and legs with increased longevity, so producers are more likely to retain females who embody these traits. Daniel and Kriese-Anderson (2013) highlight the importance of structural soundness stating that “a farmer may produce cattle that excel in muscle, maternal ability, and feed efficiency, but if cattle cannot walk easily from feed source to water source then all else has been in vain.” Selection for structural integrity will reduce culling for lameness and thus increase the longevity of the herd. Not only does foot soundness effect the female cow, but bulls as well, which also are required to spend the entirety of their lives on their feet and legs when covering females in the pasture and simply to access resources. Gadberry (2010) also states that longevity is influenced by sound hips, hocks and feet. Selection for structural soundness in breeding stock when choosing replacements and herd sires is essential to ensure survival and productivity in a pasture situation (Daniel and Kriese-Anderson, 2013). Arthur et al. (1992) found that after reproductive failure, calf survival, dystocia, and udder problems, culling for feet and leg issues is one of the most common reasons beef cows were culled from the herd.

Claw conformation has long been correlated to production traits and longevity in dairy cattle. Hahn et al. (1984) reported that cattle with shorter, steeper toes were less predisposed to lameness, were more efficient reproductively, and had higher milk yields, as well as higher longevity than cows with longer, smaller angles. Baumgarter and Distl (1990) observed higher survival rates in European Simmental cattle to 60 months of age in heifers who had steeper, shorter claws during their first lactation.

Measuring Foot Structure & its Genetic Parameters

Vermunt and Greenough (1995) describe foot quality as the result of horn hardness and claw shape in addition to the anatomy and physiology of the hoof's internal structure. Horn hardness has been more heavily associated with foot quality in the dairy industry, as cattle are subjected to different management systems, spending more time on hard surfaces such as concrete, increasing the wear of the horn (Dietz and Prietz, 1981).

However, claw conformation is frequently anecdotally associated with lameness. This is supported by Russell et al. (1982) who reported a 42% incidence rate of lesions leading to lameness issues in hooves with undesirable shape. Conformation can be defined as the shape or proportionate dimensions of an animal (Dietz and Prietz, 1981); therefore, an understanding of the visual traits which effect claw conformation is necessary.

Measurements in Relation to Management and Productive Life

The physical conformation of the hoof is just as important as the time in the animal's productive life in relation to various production practices, that the trait is recorded. The American Angus Association (2015) requires that heifers and bulls be scored between 320 and 460 days, and between 320 and 440 respectively. This practice is supported by Distl et al. (1984) who recommended claw measurements taken around a year of age as the most desirable records for selection based on foot quality, due to a reduction in variation due to physiological processes related to growth rate and maturity. The AAA (2015) has an adjustment for cow age, as older cattle weigh more than younger cattle and thus bear more weight on pastern joints and claws, in addition to requiring scoring take place before the common production practice of foot trimming, and scoring the worst foot of the four. These practices are supported by Vermunt (1990) who noted the influence that management, environment, and age on claw shape.

Foot Angle

One half of the foot scoring system put forth by the American Angus Association (2015) is comprised of traits effecting the angle of the foot. Dorsal angle, length of the dorsal border, depth of heel (heel height), toe: heel ratio and diagonal length are the dimensions of the hoof which influence foot angle (Vermunt and Greenough, 1995).

Vermunt and Greenough (1995) define dorsal angle as "the slope of the dorsal border of the claw with respect to the floor surface". Length of dorsal border is described as the distance between the periople (hairline) and the point of the claw; heel height is described as the distance from the surface to the hairline at the palmar margin of the bulb of the claw; diagonal length is the distance from the toe's apex to the hairline of the heel. Toe: heel ration is a calculation where height of toe is divided by the height of the heel, which can be more thoroughly described as the vertical distances from dorsal hairline and heel hairline to the ground (Vermunt and Greenough, 1995). An illustration of the traits which influence foot angle can be seen in Figure 1.10.

Claw Set

One half of the scoring system put forth by the American Angus Association (2015) is claw set. Claw set refers to the size spacing and shape of individual claws. Vermunt and Greenough (1995) state that claws should be relatively equal in size and spacing relative to the animal's weight and age.

Amstutz (1985) reported lameness issues in cattle with claws of different dimensions, as the large claw will bear a greater portion of the animal's body weight. This is described commonly as rolling in or out, and results in greater wear on the claw bearing most of the animal's weight. Vermunt (1990) found that front claws were wider in cattle, as they bear most of the animal's weight, resulting in greater pressure to the front medial and lateral claws than rear claws. Because of this, significant differences between the dimensions of front and hind claws have been recorded (Vermunt, 1990).

Genetic Parameters of Phenotypic Traits

Phenotype can be defined as the physical appearance of an animal, resultant of environmental interactions as well as genotype, or the expression of visual and biochemical traits as the relate to genetic makeup and environment. Therefore, heritability can be defined as the amount of phenotypic variation that is caused by genetic variation, not influenced by environmental or random effects. Greater heritability results in greater response to selection of the observed trait. The following are the heritability estimates of foot traits in beef cattle both in the United States and abroad.

Heritability estimates for foot angle in dairy cattle have been reported by Van Dorp et al. (2004), Perez-Cabal et al. (2006), and Laursen et al. (2009) based on 1 to 9 intermediate optimum scoring systems to be 0.10, 0.12, and 0.13, respectively. Hahn et al. (1984) reported foot angle heritabilities for inside and outside front toes, and inside and outside rear toes to be 0.38, 0.40, 0.55, and 0.85, which indicates moderate to high heritability. Heritability estimates for foot angle have more recently been reported in beef cattle. Jeyaruban et al. (2012) reported front and rear foot angle heritabilities of 0.50 and 0.35 respectively. Jensen (2017) found front and rear hoof angle heritabilities to be 0.20 and 0.19 in beef cattle.

Heel depth heritabilities in dairy cattle for front and rear hooves were reported by Hahn et al. (1984) to be 0.58 and 0.19. Fatehi et al. (2003) recorded heritabilities between 0.06 and 0.09 in relation to the production system the dairy cow was observed in. Jensen (2017) reported front and rear heel depth heritabilities in beef cattle of 0.17 and 0.25 respectively.

