GENETIC PREDICTIONS USING SUBJECTIVE METHODS OF BEEF CATTLE TEMPERAMENT EVALUATION, GENETIC ASSOCIATION BETWEEN BEEF CATTLE TEMPERAMENT AND PRODUCTION TRAITS, AND INFLUENCE OF SIRE AND DAM TEMPERAMENT ON CALF PERFORMANCE

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ABSTRACT

Beef cattle temperament is not only important to handler safety and animal welfare but also found to be related to productivity and thereby, considered an economically important trait. Constraints to improve cattle temperament are due to the inherent complexity of this trait and difficulty in measurement. Our findings suggest that traditional subjective methods (DS; docility score and TS; temperament score) of beef cattle temperament evaluation has less effect in genetic merit predictions (heritability estimates and estimated breeding value ranking) provided that evaluator is included in the model. Our novel movement-based objective method (four-platform standing scale, FPSS) using standard deviation of FPSS data (SSD) and coefficient of variation of SSD (CVSSD) can be use in place of DS and TS, but more appropriately with TS which had higher association based on genetic correlation analysis. Calf temperament had significant effect on adjusted birth weight (ABW), adjusted 205 weaning weight (205-d WW), weaning average daily gain (ADG), and weight gain (WG) where there is an increased ABW, 205-d WW, ADG, and WG with calmer temperament calves. Based on genetic correlation, ABW, 205-d WW, ADG, and WG may not be associated with calf temperament due to low correlations to majority of our models. Lastly, we found significant association between dam temperament and calf 205-d WW, ADG, and WG where dam with calmer temperament had increased calf 205-d WW, ADG, and WG.

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This dissertation is whole heartedly dedicated to my beloved parents Engr. Elfren and Teresita for the sacrifices, inspiration, and for molding me to who I am.

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LIST OF ABBREVIATIONS

ADG..Pre-weaning average daily gain

AN...Angus

ABW ....Adjusted birth weight

BW ....Birth weight

BIF ....Beef improvement federation

CVSSD..Coefficient of variation of SSD

DS ....Docility score

EBV...Estimated breeding value

EPD ....Expected progeny difference

FCE ....Feed conversion efficiency

FPSS..Four platform standing scale

HH...Hereford

LSMeans ....Least squares means

MMD...Movement measuring device

PCA...Principal component analysis

PC1..First principal component

PC2..Second principal component

PS ....Pen score

QBA ....Qualitative behavior attribute

SAS ....Statistical analysis system

SD ....Standard deviation

SSD ....Standard deviation of total weight over time recorded by FPSS

SM...Simmental

TI..Temperament index

TS...Temperament score

WG...weaning weight gain

WW..Weaning weight

205-d WW...Adjusted 205 weaning weight

LIST OF SYMBOLS

c^2 .... Proportion of phenotypic variance due to permanent environmental effects

h^2 .... Heritability estimates

r_s .... Spearman rank correlation coefficients

$\hat{r}^2$ .... Estimated repeatability

$\hat{\sigma}_a^2$ .... Estimated additive genetic variance

$\hat{\sigma}_{ape}^2$ .... Estimated additive and permanent environment variance

$\hat{\sigma}_e^2$ .... Estimated residual variance

$\hat{\sigma}_{me}^2$ .... Estimated maternal effect variance

$\hat{\sigma}_p^2$ .... Estimated phenotypic variance

$\hat{\sigma}_{pe}^2$ .... Estimated permanent environment variance

TI+ .... Temperament index positive

TI- .... Temperament index negative

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1. LITERATURE REVIEW

This literature review focuses on beef cattle temperament evaluation methods, genetic selection for beef cattle temperament, relationship of beef cattle temperament to productivity, and the effect of sire and dam temperament on offspring performance.

