Genetics of Udder Quality in Beef Cattle

Heather Bradford

Kansas State University

Introduction

Beef production is a billion dollar industry in the United States (USDA, 2012). With increasing cost of production, producers are faced with the challenge of reducing costs to remain profitable and efficient. Seedstock producers are responsible for the genetics that are used in the commercial segment for beef production. Thus, seedstock producers have many economically important traits to consider in their selection program. One potential trait for producers to consider is udder quality because better udder quality reduces labor costs and increases cow longevity (Wythe, 1970; Frisch, 1982).

Review of Literature

Importance of Udder Quality

Newborn calves need to nurse unassisted, particularly in range conditions where assisting those calves may not be feasible. Dam udder type is one factor that affects the calf's ability to nurse. Calves had difficulty nursing when the dams have poor udder attachment or teat sizes of either extreme (Wythe, 1970; Edwards, 1982; Ventorp and Michanek, 1992). Poor udder quality resulted in delayed consumption of colostrum, which was important for immunity. Therefore, calf mortality rates were higher when dams had large teats and pendulous udder suspension (Frisch, 1982). Thus, improving udder quality can be beneficial to producers through reducing the amount of labor associated with assisting calves to nurse and increasing the number of calves weaned per cow, an important measure of efficiency.

Mastitis involves an inflammation of the mammary gland resulting from bacteria. Infection rates in beef cows ranged from less than 10% to upwards of 66% (Haggard et al., 1983; Watts et al., 1986; Simpson et al., 1995; Paape et al., 2000; Dueñas et al., 2001; Lents et al., 2002). Cows with poor udder attachment were at a greater risk of developing mastitis because the udder came into contact with more fecal matter and bacteria (DeGroot et al., 2002; Rupp and Boichard, 2003). Infected cows then weaned lighter calves, reducing the pounds of sale weight at weaning (Watts et al., 1986; Newman et al., 1991; Paape et al., 2000). Mastitis can cause blind, unproductive quarters. Cows with at least one blind quarter weaned light weight calves due to the reduction in milk production (Dueñas et al., 2001; Lents et al., 2002). Improving udder attachment decreased the prevalence of mastitis and helped prevent the subsequent reduction in calf weight.

Because many beef producers sell feeders calves, calf weaning weight is one of the most important traits affecting revenue. Dam udder type has impacted calf growth and performance (Goonewardene et al., 2003). Cows with extremely large or small teats weaned light weight calves (Wythe, 1970; Frisch, 1982; Goonewardene et al., 2003). The difference in calf weight could be attributed to a difference in milk production because milk yield accounted for approximately 60% of the variation in calf weaning weight (Jeffery and Berg, 1971; Rutledge et al., 1971). Based on these studies, cows with intermediate teat sizes were most desirable for producing more pounds of calf at weaning.

Udder quality is one of many factors considered by producers when culling cows from the herd. Poor udder quality, defined by large teats, pendulous udder suspension, or mastitis, ranked as one of the top reasons for culling aged cows (Greer et al., 1980; Frisch, 1982). No significant difference in culling for udder problems was found across breeds in Canadian data (Arthur et al., 1992). Udder quality continuously declined with age; therefore, more aged cows were culled for this reason. By improving udder quality, cows remained in the herd longer resulting in the need for fewer replacement heifers. Replacement heifer development is a significant cost to producers; so, increasing cow longevity should result in more efficient and economical beef production.

Measuring Udder Quality

The American Hereford Association (AHA) initially recommended producers record an overall udder score, which combines suspension and teat size into a single score (Denton, 2007). This scoring system is displayed in Figure 1.1 (MacNeil and Mott, 2006). Then, the Beef Improvement Federation (BIF) created udder scoring guidelines in July 2008, which have been adopted by many of the beef breed associations including the AHA (Ward, 2012). In August 2008, the AHA stopped collecting overall scores and switched to recording suspension and teat size scores (Ward, 2012). The BIF guidelines recommend scoring udder suspension and teat size as separate traits (BIF, 2010). These guidelines are shown in Figure 1.2 (BIF, 2010). All 3 types of scores are subjective and are recorded on a one to nine scale, scores of nine are considered ideal. These traits should be scored within 24 hours after calving and should be recorded by the same person within a herd (BIF, 2010). Scoring by a single person helps ensure that scores are consistent within a contemporary group so accurate comparisons can be made among individuals for genetic evaluation purposes.