Hoof area, claw set and claw shape heritabilities have also been reported in dairy and beef cattle. Hahn et al. (1984) reported hoof area heritabilities of 0.46 for front hooves and 0.34 for rear hooves. Jensen (2017) reported a hoof area heritably of 0.36. Heritability estimates of 0.33, 0.18, 0.46, and 0.36 for front claw shape were reported by Jeyaruban et al. (2012) with estimates ranging from 0.16 to 0.29 and 0.40 to 0.44 for rear claw shape. Jeyaruban et al. reported front and rear claw set heritabilities of 0.46 and 0.42. Jensen (2017) reported claw set heritabilities of 0.09 and 0.17 for front and rear claw set scores.

With the low to moderate heritabilities of foot conformation traits, breeders of cattle are able to select for these traits and observe the effects of genetic change (Jensen, 2017). Jensen (2017), found a small relationship between longevity and foot traits, and suggests further research into its impacts on longevity and performance in beef herds. Heritabilities of the traits reported in the preceding literature can be viewed in Tables 1.4, 1.5, 1.6, and 1.7.

Importance of Udder Structure and Calf Performance in Beef & Dairy Cattle

As input cost continue to rise, longevity has become an increasingly important aspect of beef production. Regardless of production goals or marketing systems, or whether the discussion is centered around beef or dairy cattle, the longer the productive life of the cow, fewer replacements are necessary for optimum production (Bradford et al., 2013). As an emphasis on growth and performance has taken precedent in the beef industry, increased milk production and milk yield are some of the easiest ways to increased calf performance (Beard et al., 2018).

Though teat and udder conformation has traditionally been thought of as a convenience trait, particularly in beef cattle, numerous studies have reported the benefits of proper udder structure. Research has also confirmed the moderate heritability of udder traits in beef cattle, suggesting that selection for udder conformation could potentially result in genetic progress for the given operation. Proper teat and udder structure has been frequently anecdotally thought to reduce labor costs, impact calf mortality, result in heavier weaning weights and decrease the demand for purchasing and developing replacement females (Bradford et al., 2013). Poor udder quality may result increase incidences of mastitis and injury as well as reduced immunity to calves unable to obtain colostrum (Hereford World, 2009). This is of great importance to both seedstock and commercial cattlemen alike, as commercial producers expect their cattle to be relatively problem free and less intensively managed. This has resulted in emphasis on selection for udder quality in various beef breed organizations such as the American Hereford Association.

Frisch (1982) observed that "bottle teats" were the greatest cause of mortality in calves up to two months of age, especially when all four teats were bottle teats. This is supported by numerous other studies over the calf's ability to nurse dependent on the cow's udder. Extreme difficulty nursing during the early hours of life was observed by Wythe (1970). This results in decreased calf immunity and increased incidences of performance hindering disease, as they are unable to obtain an adequate amount of colostrum. Frisch (1982) found calf mortality rates of 48.6% when cows had four bottle teats, while calves with no large teats had a 6.1% mortality rate. This suggests that selection for proper teat structure and udder conformation, would likely benefit producers who calve out cows in large, open ranges where the rancher's ability to "get up" cows and milk out bottle teats manually is either un-feasible or too dangerous. Though some would say this confirms that culling for udder quality is merely for convenience, another school of thought takes into account the reduction of labor cost and subsequent increased calf performance to be the drivers behind increased profitability for producers who emphasize udder quality (Hereford World, 2009). This is further supported by Goonewardene et al. (2003) who found that cattle with bottle teats weaned lighter calves than those with desirable udders. This is especially important for the vast amount of beef producers who market their calves at weaning.

As udders and teats become less attached to the body wall and begin to distend below the hocks, dirt, debris, and pathogens can be picked up from the surface resulting in mastitis for the cow and potential infection for the nursing calf. Mastitis can be defined as the bacterial infection and subsequent inflammation of the mammary gland. DeGroot et al. (2002) confirmed that cattle with poor udder suspension were more susceptible to developing mastitis. Even if mastitis is properly treated, its effects on mammary function can be far reaching. Often times, mastitis results in what the industry commonly refers to as "blind quarter" or unproductive, non-functional quarters of the udder. Duenas et al. (2001) and Lents et al. (2002) observed lighter weaning weights in calves whose dams had at least one blind, unproductive quarter. This is likely due to the reduction of milk available for the calf to consume, further highlighting the benefits of udder and teat quality as a trait economic importance.

Udder and teat quality may be a culling factor for some producers, just as poor udder and teat quality could potentially result in involuntary culling for the diseases associated with it. Frisch (1982) ranked poor udder quality, large teats, pendulous suspension, and mastitis as one of the top contributors to culling cows of old age. USDA (2008) lists the percentage of cows culled for udder problems at 9.2%. Udder quality was found to decrease as cattle age, and that older cows were culled more frequently because of udder problems for this reason (Arthur et. al., 1992).

Through improvement of udder quality Bradford (2013) states cows can remain in the herd longer, making the purchase of more replacements unnecessary. Increasing cow longevity is one of the easiest means by which producers can reduce the added cost of developing and purchasing new replacements (Bradford, 2013).

Measuring Udder and Teat Structure and Their Genetic Parameters

Udder conformation is important to profitable cow calf production. "Poor udder and teat conformation can potentially lead to increased calf sickness as teats may be contaminated with mud," Rasby (2011) continues "producers do not have the time or labor to… 'milk out' quarters so that the calf can suckle."

Udder and teat structure have been found to be moderately heritable traits (Kirschten et al., 2001). Therefore, producers can enact selection for these traits and see change in their herds, by keeping back replacements of superior udder suspension and teat quality. The median suspensory ligament is an essential aspect of udder quality. If the ligament is weak the udder will distend below the hock, causing the calf to bend down to nurse from an odd angle, and teats will point in various directions. A prominent suspensory ligament will cause the udder to remain above the hock joint for years into productive life (Rasby, 2011).

Rasby (2011) also remarks on the importance of teat size and structure. The need for teats to be medium in length, shaped like cylinders, and rounded at the ends with consistency from base to tip allows calves to more easily find and suckle from teats especially when they are new born. Longer teats also are more susceptible to collecting dirt and pathogens.

Measurements in Relation to Management and Productive Life

Rasby (2011) states the ideal time to score Udder Suspension and Teat Size is with the first two days of birth, as the udder begins to "freshen" post-calving. The American Hereford Association has been one of the major beef breeds in the United States to emphasize udder and teat scoring systems for breed improvement. AHA recommends udder scoring with the first 24 hours post-calving as the udder will be the fullest. AHA also recommends scoring at this critical point in production, as larger, older calves may not have difficulty suckling from engorged teats, but a small, low birthweight newborn would (Hereford World, 2009). The American Hereford Association suggest that producers "make udder score collection a routine part of your performance data collection" noting the ease of recording udder scores along with calving ease data (Hereford World, 2009). Torell (2002) also states "If the cow is going to have problems with udder quality, it typically will show up when she first freshens. If you wait until the cow's udder is nursed out, teat size in particular can't be accurately scored."