1.1. Cattle temperament definition

Animal temperament is the response of the animal to environmental or social stimuli (Haskell, et al., 2014; Friedrich, et al., 2015). In beef cattle, temperament is defined as the reaction of the animal to human handling or movement by humans to the scales, crush, or bail (Tulloh, 1961; Burrow and Dillon, 1997). Similarly, the Beef Improvement Federation (BIF, 2018) defines beef cattle temperament as the ease with which animals respond to handling, treatment, and routine management. Several authors describe beef cattle temperament as behavior of escape, fearfulness, freezing, and aggression (Burrow, 1997), different aspects of an animal's fear response (Petherick et al., 2002), and behavioral characteristics like shyness-boldness, exploration-avoidance, activity, sociability, and aggressiveness (Réale et al., 2007).

1.2. Development of beef cattle temperament evaluation methods

The earliest method of temperament evaluation in cattle was done by Tulloh (1961). Cattle temperament was scored based on behavior of the cattle while entering the crush, or chute, as temperamental animals being difficult to persuade to enter. Later, this method was modified by Hearnshaw et al. (1979) where the cattle behavior was observed while inside the chute for 30 to 60 seconds with the head caught in the gate. The scale used in this method was from 0 to 5 with 5 having constant activity. Fordyce et al. (1982) modified Hearnshaw et al. (1979) crush test to allow scoring without the head caught in the gate and expanded the score range from 5-point scale to 7-point scale. Grandin (1993) modified Fordyce et al. (1982) crush test by reducing the scale to 5 arguing that evaluators cannot distinguish scores of 6 and 7. In addition, Fordyce et al. (1982) also developed the objective method called flight distance, a modification of the flight speed described by Burrow et al. (1988) that measures the distance traveled by the cattle exiting the chute. Flight distance was difficult to implement in routine cattle management and requires interaction to cattle which is dangerous to the observer. On the other hand, flight speed measures the speed of cattle while exiting the chute given a fixed distance of 1.8 meters. Even though flight speed is more objective and safer, it requires specialized equipment. Since these early studies, several methods have been developed.

1.3. Traditional methods of beef cattle temperament evaluation

Traditional methods of beef cattle evaluation are chute/crush score (Tulloh, 1961; Hearnshaw et al., 1979; Grandin, 1993), and flight speed/time (Burrow et al., 1998) in European countries and Australia. Chute or crush score measures response of the cattle to confinement (i.e. inside the chute). Flight speed/time also measures response to confinement or handling facility because it assesses the speed or flight time the cattle are moving away from confinement (Haskell et al., 2014). Other traditional methods are pen score (PS) and docility score (DS) (BIF, 2018), which are widely used in United States. These methods assess response of the cattle to human handling, confinement and human approach, respectively.

In a study by Hoppe et al. (2010) using German Angus, Charolais, Hereford, Limousin, and German Simmental, genetic correlation coefficients between chute score and flight speed ranged from 0.57 to 0.98. Moderate correlation coefficients between flight speed and crush score were found by Cafe et al. (2010) in Brahman cattle (r = 0.23 to 0.69). Comparable correlation coefficients were observed by Olmos and Turner (2008) between crush score and flight speed (0.27 to 0.53). These correlations indicate different temperament scoring methods are measuring a similar attributes of beef cattle temperament. Until 2000, very little comparison between the objective method of flight speed and other subjective methods had been published. Burrow and Corbet (2000) found low phenotypic and genetic correlations (0.00 and -0.07, respectively) between visual flight speed and crush scores, suggesting those methods were measuring different attributes of beef cattle temperament.

1.4. Classification of methods for beef cattle temperament evaluation

Methods for beef cattle temperament evaluation are generally categorized into restraint and non-restraint. Restraint methods assess cattle behavior when inside a restraining facility such as a chute or crush. On the other hand, non-restraint methods assess cattle behavior in a larger area, for example inside a pen. These two different methods assess distinct or different temperament behavior. Burrow and Corbet (1999) and Haskell et al. (2014) stated that restraint methods assess cattle response both to human handling and confinement, but non-restraint methods assess mainly response to human approach. Furthermore, Anon (1988) stated that it is not always possible to relate behaviors in a restrained situation to behaviors in a non-restrained situation because some animals that are difficult to handle in a paddock demonstrate a freeze response when restrained.