Dairy breed associations record data on more udder type traits than the beef industry. Holstein Association USA, Inc. (2012) has a scoring system for fore udder attachment, front teat placement, rear udder height, teat length, rear udder width, udder tilt, udder cleft, rear teat placement, and udder depth. These scores are recorded on a 1 to 50 scale with either scores of 25 or 50 being most desirable, depending on the trait (Holstein Association USA, Inc., 2012). These scores are often associated with a quantifiable measurement of the udder. For example, a teat length of 2.25 inches is equivalent to a score of 25 (Holstein Association USA, Inc., 2012). Trained evaluators travel to farms to score cows making these scores less subjective than those recorded in the beef industry. The other dairy associations also have programs to collect similar udder type traits and use the data in genetic evaluations.

Genetic and Phenotypic Parameters

Heritability

Heritability is the proportion of phenotypic variation that is explained by additive genetics. A phenotype results from the combination of additive genetics, gene combination value, environment, and the interaction between genetics and environment. The equation for calculating heritability is where σ_a^2 is the additive genetic variance and σ_p^2 is the phenotypic variance. This measure is important because the higher the heritability, the greater the response to selection because additive genetics, which are passed from parent to offspring, have a relatively large role in determining a phenotype.

Most research on udder type traits has been in the dairy industry because these traits are of greater importance. Heritabilities for teat size in dairy cattle range from 0.29 to 0.33 (Rupp and Boichard, 1999; DeGroot et al., 2002; Royal et al., 2002). Similarly, heritabilities in Simmental and Gelbvieh cattle were 0.38 and 0.21, respectively (Kirschten et al., 2001; Sapp et al., 2003). The dairy industry measures different types of udder suspension including fore and rear udder attachment. Udder attachment heritabilities for dairy cows ranged from 0.18 to 0.37 (Rupp and Boichard, 1999; DeGroot et al., 2002; Royal et al., 2002). The heritabilities of attachment in Simmental and Gelbvieh cows were 0.23 and 0.22, which were in the range estimated in the dairy industry (Kirschten et al., 2001; Sapp et al., 2003). In addition, the heritability of a total udder score, considering both suspension and teat size, was 0.23 in Line 1 Herefords (MacNeil and Mott, 2006). The heritability of udder quality in beef cows was very similar to that seen in the dairy industry. Thus, udder quality is moderately heritable, and genetic progress can be made through genetic selection.

Repeatability

Repeatability measures the strength of the relationship between repeated records in a population. The equation for calculating repeatability is where σ_a^2 is additive genetic variance, σ_c^2 is permanent environmental variance, and σ_p^2 is phenotypic variance. The first record for a highly repeatable trait is a good indicator of future performance, but the first record for a lowly repeatable trait is a poor indicator of future performance. MacNeil and Mott (2006) found a repeatability of 0.34 for udder scores, making udder quality a moderately repeatable trait. Estimates of repeatability in dairy cows ranged from 0.36 to 0.51 (Gengler et al., 1997). Fore udder attachment was one of the least repeatable traits, and teat length was one of the most repeatable traits (Gengler et al., 1997). The potential difference between industries was likely due to how the traits were scored. Trained classifiers recorded type traits on dairy cows, while individual beef producers recorded scores on beef cows. Beef producers were less likely consistent when scoring their cows. In addition, beef and dairy cows have been selected for different traits; udder quality could decline more rapidly in beef cows than dairy cows. Nonetheless, udder quality can be used in making culling decisions, especially because udder quality decreases with age. When a cow's udder begins becoming a problem for the calf to nurse, producers should consider culling that female to prevent the additional labor required when assisting future calves to nurse and the subsequent decrease in calf performance.

Genetic Correlations

Between Udder Type Traits

Correlated traits are important to consider, because selection for one trait can result in potentially undesirable changes in other traits. Phenotypic correlations between udder type traits in Simmental cattle were positive (r = 0.31 to 0.49; Kirschten et al., 2001). Genetic correlations among udder attachment, udder depth, and teat size were very strong and positive (r = 0.52 to 0.60; Kirschten et al., 2001). Data used in this analysis were collected by trained evaluators similar to recording type traits in the dairy industry (Kirschten et al., 2001). However, Sapp et al. (2004) found an extremely high correlation between teat size and udder suspension in beef cows (r = 0.95). Thus, beef producers could be misusing the 2-part scoring system by submitting the same score for both traits. These data were recorded using a 0 to 50 scoring system making it very unlikely that the majority of cows would have the exact same score for both traits. In addition, the evaluators in the dairy industry have considerably more experience and expertise in measuring these subjective traits. Overall, there was a positive correlation among udder traits; so, selection for one trait should result in improvement in the others as well.