As cattle age suspensory ligaments begin to weaken with years of use, and udder structure becomes altered from multiple successive nursing intervals. This further highlights udder scoring as means by which producers can cull cattle voluntarily. Rasby (2011) even states "Udder conformation will decline as the female ages, but do not take age into account when assigning an udder score." The lack of an age adjustment supports the school of thought that unacceptable udder structure should be a trait producers cull for. Torell (2002) also remarks that it is best to score udders on an "as-is" basis and to not take cow age into account.

Udder Suspension

One half of the udder scoring system pertains to the suspensory ligament. This is called the Udder Suspension score and is a 1 to 9 scale. A score of one is undesirable and a score of 9 is ideal. A score of five is thought the be the average udder suspension score of a typical commercial cow (Rasby, 2011). Cattle who score below five are discouraged from being retained as replacements.

An udder suspension score of nine, the ideal, can best be described as an udder "placed tight to the body cavity, well above the hocks…" Rasby (2011) continues, "The quarters are mostly level form the side and rear view. The udder has high rear attachment and the median suspensory ligament is pronounced." The average commercial cow udder score of five can be described as a less prominent median suspensory ligament, which results in teats that point outward when the udder is full. Quarters are also unlikely to be level. Cattle who score between one and three should be culled and their udder suspension is best described as completely lacking, below the hock joint, with teats that do not point perpendicular to the surface. Rasby (2011) notes the difficulties this presents to nursing at calving, requiring producer intervention further highlighting the need to cull such females.

Teat Size

One half of the udder scoring system is Teat Size or Teat Shape. Considerable variation exists among teat conformation, but more centrally located smaller teats are most desirable (Rasby, 2011). Teats are frequently anecdotally categorized ranging from very small to very large, though cattle most often have just “small” to “intermediate” teats. Longer teats are more frequently observed to be thicker. The score system ranges from one to nine. With scores of 9 being the most desirable and 1 being unacceptable.

A score of nine is described by Rasby (2011) as very small teats in length, very symmetrical and rounded off at the tips, centrally located on the quarters and pointing straight to the ground. Scores ranging from six to nine are thought to be the average in the nations cow herd. An intermediate score of 5 describes teats that have a greater circumference, longer and not as symmetrical; they may not point perpendicular to the ground (Rasby, 2011). The least desirable teat score of one indicates thick cone shaped teats, that dangle far below the hock joint, resulting in greater difficulty for the calf to find a teat to nurse from. Rasby (2011) discourages retention of replacements between one and three.

Genetic Parameters of Phenotypic Traits

Phenotype can be defined as the physical appearance of an animal, which is the combination of genotype and environment. Heritability can be defined as the amount of phenotypic variation that is caused by genetic variation, not influenced by environmental or random effects. Increased heritability results in more realizable response to selection of the trait in question. The following are the heritability estimates of udder and teat traits in beef and dairy cattle both in the United States and abroad.

In dairy cattle Rupp and Boichard (1999) reported teat length heritability of 0.30. Degroot et al. (2002) reported teat length heritability of 0.29. Royal et al. (2002) reported teat length heritability of 0.33. Teat placement heritabilities in dairy cattle were reported as 0.26, 0.29, and 0.52 by Rupp and Boichard (1999), Royal et al. (2002), and Degroot et al. (2002) respectively. In beef cattle Kirschten et al. (2001) reported teat size heritability of 0.38. Sapp et al. (2003) reported teat size heritability of 0.21. Bradford (2013) found teat size heritability of 0.28.

Heritabilities for traits which are effected by udder suspension have also been reported. In dairy cattle udder depth heritabilities of 0.29, 0.33, and 0.23 were reported by Rupp and Boichard (1999), Royal et al. (2002), and Degroot et al. (2002), respectively. Rupp and Boichard (1999), Royal et al. (2002), and Degroot et al. (2002) found udder attachment heritabilities of 0.18, 0.21, and 0.37. In beef cattle Kirschten et al. (2001), Sapp et al. (2003), and Bradford (2013) reported udder attachment and suspension heritabilities of 0.33, 0.22, and 0.31, respectively.

These moderate heritabilities suggest producers can select for udder and teat quality and realize the effects of genetic change more readily. Teat and Udder Suspension heritabilities can be found in Tables 1.8 and 1.9.

Tables

Table 1.1. Cow Body Condition Score (BCS).

Condition Score	Appearance of Cow
1	Emaciated- Bone structure of shoulder, ribs, back, hooks and pins sharp to touch and easily visible. Little evidence of fat deposits or muscling.
2	Very thin—Little evidence of fat deposits but some muscling in hind quarters. The spinous processes feel sharp to the touch and are easily seen, with space between them
3	Thin—Beginning of fat cover over the loin, back and foreribs. Backbone still highly visible. Processes of the spine can be identified individually by touch and may still be visible. Spaces between the processes are less pronounced.
4	Borderline—Foreribs not noticeable; 12^{th} and 13^{th} ribs still noticeable to the eye, particularly in cattle with a big spring of rib and ribs wide apart. Full but straightness of muscling in the hindquarters. The transverse spinous processes can be identified only by palpation (with slight pressure) to feel rounded rather than sharp.
5	Moderate—12^{th} and 13^{th} ribs not visible to the eye unless animal has been shrunk. Areas on each side of the tail head are fairly well filled but not mounded. The transverse spinous processes can only be felt with firm pressure to feel rounded—not noticeable to the eye. Spaces between processes not visible and only distinguishable with firm pressure
6	Good—Ribs fully covered, not noticeable to the eye. Hindquarters plump and full. Noticeable sponginess to covering of forerib and on each side of the tail head. Firm pressure now required to feel transverse process.
7	Very good—Abundant fat cove on either side of the tail head with some patchiness evident. End of the spinous processes can only be felt with firm pressure. Spaces between processes can barely be distinguished at all.
8	Fat—Animal taking on a smooth blocky appearance; bone structure disappearing from sight. Far cover thick and spongy with patchiness likely.
9	Very fat—Bone structure not seen or easily felt. Tail head buried in fat. Animal's mobility may actually be impaired by excess amount of fat.

Adapted from Herd and Sprott (1986).