Within each category, methods of temperament evaluation are classified into objective and subjective methods. Studies have shown low to moderate correlations coefficients between objective and subjective methods. Olmos and Turner (2008) found low to moderate correlation ($r = 0.23$ to 0.47) between crush score and flight speed while Sebastian et al. (2011), reported low to moderate negative correlation ($r = -0.27$ to -0.40) between exit time and MMD peaks. On the other hand, Burrow and Corbet (2000) found no to moderate genetic correlations between these methods that ranged from 0.00 to 0.45. Subjective methods may capture different aspects of cattle temperament while objective may not. Flight speed, or exit velocity, is an example of objective method. Some authors describe flight speed as a measure of agitation (Petherick et al., 2009) or escape behavior (Curley et al., 2006) and theorize it may not capture other aspects of beef cattle temperament like aggression, response to handling, and proximity to human approach.

1.4.1. Objective methods

Flight speed (Burrow et al., 1988; later called exit velocity by Curley et al., 2006) measures the speed when cattle exit the chute covering a fixed distance of about 1.8 meters. This method is still used at present and studies have been conducted using flight speed as measure of temperament (Burrow and Corbet, 2000). Associations of this measure of temperament to economically important traits in cattle were studied. Relationship of the method on growth, birth weight, feed efficiency, carcass merit and meat quality, and feeding behavior were established (Burrow and Dillow, 1997; Vossinet et al., 1997; Nkrumah et al., 2007).

Movement measuring device (MMD) (Stookey et al., 1994) is an objective method used to assess temperament of the cattle based on movement in an electronic weighing scale. According to Waynert et al. (1998), this device is connected to a weighing scale and records animal movement in terms of peaks indicative of the amount of movement of the animal for a period of 1 minute. Using this method, Stookey et al. (1994) observed that MMD scores were elevated if the cattle were separated from other cattle. This is likely because cattle are gregarious, meaning they prefer to live in a herd (organized community). Therefore, MMD may focus on gregariousness of cattle unless they can visually see their cohorts.

A recent objective method of temperament evaluation is using a Four Platform Standing Scale (FPSS) to measure the standard deviation of total weight over time (Yu et al., 2020). Genetic correlations of this method to pen score (unrestraint procedure) have been established and has the potential to objectively measure cattle temperament.

Strain gauges measure the amount of force exerted by the cattle while inside the chute. This device is attached to the headgate and arms of the squeeze chute and an output signal is measured in millivolts (Schwartzkopf-Genswein et al., 1997). A significant relationship was established between strain gauges and traditional temperament scoring (similar to chute score) and may provide an advantage to subjective scoring by eliminating evaluator bias (Sebastian et al., 2011).

Instead of flight speed, other studies use flight time to record the time for the cattle exiting the chute over a set distance. Significant correlation was observed between blood cortisol concentration and exit velocity with flighty cattle having increased blood cortisol level, suggesting that exit velocity may be capturing fear or stress response of the cattle (Curley et al., 2006).

Physical features of cattle have also been investigated for their association to temperament. Studies include the use of eye white percentage (Core et al., 2009), hair whorl (Grandin et al., 1995), head color pattern (Rose et al., 2002), and foreleg thickness (Lanier et al., 2000). These methods of temperament measurement are indirect (Cooke, 2011). Significant correlation coefficients were found between eye white percentages and chute score (0.67 to 0.95), indicating this method could be used to evaluate beef cattle temperament (Core et al., 2009). Grandin et al. (1995) found that cattle with a hair whorl above the eyes are more temperamental in a squeeze chute than cattle with hair whorl below the eyes in a study using 1,500 Brahman crosses and *Bos taurus* cattle in a feedlot. However, Olmos and Turner (2008) found no relationship of hair whorl position and temperament. They concluded that the value of hair whorl position for temperament evaluation is limited. *Bos taurus* steers with wider cannon bones have lower exit scores and heifers with wider and thicker cannon bones are less likely to balk at the head restraint (Lanier et al., 2002). In Holstein cattle, Rose et al. (2002) reported that mostly white heads were more temperamental while those with large percentages of black on the head had calmer temperament.