Several measures of teat quality are recorded in dairy cows. An important difference between beef and dairy cows is longer teats are more desirable in dairy cows for milking purposes. Teat length was highly correlated to teat form, placement, and position (r = 0.54 to

0.82; Vukasinovic et al., 1997). Cows with longer teats had better form, placement, and position, because these data were scored so larger numbers were always more desirable. However, Gengler et al. (1997) found a negative correlation between teat length and front teat placement (r = -0.10). In this case, cows with longer teats had genetics for slightly wider teat placement. Teat placement was moderately to strongly correlated to measures of udder attachment, width, and depth (r = 0.16 to 0.58; Vanraden et al., 1990; Gengler et al., 1997; Vukasinovic et al., 1997). Generally cows with genetics for closer teat placement had genetics for tighter attachment, wider udders, and shallower udders. Teat length was generally positively correlated to measures of udder attachment (r = 0.01 to 0.40), but this relationship was not consistent for fore udder attachment (r = -0.22 to 0.31; Vanraden et al., 1990; Gengler et al., 1997; Vukasinovic et al., 1997).

The dairy industry quantifies a variety of traits relating to udder attachment. Measures of udder attachment including fore udder, rear udder, rear udder height, and rear udder width generally had strong positive genetic correlations between traits (r = 0.17 to 0.91; Vanraden et al., 1990; Gengler et al., 1997; Vukasinovic et al., 1997). Specifically, rear udder width and height had extremely strong correlations along with the correlation between udder depth and fore udder attachment (r = 0.83 to 0.92; Vanraden et al., 1990; Gengler et al., 1997; Berry et al., 2004). Cows that had very high udders also had very wide udders. If a cow had genetics for tight fore udder attachment, she likely had genetics for tight rear udder attachment and shallow udder depth as well. Thurl width and rear udder width had a strong positive correlation meaning wider based cows also had wider udders (r = 0.56 and 0.40; Gengler et al., 1997; Vukasinovic et al., 1997). Fortunately, these genetic correlations were all in a desirable direction for both beef and dairy cows.

Udder Type and Longevity

Replacement heifer development is an important cost to producers, and fewer heifers are needed when cows remain in the herd longer. Udder quality had a low to moderate positive genetic correlation with dairy cow longevity (r = 0.17 to 0.44; Vukasinovic et al., 1997; Tsuruta et al., 2004; Strapák et al., 2005). Most udder type traits had a weak positive correlation with stayability in Czech Fleckvieh cows (r = 0.06 to 0.18; Bouška, 2006). Teat placement had a slight negative correlation with stayability, but teat placement is not evaluated in most beef cows (r = -0.06; Bouška, 2006). Cows with better udder quality have longer productive lives and are more profitable for producers because they produce more calves in their lifetime. With the trend toward publishing stayability EPD in beef cattle, stayability could be one of the more highly correlated traits to udder quality.

The relationship between milk production and longevity is important for dairy producers. There was a significant positive correlation between estimated breeding values for longevity and milk yield (r = 0.41; Strapák et al., 2005). In first parity females, there were a positive relationships for mean milk yield with percent survival and calving interval, and these relationships persisted in second parity females (r = 0.28 and 0.58; Haile-Mariam et al., 2003). Visscher and Goddard (1995) found an even stronger relationship between survival to the second lactation and first lactation milk yield in different dairy breeds (r = 0.62 and 0.90). Hence, cows with greater genetic potential for milk production also had greater genetic potential for longevity.

Udder Type, and Milk Production

Udder quality is generally negatively correlated to production traits. Cows with larger udders and larger teats produce more milk than cows with better udder quality (r = -0.22 to -0.09; Tsuruta et al., 2004; MacNeil and Mott, 2006). Dairy cows with weaker fore udder attachment and deeper udders had greater genetic potential for milk yield (r = -0.45 and -0.65; DeGroot et al., 2002); however, tight fore and rear udder attachment, tight udder support, and shorter teats were all associated with greater milk yield (r = -0.14 to 0.48; Berry et al., 2004). The maternal component of preweaning gain and udder quality were strongly negatively correlated (r = -0.47 to -0.66; Sapp et al., 2004). Thus, beef cows with better udder quality produced less milk resulting in less calf growth, which is undesirable for beef producers. An intermediate udder type likely exists that best combines sufficient calf growth with the benefits of cow longevity, calf nursing ability, and calf survival from improved udder quality. In addition, producers should find those elite individuals that have the genetic potential for both good udder quality and greater maternal calf growth.