Table 1.2. Udder Suspension

1	Median suspensory ligament is absent resulting in a loose and pendulous attachment of the udder. The udder suspends below the hocks and teats reside below the hock. Quarters are not level and teats are not perpendicular to the ground when filled with milk.
3	The median suspensory ligament is vague resulting in loose attachment of the udder. The udder is suspended down to the hocks of the cow meaning that the teats reside below the hock. The quarters are not level and teats splay in an outward direction that is very pronounced when engorged with milk.
5	The median suspensory ligament is less pronounced and the udder is suspended farther form the body cavity. The teats begin to splay slightly outward when engorged with milk because of the weaker ligament. Quarters may not be level.
7	Similar to an udder suspension score of 9, but the udder is suspended slightly farther form the body cavity. The median suspensory ligament is pronounced keeping the udder level and suspending the teats perpendicular to the ground and above the hock. Because the medium suspensory ligament is pronounced, the teats suspend perpendicular to the ground when filled with milk.
9	The udder is placed tight to the body cavity, well above the hocks and close to the body cavity. The quarters are mostly level from the side and rear view. The udder has high rear attachment and the median suspensory ligament is pronounced.

Adapted from Rasby (2011).

Table 1.3. Teat Size

1	The teats are long, appear thick, and usually large and funnel/pear shaped. Teats suspend well below the hock which makes it difficult for a new-born calf to find, attach, and suckle. Intervention is required at calving.
3	The teats are long and large in diameter, appear thicker, and not symmetrical. They may appear to be funnel shaped. The teats may appear to begin to balloon at the point of attachment to the quarter. Because the teats are long, they are usually suspended below the hock. When engorged with milk, teats will not be perpendicular to the ground.
5	Teats are longer, larger in diameter, appear to be thicker, and are less symmetrical compared to teat size 9,8,7 and 6. They may not be perpendicular to the ground or centered on the quarters.
7	Similar to teat score 9, but the teats are longer. Teats are located in the center of the quarters and face perpendicular to the ground.
9	Teats are very small in length, rounded at the ends, and symmetrical. Teats are located in the center of the quarters and face perpendicular to the ground.

Adapted from Rasby (2011).

Table 1.4. Foot Angle Heritabilities

	Overall Foot Angle	Overall Front	Overall Rear	Inside Front	Outside Front	Inside Rear	Outside Rear
Van Dorp et al. (2004)	0.10						
Perez-Cabal et al. (2006)	0.12						
Laursen et al. (2009)	0.13						
Hahn et al. (1984)				0.38	0.40	0.55	0.85
Jensen (2017)		0.20	0.19				
Jeyaruban et al. (2012)		0.50	0.35				

Table 1.5. Heel Depth Heritabilities

	Front Heel Depth	Rear Heel Depth
Hanh et al. (1984)	0.58	0.19
Jensen (2017)	0.17	0.25

Table 1.6. Hoof Area Heritabilities

	Front Hoof Area	Rear Hoof Area	Overall Foot Area
Hahn et al. (1984)	0.46	0.34	
Jensen (2017)			0.36

Table 1.7. Claw Set and Shape Heritabilities

	Front Claw Shape	Rear Claw Shape	Front Claw Set	Rear Claw Set
Jeyaruban et al. (2012)	0.18 - 0.33	0.36 - 0.46	0.46	0.42
Jensen (2017)			0.09	0.17

Table 1.8. Teat Size, Shape and Placement Heritabilities

	Teat Length	Teat Placement	Teat Size
Rupp & Boichard (1999)	0.3	0.26	
Royal et al. (2002)	0.33	0.29	
Degroot et al. (2002)	0.29	0.52	
Kirschten et al. (2001)			0.38
Sapp et al. (2003)			0.21
Bradford (2013)			0.28

Table 1.9. Udder Suspension, Depth and Attachment Heritabilities

	Udder Depth	Udder Attachment
Rupp & Boichard (1999)	0.29	0.18
Royal et al. (2002)	0.33	0.21
Degroot et al. (2002)	0.23	0.37
Kirschten et al. (2001)		0.23
Sapp et al. (2003)		0.22
Bradford (2013)		0.31

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Chapter 2 Foot Scoring Effects on Cow and Calf Performance

Abstract

Foot soundness is essential for optimum performance in beef cattle. The objective of this study was to investigate the effects of foot angle (FA) and claw set (CS) scores on cowherd performance. Data were analyzed for 580 observations of Angus-based cows over a four-year period. At weaning, FA and CS were evaluated. Scores are based on a nine-point scale. A score of one indicates straight pasterns, and divergent toes; nine indicates weak pasterns and curled toes. Cows that exhibited scores from four to six were considered acceptable. Cows that exhibited scores outside this range were considered undesirable. All cows were evaluated for age and performance traits including pre-breeding weight (PBW), pre-breeding body condition score (PBCS), pregnancy rate, calf birthweight (BW), calf weaning weight (WW), calf adjusted weaning weight (AWW), cow body weight at weaning (CWW), and weaning body condition score (WBCS). Data were analyzed using the GLIMMIX procedure of SAS. Significance was declared at $P \leq 0.05$. Acceptable cows had a WBCS 10.14% greater ($P < 0.01$) compared to undesirable cows. Acceptable cows possessed an average WBCS of 4.83 compared to 4.34 in undesirable cows. Acceptable cows were 9.50% younger ($P = 0.05$) than undesirable cows. The mean age for acceptable cows was 4.67 compared to 5.16 in undesirable cows. The results from this study suggest that cows with acceptable foot scores may maintain more desirable BCS and that foot soundness decreases with age. These results could be used to help predict cow performance based on FA and CS.

Key Words: Claw Set, Foot Angle, Body Condition Score, Cow Performance, Foot Soundness

Introduction

Cow efficiency and resulting longevity have become traits of increased economic relevance to cow-calf producers as rising input costs, volatile markets, and ever-changing environmental hardships increasingly reduce profit margins. Cost reduction is one of the easiest means by which producers can increase profit margins, and increasing longevity reduces the costs associated with developing or purchasing new replacement females (Forabasco et al., 2004). Longevity in beef cattle is defined as the measure of productive life from first calving to culling. Cattle are culled for voluntary and involuntary reasons. To be culled voluntarily would be for lack of performance or economic reasoning, such as failing to calve in regular intervals. Involuntary culling would be due to reasons beyond the producers control such as death or disease. Ducrocq et al. (1988) defines longevity corrected for *voluntary* culling as functional longevity, while actual age was defined as true longevity.