1.4.2. Subjective methods

Crush test and chute/docility score are the most widely used methods of beef cattle temperament evaluation due to ease of use, speed of scoring, and requires no additional cost. These methods evaluate cattle temperament while inside the chute and thereby are considered restraint methods. The difference of these two methods is that crush test measures cattle temperament while head is not caught in the head gate (Hearnshaw, 1979). Parham et al. (2019) reported that crush test is a measure indicative of acclimatization to a novel environment because chute scores significantly decreased across days and events. As crush test has been used in research, the score range has fluctuated based on the study. For example, Tulloh (1961) used a 6-point scale, Hearnshaw (1979) utilized a 5-point scale, Fordyce (1982) used a 7-point scale, Grandin (1993) utilized a 5-point scale and later reduced to a 4-point scale as a way to improve accuracy (Grandin, 2018). Lastly, BIF guidelines used a 6-point scale for docility score (BIF, 2018). In terms of evaluator bias, Parham et al. (2019) reported that chute score is insensitive to evaluator biases because of acceptable reliability of this method, however more variation in scores were found in inexperienced evaluators that reduced reliability.

Pen score, also called docility test, in Australia is an unrestrained method that assesses the response of cattle to human approach. Docility test is different from docility score where the latter is a restraint procedure. In this method, a human handler will approach the animal in a pen and an observer will evaluate the response of the animal with a score of 1 when the animal is docile, walks slowly, and can be approached by humans and a score of 5 when the animal is very aggressive, runs into the fences, and runs over humans and anything else in its path (BIF, 2018). This method is dangerous both to the handler and observer because this procedure requires approaching the animal. Burrow and Corbet (2000) reported low genetic correlation between pen score and chute score while Curley et al. (2006) found moderate genetic correlation between the two traits. Overall, these correlations may indicate that these two traits are assessing similar if not identical traits (Haskell et al., 2014).

Exit score is a modification of flight speed or exit velocity. Using this method, evaluators will assign numbers from 1 to 5 with 5 being cattle that exit the chute frantically (Curley et al., 2006 and Parham et al., 2019). However, variations in this scoring can be found. A study of Lanier and Grandin (2002) utilized scores from 1 to 3 with 1 = walked, 2 = trotted, and 3 = ran. Vetters et al. (2013) utilized a 4-point scale similar to Lanier and Grandin (2002) with addition of 3 = canter while 4 = ran. On the other hand, Kasimanickam et al. (2014) reduced it to a 2-point scale with 0 = calm (slowly exit or walk) and 1 = excitable (run, trot, jump, fast exit). In comparison to flight speed, Vetters et al. (2013) reported that exit score can be used in place of flight speed since it is also repeatable and has the ability to predict average daily gain in the same manner as flight speed. There is limited literature relating exit score to other measures of temperament, perhaps due to less popularity of this method.

1.5. Constraints and issues on beef cattle temperament evaluation

Evaluation of cattle temperament is difficult due to subjectivity of measurement and differences in authors' definitions (Adamczyk et al., 2013). Subjectivity of measurement may be associated with the use of subjective methods with humans as the evaluator. Due to differences in an author's definition, different methods of beef cattle temperament measurement were formulated. This led to development of objective methods which are more accurate and repeatable.

Recent studies have shown that subjective methods are associated with evaluator bias because scoring was based on the individual perception of the observer (Hieber et al., 2016). Furthermore, these methods made temperament evaluation difficult due to subjectivity (Adamczyk et al., 2013). However, subjective methods are the most widely used method due to cost and ease of incorporation to routine farm management practices and research as well. The strength of subjective methods is that it can capture the temperament of the beef cattle entirely. Temperament is a complex trait and to measure temperament, a holistic approach is more appropriate. These methods do not require additional equipment and can easily be incorporated in routine farm operation. Objective methods on the other hand, are more repeatable but may not capture the beef cattle temperament entirely (e.g., Sebastian et al., 2011). Furthermore, objective methods require additional equipment and added cost to the farmer. However, the advantage of these methods is that evaluator bias is eliminated and the data is on a continuous scale, resulting in more accurate estimates with higher heritabilities (Hoppe et al., 2010). Even so, Parham et al. (2019) stated that subjective methods of beef cattle temperament evaluation using chute and exit scores are insensitive to observer bias and highly repeatable. Despite the amount of current literature on temperament scoring in cattle, no study has been found reporting the effect of subjective methods on genetic parameter estimation and predicting genetic merit.