Fore udder attachment, udder depth, and teat size were all negatively correlated to milk fat (r = -0.51 to -0.38; DeGroot et al., 2002). Because longer teats are more desirable in dairy cows, cows with shorter teats had greater genetic potential for milk fat, which would be a desirable relationship in beef cattle. Likewise, udder depth was negatively correlated to milk protein (r = -0.44; DeGroot et al., 2002). In addition, protein and fat percentage in the milk was negatively correlated to milk yield (r = -0.67 to -0.52), and protein and fat percentage were positively correlated to each other (r = 0.66 and 0.78; Van Der Werf and De Boer, 1989; Schultz et al., 1990). Cows that produced large quantities of milk also produced less fat and protein as a percentage of total output.

Milking speed in dairy cows is important because cows that are milked faster require less time, and labor is a significant cost involved in milk production. Milking speed had positive genetic correlations with udder depth, texture, and fore udder attachment (r = 0.11 to 0.18; Boet-

-tcher et al., 1998). Wiggans et al. (2007) also found miking speed to be positively correlated to udder depth and fore udder attachment along with rear udder width (r = 0.18 to 0.22). Yet, milking speed was negatively correlated to rear udder height, rear udder width, teat length, and front teat length (r = -0.35 to -0.12; Boettcher et al., 1998; Wiggans et al., 2007). A more recent study found all measures of udder attachment, teat length, and teat placement to be positively correlated to milking speed (r = 0.09 to 0.50; Berry et al., 2004). While the relationships between milking speed and some measures of attachment and teat length were desirable, other udder traits had undesirable relationships with milking speed. Due to the conflicting nature of these studies, there was no clear connection between milking speed and udder type.

Udder Type, Mastitis, and Milk Production

Indicators of mastitis are frequently recorded in the dairy industry and have been correlated to udder type. Somatic cell count (SCC) and somatic cell score (SCS) are common indicators of mastitis. Milk SCC increased when the cow had a mastitis infection because of the increased quantity of white blood cells traveling from the blood to the milk to fight the infection (Rupp and Boichard, 2003). Given SCC, SCS can be calculated by the equation
(Rupp and Boichard, 2003). There were negative genetic correlations between udder attachment and depth with SCC and mastitis (r = -0.70 to -0.19; DeGroot et al., 2002; Rupp and Boichard, 2003). Dairy cows with deeper and weakly attached fore udders were more prone to mastitis infection, possibly due to the proximity of the udder to the ground. Teat length and SCS were negatively correlated indicating that cows with genetics for longer teats had greater genetic resistance to mastitis (r = -0.24; DeGroot et al., 2002); however, teat length had a positive relationship with SCC in another study (r = 0.31; Berry et al., 2004). Udder type traits can be important in preventing mastitis in dairy cows.

Milk production and mastitis are positively correlated in dairy cattle. The genetic correlation between clinical mastitis and milk production in dairy cattle was positive (r = 0.24 to 0.55; Simianer et al., 1991; Rupp and Boichard, 2003). The correlation between SCS and milk yield was not different from zero (r = 0.13 and -0.21; Schultz et al., 1990; DeGroot et al., 2002). Yet, Simpson et al. (1995) found Simmental cows with greater milk production had lower SCC at 189 days postpartum than cows with lesser milk production (P = 0.03). The lower SCC in some heavy milking cows could be caused by the dilution of somatic cells in larger quantities of milk. Generally, cows with greater genetic potential for milk production had lesser genetic resistance to mastitis than cows with lesser genetic potential for milk production.

Protein and fat content of milk are other important factors besides milk yield. Protein and fat percentage had a slight negative correlation with mastitis incidence (r = -0.15 and -0.12; Simi-

-aner et al., 1991; Rupp and Boichard, 2003). The correlation between SCS and milk yield was not different from zero (r = 0.13 and -0.21; Schultz et al., 1990; DeGroot et al., 2002). Yet, Simpson et al. (1995) found Simmental cows with greater milk production had lower SCC at 189 days postpartum than cows with lesser milk production (P = 0.03). The lower SCC in some heavy milking cows could be caused by the dilution of somatic cells in larger quantities of milk. Generally, cows with greater genetic potential for milk production had lesser genetic resistance to mastitis than cows with lesser genetic potential for milk production.