Gadberry (2010) states that longevity is influenced by sound hips, hocks and feet. Industry rhetoric associates moderation of frame, and sound feet and legs with increased longevity, so producers are more likely to retain females who possess these traits. Daniel and Kriese-Anderson (2013) note the importance of structural soundness stating that "a farmer may produce cattle that excel in muscle, maternal ability, and feed efficiency, but if cattle cannot walk easily from feed source to water source then all else has been in vain." Selection for structural soundness in breeding stock when choosing replacements and herd sires is essential to ensure survival and productivity in a pasture situation.

Foot and leg structure impacts the likelihood of a cow to be culled, according to (Forabasco et al., 2004). Arthur et al. (1992) found that after reproductive failure, calf survival, dystocia, and udder problems, culling for feet and leg issues is one of the most common reasons beef cows were culled from the herd.

Heritability can be defined as the amount of phenotypic variation that is caused by genetic variation, not influenced by environmental or random effects. Greater heritability results in greater response to selection of the observed trait. With the low to moderate heritabilities reported for foot conformation traits (Jeyaruban et al., 2012) (Jensen, 2017), breeders of cattle are able to select for these traits and observe the effects of genetic change.

Selection for structural integrity should reduce culling for lameness and increase the longevity of the herd. Therefore, the objective of this research was to investigate the effects of foot angle and claw set scores on production traits in the University of Arkansas beef research cowherd located near Fayetteville, Arkansas.

Materials and Methods

This study was conducted at the University of Arkansas' Cow Calf Unit located in Savoy, Arkansas. All methods and procedures were approved by the University of Arkansas' Institutional Animal Care and Use Committee (approval #19117) before to the beginning of the study.

Data were analyzed for 580 observations on Angus-based cows ($n \approx 200$) in a fall calving system over a four-year period.

At weaning, foot angle (FA) and claw set (CS) scores were assigned in accordance with American Angus Association guidelines. FA and CS scores range from one to nine and can be described as intermediate optimum traits, where a score of five is ideal. A FA score of one indicates an extremely straight, upright pastern angle and a short toe; a score of nine indicates an extremely week pastern and long toe. A FA score of five indicates a pastern with a 45-degree angle, appropriate length of toe and desirable depth of heel. A CS score of one indicates extremely divergent toe spread and a score of nine indicates close, collectively gathered, and curled toes. A CS score of five indicates symmetrical, evenly spaced toes. Cows that exhibited FA and CS scores ranging from four to six were considered “acceptable”. If either score fell outside this range, the cow was considered “undesirable”. Cattle who received undesirable scores, and cattle who displayed various locomotive disorders had their feet trimmed two weeks after weaning and scoring.

Acceptable and undesirable cows were evaluated for age and performance traits including pre-breeding weight (PBW), pre-breeding body condition score (PBCS), pregnancy rate, calf birthweight (BW), calf weaning weight (WW), calf adjusted weaning weight (AWW), cow weight at weaning (CWW), and cow body condition score at weaning (WBCS). Adjusted weaning weight was adjusted for calf sex and cow age. Pre-breeding data came from the following breeding season after weaning.

Statistical Analyses

Data were analyzed using the GLIMMIX procedure of SAS. Significance was declared at $P \leq 0.05$ and tendencies were observed at $0.05 < P \leq 0.1$. The fixed effect was foot score acceptability. The main effects observed for were age, PBW, PBCS, pregnancy rate, BW, WW, AWW, CWW, and WBCS. The experimental unit was the cow.

Results and Discussion

Cow Performance

Cattle with acceptable foot scores were 10.39% younger ($P = 0.05$) than cattle with undesirable foot scores, where cattle with acceptable foot scores were on average 4.67 years of age compared to cattle with undesirable foot scores that were on average 5.15 years of age. See figure 2.1 for descriptions of cow age results. Pre-breeding weight was unaffected by foot score acceptability (P = 0.64); however, cattle who displayed acceptable foot scores recorded an average PBW of 539.71 kg. compared to cattle who displayed undesirable foot scores that recorded and average PBW of 530.49 kg. Cattle with acceptable foot scores tended to display a PBCS 2.21% greater (P = 0.07) than cattle with undesirable foot scores, where cattle with acceptable foot scores displayed an average PBCS of 5.44 compared to cattle with undesirable foot scores that displayed an average PBCS of 5.32. See figure 2.2 for descriptions of PBCS results. While unaffected by foot score acceptability (P = 0.88), cattle with acceptable and undesirable foot scores both displayed a pregnancy rate of 95%. Though unaffected by foot score acceptability (P = 0.32), cattle with acceptable foot scores recorded an average CWW of 505.32 kg. compared to cattle with undesirable foot scores that recorded an average CWW of 499.61 kg. Cattle with acceptable foot scores did display a WBCS 10.14% greater (P = 0.01) than cattle with undesirable foot scores, where cattle with acceptable foot scores possessed an average WBCS of 4.83, compared to cattle with undesirable foot scores who possessed an average WBCS of 4.34. See figure 2.3 for descriptions of WBCS results.

Calf Performance

Though unaffected by dam's foot conformation (P = 0.34), offspring of acceptable cows recorded an average BW of 30.70 kg. compared to offspring of undesirable cows who recorded an average BW of 30.26 kg. Unaffected by foot score acceptability (P = 0.52), offspring of acceptable cows recorded an average WW of 228.55 kg. compared to offspring of undesirable cows who recorded an average WW of 226.68 kg. Similarly, though unaffected by dam's foot acceptability (P = 0.12), the offspring of cows with acceptable foot scores recorded an average AWW 3.95 kg. greater than offspring of cows with undesirable foot scores. Offspring of cows with acceptable foot scores recorded an average AWW of 228.20 kg. compared to offspring of undesirable cows who recorded an average AWW of 224.25 kg.

Discussion

The results from this study suggest that foot conformation and subsequent foot scores decline with age. Cattle bear the majority of their weight on their front limbs, and as they develop to mature size the added body weight causes the shoulder, knee, and hock joints to become less stable and subsequently pastern joints weaken resulting in longer, curled toes, as more weight is placed on the heel as opposed to the center of the foot. Alternatively, Jensen (2017), and Jeyaruban et al. (2012) reported moderate heritabilities for FA and CS. The results from this study may suggest that since implementing foot scoring into the management system, foot conformation has become more desirable in the University of Arkansas beef research herd.