1.6. Genetic selection for beef cattle temperament

Traits that are related with profitability, such as milk yield and body weight, were the focus of selection in the past. However, producers are now realizing that traits related to fitness and health can improve productivity and be maintained with holistic approach in selection (Haskell et al., 2014; Stephansen et al., 2018). In the United States, several cattle breed associations are incorporating docility score as a trait in selection where expected progeny differences (EPDs) have been estimated. The interest to improve cattle temperament is reflective of the trend that less labor due to ease in management has been the industry standard (Benhajali et al., 2010). Handling is more labor intensive and time consuming and therefore increases production costs (Grandin, 1989). Furthermore, temperament is considered an economically important trait in cattle as fluctuation in profit is associated with changes in this trait (Golden et al, 2000).

Cattle temperament has been reported to be low to moderately heritable and thereby can be improved by selection for many years now (e.g., since Burrow, 1997). In addition, the genomic regions governing beef temperament have been studied for some measurement methods and quantitative trait loci have been identified (Haskell et al., 2014). Glenske et al. (2011) found an association between a candidate gene *DRD4* on chromosome 29 and performance in a docility test using German Angus and German Simmental calves. In addition, genes regulating sodium ion transport was identified to be associated with social separation in Nellore-Angus beef cattle (Hulsman Hanna et al., 2014). In dairy cattle, three genomic regions with suggestive linkage for milking speed were found located on chromosomes 2, 3 and 23 (Schrooten et al., 2000).

Breed associations have EPDs for beef cattle breeds as the importance of this trait have been realized. The most important reason for selection on temperament is animal welfare and handler safety (Le Neindre et al., 1996). However, this trait is not commonly included in selection indices despite economic, welfare, and humane safety reasons. Reasons for this are due to difficulty in collecting behavioral data in sufficiently large populations of animals to estimate genetic parameters and difficulty in assigning economic value to temperament trait (Haskell et al., 2014).

1.7. Genetic parameter estimations of beef cattle temperament

Genetic parameters estimation on cattle temperament generally were based on the three major methods of temperament evaluation (i.e., docility score or chute test, pen score or docility test, and flight distance/speed or exit velocity). However, other methods of temperament evaluation were also utilized for this purpose.

Comparing objective methods to subjective methods of evaluation, in most cases objective methods have higher heritabilities (Benhajali et al., 2010). This is supported by the study of Valente et al. (2017), wherein heritability estimates for chute score, flight speed, temperament score in Nellore cattle were 0.09 ± 0.03, 0.22 ± 0.02, and 0.19 ± 0.04, respectively. Among the methods used, flight speed is an objective method and had the highest heritability estimates.

Heritability estimates also vary between breeds and are generally higher for *Bos indicus* breeds and crosses than for *Bos taurus* breeds (Haskell et al., 2014). In a study by Hoppe et al. (2010), heritability estimates for five *Bos taurus* breeds (German Angus, Charolais, Hereford, Limousin, and German Simmental) ranged from 0.11 to 0.33 while *Bos indicus* breeds, which includes Brahman and Nellore, heritability estimates ranged from 0.26 to 0.49 using exit velocity and pen score (Sant' Anna et al., 2012 and Schmidt et al., 2014). The ranged values of heritability estimates were higher on *Bos indicus* breeds and proves that *Bos indicus* generally have higher heritability estimates than *Bos taurus* breeds. However, in a study by Valente et al. (2017), heritability estimates for Nellore cattle (i.e. a *Bos indicus* breed) ranged from 0.09 to 0.22 which is lower than *Bos taurus* breeds. Haskell et al. (2014) summarized heritability estimates by method of evaluation regardless of breed. Chute score had a mean heritability estimates of 0.24 and ranged from 0.03 to 0.67, flight speed/exit velocity had a mean of 0.36 and ranged from 0.05 to 0.70, and docility score had a mean of 0.26 and ranged from 0.0 to 0.61.