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Genetic Evaluation

Genetic evaluations are important to purebred livestock industries for producers to identify the superior animals for specific traits. Thus, these evaluations need to be as accurate as possible so that the elite individuals are identified correctly and genetic progress is maximized. The general form of the model used for genetic predictions is $Y = Xb + Zu + e$, where Y is a vector of observations, X is a matrix relating fixed effects in vector b to observations in Y, Z is a matrix relating random effects in vector u to observations in Y, and e are random errors (Golden et al., 2009).

Evaluations for type traits using a sire model began in 1978 with Jerseys and other breeds followed shortly thereafter (Wiggans, 1991). Later, multiple trait sire models were used for genetic prediction (Wiggans, 1991). Holsteins included the correlations between traits in their analyses while the other breeds assumed no correlations between traits (Wiggans, 1991). With the move to a multiple trait animal model in 1998, correlations between predicted transmitting abilities (PTA) for udder type traits calculated with a sire model and calculated with an animal model in Ayrshire, Brown Swiss, Guernsey, Jersey, and Milking Shorthorn cattle were strong (r = 0.62 to 0.91; Gengler et al., 1999). Differences in the PTA could result from the additional relatives that were included in the analysis as well as different adjustments, models, and genetic parameters (Gengler et al., 1999).

Presently, no beef breed association publishes an EPD for udder quality while the dairy industry publishes numerous PTA for udder traits. Early records of teat and udder quality were impacted by sire of dam, age of dam, and month of calf birth (Wythe, 1970). Teat scores from the American Gelbvieh Association were modeled with random effects for animal and residual and fixed effects for herd-year class, calving month, age at calving, and a regression coefficient of the percent Gelbvieh (Sapp et al., 2003). Breeds without open herd books and percentage individuals would not need to incorporate the percentage of that respective breed into the model. Line 1 Hereford udder score data were modeled with the sum of a constant, class effect, linear regression on the inbreeding of the cow, direct genetic effect, permanent environmental effect from repeated observations, and temporary environmental effect with each phenotype (MacNeil and Mott, 2006). Future work might not include the variable for inbreeding since Line 1 Herefords are more inbred by definition. Thus, some components of the model may need to differ by breed; yet, both genetic and environmental factors still need to be considered in predicting udder quality.

Conclusion and Implications to Genetic Improvement of Beef Cattle

Udder quality is an important trait for beef producers because udder structure affects nursing ability and longevity. Previous research indicates that measures of udder quality are moderately heritable and generally highly correlated. The dairy industry has incorporated udder type traits into their national genetic evaluation, and producers have used the results of this evaluation to improve udders in their herds. Thus, beef breed associations could include udder quality in their genetic evaluations and provide producers with a selection tool for improving udders. Improving udder quality would increase cow longevity resulting in the need for fewer replacement females and reducing heifer development costs. Also, producers would assist fewer calves to nurse at birth reducing labor costs. Calf mortality rates would decrease with improved udder quality resulting in a greater percent calf crop weaned and more total pounds for sale at weaning. Thus, genetic selection for udder quality by beef producers could potentially improve profitability.

Figure 1.1 American Hereford Association udder scoring guidelines prior to August 2008 (MacNeil and Mott, 2006)