The results from this study also suggest that cows with acceptable foot scores may maintain a more desirable BCS throughout the production cycle. These results suggest cattle with acceptable foot scores can move with greater ease to feed, water, and mineral resources. This is of great importance for fall calving systems, where cows are expected to nurse, wean calves, and re-breed during a time of decreased forage quality, quantity and nutrient availability. Additionally, cows are expected to raise calves during the coldest and often wettest months of the year in Northwest Arkansas, requiring them to travel to these critical resources on wet, muddy, and often eroded, rocky terrain. The increased BCS at weaning of acceptable cows compared to undesirable cows is most likely explained by the ability of acceptable cows to walk with more ease and comfort to critical resources, allowing them to maintain flesh while simultaneously providing for their calves. The tendency for increased BCS prior to breeding could be explained similarly; the cow must walk on the foot scored at weaning until she calves and is rebred. It is likely that the cow is able to access more quality forage through the summer and early fall allowing her to regain and maintain flesh more easily during mid to late gestation and calving.

The increased BW of calves born to acceptable cows in this fall calving system could possibly be explained their ability to accesses greater amounts of high quality forage post-weaning into the summer months. However, this data could also be interpreted as contradictory to cow age results. It is commonly thought that older cows give birth to heavier calves and the preceding results suggest that cattle with undesirable foot scores are older. Birthweight was statistically insignificant, which is likely the reason for this inconsistency. Regardless, heavier birthweights when not extreme are thought by the industry to result in increased calf health and vigor.

Though statistically insignificant, the increased WW and AWW of calves born to acceptable cows could be explained by their dam's ability to provide a greater volume of more nutrient dense milk, as she is able to access critical resources more easily during early to mid-lactation when the calf's rumen is developing. An increased weaning weight would likely result in greater profit margins for the vast majority of small and mid-size cow-calf producers who market their calf crops at weaning.

Conclusion

The results from this study suggest that cows with acceptable foot scores perform at a more optimum level than cows with undesirable foot scores, and that foot quality decreases with age. The significant increase in BCS for acceptable cows throughout the production cycle could influence cow-herd efficiency and further investigation into subsequent calf performance could explain the anecdotal evidence of acceptable cows weaning heavier calves. Ultimately, foot scoring beef cattle may be a means by which producers can enhance cow performance and longevity.

Figures

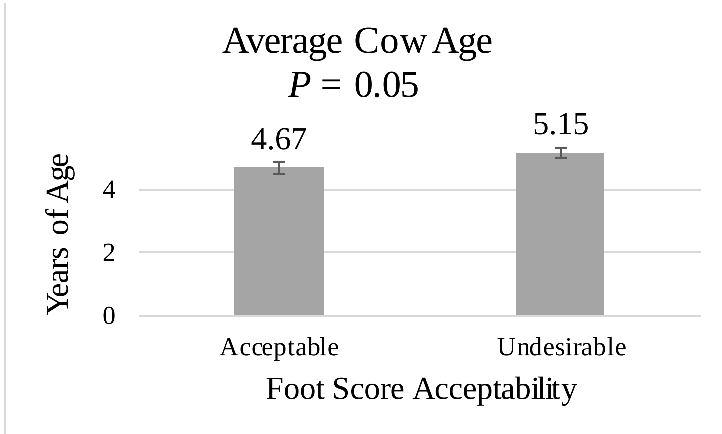


Figure 2.1 Foot Score Acceptability Effects on Cow Age

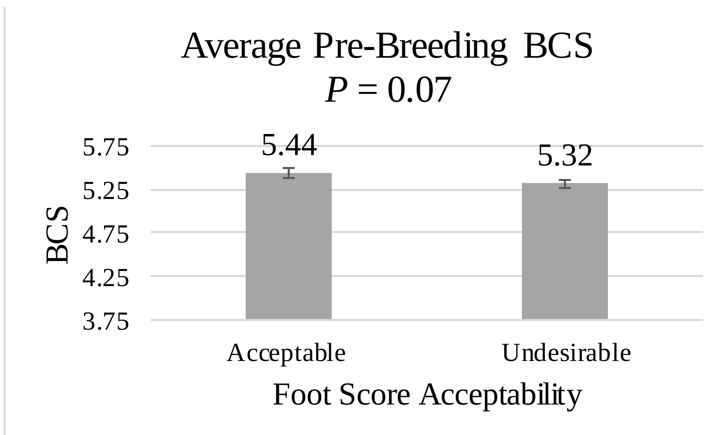
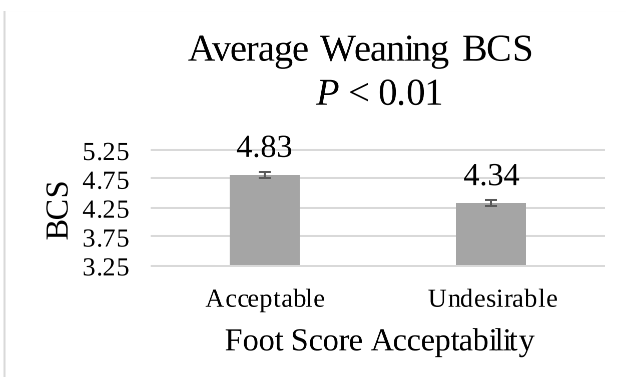


Figure 2.2 Foot Score Acceptability Effects on Pre-Breeding Body Condition Score



2.3 Foot Score Acceptability Effects on Weaning Body Condition Score

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Chapter 3 Udder Scoring Effects on Cow and Calf Performance

Abstract

Research has suggested that selection for udder structure may result in increases calf performance. The objective of this study was to investigate the effects of udder suspension (US) and teat size (TS) scores on cowherd performance. Data were analyzed for 1105 observations on Angus-based cows over a four-year period. At weaning, US and TS were evaluated. Scores are based on a nine-point scale. A score of one indicates a pendulous attachment and bottle shaped teats. A score of nine indicates a tight attachment and refined evenly spaced teats. Both mature cows and first calf heifers were evaluated. Cattle with US and TS scores ranging between 4 and 8 were evaluated for age and performance traits including cow weaning weight (CWW), weaning body condition score (WBCS), weaning weight (WW), adjusted weaning weight (AWW), and adjusted weaning performance (AWP). Data were analyzed using the GLIMMIX procedure of SAS. Significance was declared at $P \leq 0.05$. There were no US differences ($P \geq 0.24$) for WBCS. There were no TS differences ($P \geq 0.13$) for CWW, WBCS, WW, AWW, and AWP. Cattle with US scores of 4 were on average the oldest ($P < 0.01$) at 7.75 years of age. Cattle with TS scores of 8 were on average the youngest ($P < 0.01$) at 3.20 years of age. Cattle with US scores of 4 weaned the heaviest calves ($P < 0.01$) at 246.92 kg. These results could be used to help predict cowherd performance base on US and TS.