It is interesting to note that heritability is a population measure and vary from one population to another. Thereby, differences between breeds can be due to differences in environment, method, age of scoring, or habituation. This review gives an overview of heritability estimates of beef cattle temperament and factors that can affect differences in estimates. However, in most literature, objective methods generally had higher heritability estimates as compared to subjective methods.

1.8. Factors affecting beef cattle temperament

There are several factors that affect cattle temperament outside of evaluation method. These include breed, acclimation to human handling and facility design, age, and sex (Kasimanickam et al., 2017).

Bos taurus breeds have calmer temperament as compared to *Bos indicus* breeds including crosses (Voisinet et al., 1997, and Burrow, 2001). Within *Bos indicus* breeds, Nellore calves are more docile than Gir and Gurezá (Paranhos da Costa et al., 2002). Within *Bos taurus* breeds, Angus and Hereford have calmer temperament as compared to Simmental and Limousin. Angus and Hereford sired calves have decreased temperament scores as compared to Simmental and Limousin sired calves using Angus and Hereford dams (Graham et al., 2001). This is supported by the study of Hoppe et al. (2010), where German Angus and Hereford cattle received the lowest behavior scores compared with Charolais, Limousin, or German Simmental using chute score and flight speed. Furthermore, Tulloh (1961) found that Hereford and Angus have lower temperament (calmer) scores than Shorthorns. Moreover, sire breeds can have an effect on calf temperament, where *Bos taurus* sired calves are significantly calmer compared to *Bos indicus* sired calves. In a study by Hearnshaw and Morris (1984), Brahman sired calves and Brahman cross (Braford) sired calves have increased temperament scores (i.e., more temperamental) as compared to Simmental and Friesian sired calves using Hereford as the dam breed.

Effects of acclimatization or habituation on cattle temperament has been studied. Acclimatization or habituation is a process wherein an animal becomes adjusted to the environment. For example, this occurs in a handling facility or when the animal become accustomed to human handling or interaction. In an experiment using Angus x Hereford steers, acclimated steers in a handling facility have ameliorated cattle temperament (Francisco et al., 2012). Cooke et al. (2009) found that acclimatized Brahman crossbred cows have increased pregnancy rates. Excitable responses or changes in temperament may be expressed in a novel environment, including interaction with other animals (Haskell et al., 2014). Lastly, effects of acclimatization to human handling was demonstrated by Burrow and Dillon (1997), where groups of calves at weaning were subjected to intense handling for a period of 4 months (acclimatized). This period of intense handling resulted in only 12% of the cattle having fast flight speeds whereas the group with minimal handling at weaning had 51% exhibiting a fast flight speed.

Cattle temperament is generally assessed at the time of weaning to minimize environmental effects as cattle mature. As calves mature, they get acclimatized to handling and human interaction thereby temperament scores tend to be lower in repeated measurements or when scored in later in life. In a study by Brehrends et al. (2009), a significant decrease in temperament scores using exit velocity were observed between weaning and initial feedlot stage. In addition, repeated measurements using exit velocity and chute score showed a decrease in temperament scores, which also reflected acclimatization (King et al., 2006; Parham et al., 2019). Crosshank et al. (1979) observed that cattle accustomed to handling had lower blood cortisol levels and were less agitated during transport. Furthermore, acclimated steers had decreased temperament scores and plasma cortisol compared to steers that were not acclimatized (Francisco et al., 2012). This is an indication that temperament can be affected as the cattle age and are accustomed to handling and human interaction.

Heifers have a more excitable temperament compared to steers (Hearnshaw, 1979; Voisinet et al., 1997). Riley et al. (2014) found heifers have more excitable temperaments than both bulls and steers with bulls having the lowest mean temperament scores. Comparing between bulls and cows, Burrow et al. (1988) observed that bulls are more excitable than cows. Based on this literature, heifers are the most temperamental followed by bulls, and cows or steers. Limited studies have been done comparing cow temperament and steer temperament.