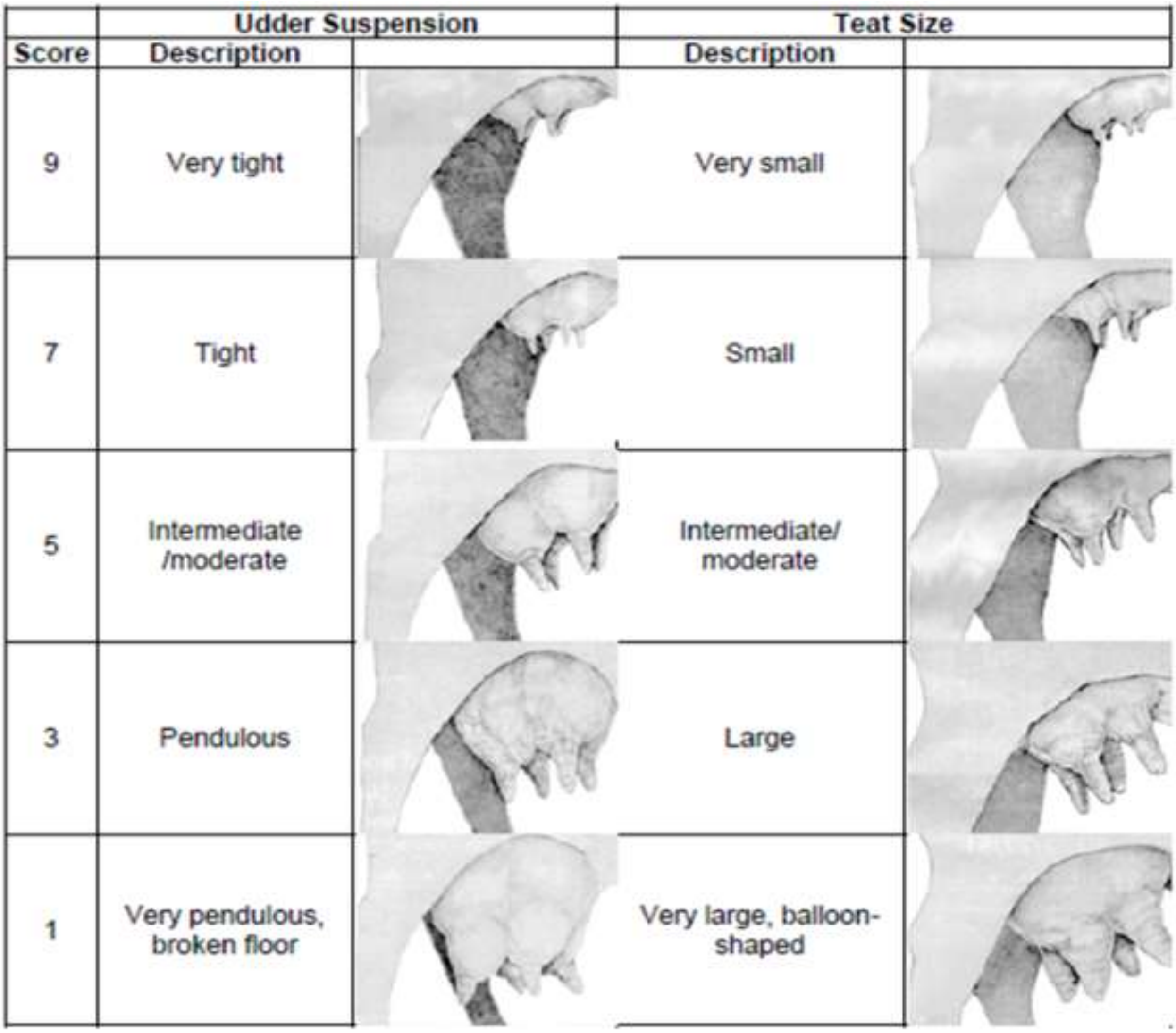
Score	Description
9	An ideal mammary system. Udder is held high up near the rear and is level in front. Teats are small.
8	Very good udder with level attachment in front and high attachment in the rear with desirable teats.
7	A sound and functional udder fairly level with small, good teats.
6	A very functional udder and teats. This is a problem free udder and teats, but will not have the balance of an udder scored 7, 8, or 9.
5	A functional udder and teats and labor free. Udder and teat scores of 5 or better should be "Labor Free."
4	An udder that could become a problem because of attachments and/or shape and size of teats.
3	A problem udder and teats. The udder will show tendencies of breaking down and teats are too large and balloon shaped.
2	A definite problem udder and teats. The udder is poorly attached in the front and back with weak suspension and teats are large and balloon shaped.
1	A very pendulous udder and balloon teats. These udders will cause frequent labor problems.

Udder score = 8

Udder score = 5

Udder score = 2

Figure 1.2 Beef Improvement Federation udder scoring guidelines (BIF, 2010)



	Udder Suspension		Teat Size	
Score	Description		Description	
9	Very tight		Very small	
7	Tight		Small	
5	Intermediate /moderate		Intermediate/ moderate	
3	Pendulous		Large	
1	Very pendulous, broken floor		Very large, balloon-shaped	

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