Key Words: Udder Suspension, Teat Size, Cow Performance, Calf Performance

Introduction

As input cost continue to rise, longevity has become an increasingly important aspect of beef production. Regardless of production goals or marketing systems, the longer the productive life of the cow, the fewer replacements are necessary for optimum production (Bradford et al., 2013). As an emphasis on growth and performance has taken precedent, increased milk production and milk yield are some of the easiest ways to increased calf performance in the beef industry (Beard et al., 2018).

Though teat and udder conformation has traditionally been thought of as a convenience trait, particularly in beef cattle, numerous studies have reported the benefits of proper udder structure. Research has also confirmed the moderate heritability of udder traits in beef cattle, suggesting that selection for udder conformation could potentially result in genetic progress for cow-calf operations.

Proper teat and udder structure has been frequently anecdotally thought to reduce labor costs, impact calf mortality, result in heavier weaning weights and decrease the demand for purchasing and developing replacement females (Bradford et al., 2013). Poor udder quality may result in increased incidences of mastitis and injury as well as reduced immunity to calves unable to obtain colostrum. This is of great importance to commercial cattlemen, as many expect their cattle to be relatively problem free and less intensively managed. This has resulted in emphasis on selection for cattle with desirable udder conformation.

Though it is thought culling for udder quality is merely for convenience, taking into account the reduction of labor cost and subsequent increased calf performance could be the drivers behind increased profitability for producers who emphasize udder quality. This is further supported by Goonewardene et al. (2003) who found that cattle with "bottle teats" weaned lighter calves than those with desirable teats. This is especially important for great portion of beef producers who market their calves at weaning.

Selection for proper udder conformation should reduce the incidences of cow and calf disease, and decrease the incidences of culling, resulting in greater calf performance and increased cow longevity. Therefore, the objective of this study was to investigate the effects of udder suspension (US) and teat size (TS) scores on cow and calf performance in the University of Arkansas cowherd located at the beef research unit in the Savoy community near Fayetteville, Arkansas.

Materials and Methods

This study was conducted at the University of Arkansas' Cow Calf Unit located in Savoy, Arkansas. All methods and procedures were approved by the University of Arkansas' Institutional Animal Care and Use Committee (approval #19117) before to the beginning of the study.

Data were analyzed for 1105 observations on Angus-based cows ($n \approx 200$) in a fall calving system over a four-year period.

At weaning, US and TS scores were assigned in accordance with BIF (2016) guidelines. US and TS scores are assigned on a nine-point scale. An US score of one indicates an extremely weak median suspensory ligament, loose pendulous quarters, with the udder distending below the hock joints. Teats will not be perpendicular to the ground and intervention is likely necessary at calving in cows assigned US one. A US score of nine indicates an udder that is tight to the body wall, above the hock joint, with level quarters both front and rear, supported by a prominent median suspensory ligament. A TS score of one indicates thick, abnormally large, cone shaped teats, which hang loosely below the hock joints. This often results in mastitis and require intervention at calving to facilitate nursing. When there is variation among teats, the worst scoring teat is recorded.

Cattle with US and TS scores ranging from four to eight were analyzed for age and performance traits including cow weaning weight (CWW), weaning body condition score (WBCS), calf weaning weight (WW), calf adjusted weaning weight (AWW), cow weaning performance (WP), and cow adjusted weaning performance (AWP). AWW and AWP was adjusted for dam age and calf sex. WP was calculated by dividing WW by CWW.

Statistical Analyses

Data were analyzed using the GLIMMIX procedure of SAS. Significance was declared at $P \leq 0.05$ and tendencies were observed at $0.05 < P \leq 0.1$. The fixed effects were US and TS scores ranging from four to eight. Outliers for US and TS score, and cow age were removed to reduce statistical differences. The model included co-variables for year and cow age. The main effects observed for were age, CWW, WBCS, WW, AWW, WP, and AWP. The experimental unit was the cow.

Results and Discussion

Cow Performance

Cattle with US scores of four were the oldest ($P < 0.01$) with an average age of 7.75. Cattle with US scores of seven and eight were the youngest ($P < 0.01$) with an average age of 3.85 and 3.31, respectively. Cattle with US scores of five and six were on average 6.47 ($P < 0.01$) and 4.53 ($P < 0.01$) years of age, respectively.

Cattle with TS scores of five and six were older ($P < 0.01$) compared to cattle with TS scores of seven and eight, where cattle with score of five and six were on average 6.26 and 5.37

years of age compared to 4.38 and 3.20 for TS of 7 and 8, respectively. Cattle with TS scores of four were older ($P < 0.01$) compared to cattle with TS scores of eight, where cattle with TS scores of four were on average 5.14 years of age and cattle with TS scores of eight were on average 3.20 years of age.

Cattle with US scores of five recorded an average CWW of 522.58 kg. and were heavier ($P < 0.01$) than cattle with US score of six and seven, who recorded average weights of 498.00 kg and 491.31 kg., respectively. This observation is likely due to the age difference between these groups.

Cattle with US scores of four possessed the greatest ($P = 0.02$) WP at 48.87% compared to cattle with US scores of seven and eight who possessed a WP of 45.14% and 42.38%, respectively. Cattle with US scores of five and six possessed a WP greater ($P = 0.02$) than cattle with an US score of eight and recorded WP values of 46.67% and 45.95%, respectively.

Conversely, cattle with US scores of seven and six possessed the greatest ($P = 0.03$) AWP compared to cattle with US scores of five, where cattle with US scores of seven and six recorded AWP values of 47.22% and 46.62% respectively compared to cattle with a US score of 5 who recorded AWP values averaging 43.92%.

There were no statistical differences ($P > 0.13$) for TS when compared to WBCS, CWW, WP, or AWP. There were no statistical differences ($P = 0.24$) for US when compared to WBCS. Cow performance results for US and TS are displayed in Tables 3.1 and 3.2.

Calf Performance

Cattle with US scores of four and five weaned calves weighing on average 246.92 kg. and 241.49 kg., respectively and were heavier ($P < 0.01$) than calves weaned by cattle who recorded US scores of six, seven and eight. Cattle with US scores of six weaned heavier calves ($P < 0.01$) than cattle who recorded US scores of seven and eight, where cattle with US scores of six recorded WW values of 226.25 kg. compared to 218.23 kg. and 209.16 kg., respectively.

Cattle with US scores of four and five recorded AWW values of 240.11 kg. and 232.46 kg., respectively and were adjusted to heavier weights ($P < 0.01$) than calves weaned by cows with US scores of six and seven, where cattle who scored US of six and seven possessed an AWW of 224.56 kg. and 221.97 kg., respectively.

Calf performance was unaffected ($P > 0.79$) by TS. Calf performance results are displayed in tables 3.3 and 3.4.

Discussion

Poor udder conformation and teat structure has been shown to affect calf mortality and reduce cow longevity (Wythe, 1970; Frisch, 1982). Beard et al. (2018) found that steer calves nursing dams with desirable udder structure possessed heavier carcass weights, however; no differences were found between calves nursing desirable or undesirable udders in the pre-weaning phase.

The differences found in age are likely due to the weakening of the median-suspensory ligament over time. This could also explain the enlargement of teats with age, as they become less centralized and evenly space, and become more prone to injury and infection.

Heavier CWW can be explained similarly, cattle who possessed lower US scores were on average older. Mature cows in the same production system are most often larger than first calf heifers and young cows. This also could explain the greater WP, WW, and AWW of cattle with lower US scores, as older cows are generally thought to wean heavier calves. The adjustment for dam age may also explain the AWP results which directly oppose WP results; where younger cows weaned lighter calves until their young age was taken into account. This supports the idea that cattle with more desirable udder structure may raise higher performing calves.

Teats likely had no effect on cow and calf performance, as the worst teat is scored, and three other higher functioning, or more desirable teats remain.

Conclusion

The results from this study suggest that US and TS scores decline with age, and that the BIF udder scoring system should likely be used to determine when to cull replacements based on udder quality, and as an aid to select replacements by evaluating the dam's udder conformation. US scores may affect cow and calf performance, however; these differences are likely due to cow age.

Tables

Table 3.1. Udder Suspension Effects on Cow Performance

Item[2]	Suspension					SEM	*P* Value[1]
	4	5	6	7	8		
Age	7.75[a]	6.47[b]	4.53[c]	3.85[d]	3.31[d]	0.33	< 0.01
CWW	506.47[ab]	522.58[a]	498.00[b]	491.31[b]	506.23[ab]	15.32	< 0.01
WBCS	4.26[ab]	4.68[a]	4.60[ab]	4.57[ab]	4.64[ab]	0.11	0.24
WP	48.87[ab]	46.67[ab]	45.95[ab]	45.14[cb]	42.38[c]	4.78	0.02
AWP	45.53[ab]	43.92[b]	46.62[a]	47.22[a]	46.35[ab]	1.10	0.03

1 Significance was declared at $P \leq 0.05$ and tendencies were observed at $0.05 < P \leq 0.1$.

2 CWW, cow weaning weight; WBCS, weaning body condition score; WP, weaning performance; AWP, adjusted weaning performance

Table 3.2. Teat Size Effects on Cow Performance.

Item[2]	Teat					SEM	*P* Value[1]
	4	5	6	7	8		
Age	5.14[ab]	6.26[a]	5.37[a]	4.38[b]	3.20[c]	0.34	< 0.01
CWW	504.22[a]	507.54[a]	509.59[a]	495.37[a]	494.28[a]	15.11	0.13
WBCS	4.36[a]	4.60[a]	4.67[a]	4.50[a]	4.73[a]	0.11	0.15
WP	46.02[a]	45.32[a]	45.53[a]	46.56[a]	45.71[a]	0.95	0.72
AWP	45.29[a]	46.01[a]	45.73[a]	45.55[a]	46.37[a]	0.99	0.75

1 Significance was declared at $P \leq 0.05$ and tendencies were observed at $0.05 < P \leq 0.1$.

2 CWW, cow weaning weight; WBCS, weaning body condition score; WP, weaning performance; AWP, adjusted weaning performance.

Table 3.3. Udder Suspension Effects on Calf Performance

Item[2]	Teat					SEM	*P* Value[1]
	4	5	6	7	8		
WW	246.92[a]	241.49[a]	226.25[b]	218.23[c]	209.16[c]	8.96	< 0.01
AWW	240.11[a]	232.46[a]	224.56[b]	221.97[b]	224.87[ab]	8.06	0.01

1 Significance was declared at $P \leq 0.05$ and tendencies were observed at $0.05 < P \leq 0.1$.

2 WW, weaning weights; AWW, adjusted weaning weights.

Table 3.4. Teat Size Effects on Calf Performance

Item[2]						SEM	*P* Value[1]
	4	5	6	7	8		
WW	229.73[a]	227.43[a]	228.98[a]	227.48[a]	222.73[a]	9.06	0.85
AWW	221.13[a]	224.35[a]	226.81[a]	228.02[a]	224.89[a]	8.02	0.79

1 Significance was declared at $P \leq 0.05$ and tendencies were observed at $0.05 < P \leq 0.1$.

2 WW, weaning weights; AWW, adjusted weaning weights.

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Conclusion

In conclusion, foot scoring may result in increased cow performance. If measures are taken to select for proper foot conformation, an increase in cow body condition score may be seen. Udder scoring may also result in increased cow and calf performance, as younger cows may have more desirable udders, and cows with more desirable udder scores may wean heavier calves. The results from this study suggest that selection for proper foot and udder structure may result in phenotypic and genetic progress for producers.

Appendix

UNIVERSITY OF ARKANSAS

Office of Research Compliance

To:	Jeremy Powell
Fr:	Craig Coon
Date:	June 17th, 2019
Subject:	IACUC Approval
Expiration Date:	June 6th, 2022

The Institutional Animal Care and Use Committee (IACUC) has APPROVED your protocol # **19117:** *Enhancing sustainability of beef cattle production in Southern and Central US through genetic improvement.*.

In granting its approval, the IACUC has approved only the information provided. Should there be any further changes to the protocol during the research, please notify the IACUC in writing (via the Modification form) prior to initiating the changes. If the study period is expected to extend beyond June 6th, 2022 you must submit a newly drafted protocol prior to that date to avoid any interruption. By policy the IACUC cannot approve a study for more than 3 years at a time.

The following individuals are approved to work on this study: Jeremy Powell, Bryan Kutz, Clay McGuire, Reagan Cauble, and Toby Lester. Please submit personnel additions to this protocol via the modification form prior to their start of work.

The IACUC appreciates your cooperation in complying with University and Federal guidelines involving animal subjects.

CNC/tmp