1.9. Relationship of beef cattle temperament on production traits

Animal temperament is now considered an important economic trait in cattle not only because of its effects on human safety and animal welfare but also because of its influence on productivity of livestock (Norris et al., 2014). Research suggests that cattle temperament influences important production and reproductive traits such as average daily gain, feed conversion efficiency, pregnancy rate, and immunity. Cattle that are calm during handling have a higher average daily gain, improved feed efficiency, increased pregnancy rates, and increased immune function compared to cattle that become agitated (Burrow and Dillon, 1997; Voisinet et al., 1997; Fell et al., 1999; Petherick et al., 2002; Oliphint, 2006; and Cooke et al., 2009). The following subsections are studies that summarizes the relationship of beef cattle temperament on selected productive traits.

1.9.1. Birth weight

Birth weight is an important trait in beef cattle production and represents the first phenotypic variable of a new individual in a population (Garza-Brenner et al., 2018). This trait is important because it is considered an indicator of calving ease (Canellas et al., 2012). The expression of this trait is controlled by the genes responsible for growth from the sire and the dam and multiple environmental factors such as parity of the dam, nutrition of the dam, and year or season of birth. The effect of sire and dam temperament on calf birth weight has been studied. Using phenotypic data, Burrow and Corbet (2000) found no association of sire temperament using flight speed scores on calf birth weight. Birth weights of calves from bulls with low flight speed and high flight speed scores were statistically similar. However, molecular markers on the other hand found significant association of candidate genes for beef cattle temperament on birth weight (Garza-Brenner et al., 2018).

1.9.2. Weaning weight

Weaning weight is one of the most important traits in beef cattle. Calves with greater weaning weights are more morphologically developed and are better equipped to successfully cope with the environment (Jahuey-Martnez et al., 2016). This trait is expressed by the calf, but its dam had a major influence. Studies have found significant association of calf temperament to weaning weight, however limited studies are conducted that evaluates the effect of dam temperament on weaning weight of the offspring.

Studies involving temperament and weaning weight report that cattle with mild temperament had better growth performance. Sant' Anna et al. (2012) found that cattle with slow flight speed (calm temperament) had increased weaning weight than cattle with fast flight speed. Furthermore, decreased body weight at weaning was reported in excitable calves compared to calves that are calm (Francisco et al., 2012).

1.9.3. Average daily gain

Several studies have examined the association of average daily gain (ADG) and temperament in cattle. In these studies, beef cattle temperament influenced ADG. The earliest studies on the influence of temperament on ADG was done by Burrow and Dillon (1997) and Voisinet et al. (1997). Burrow and Dillon (1997) used crosses of *Bos indicus* and *Bos taurus* cattle and flight time to measure temperament. Flight time had a negative effect on ADG where the slow cattle grew faster in feedlot compared to the faster cattle. Voisinet et al. (1997) used chute score to measure temperament and assessed ADG in *Bos taurus* and Brahman cross (≥ 25% Brahman) calves. Calmer and quieter calves during handling had greater ADG compared to calves that were agitated during handling (Voisinet al., 1997). Fell et al. (1999), using flight time, crush score, endocrine and immunological assays to measure temperament, found that nervous cattle with faster flight time and higher chute scores had lower ADG than the calm cattle. Recent studies conducted by Hoppe et al. (2010), Sant' Anna et al. (2015), and Vann et al. (2017) report cattle temperament has an effect on ADG, where cattle with increased chute and pen scores, and fast flight speed or exit velocity (aggressive temperament) were negatively correlated to ADG.

1.9.4. Feed conversion efficiency

Similar to ADG, temperament had an effect on feed conversion efficiency (FCE). Using flight speed as measure of temperament, Patherick et al. (2002) found that cattle with aggressive temperament had decreased FCE. However, a recent study by Llonch et al. (2016) found no significant difference between temperament and FCE using chute score and flight speed as methods of temperament evaluation. In the same study, cattle with high cortisol level (as a marker for aggressive temperament) had improved FCE. This was contradictory to Herd et al. (2004), which showed that less efficient cattle may be more physiologically responsive to stress.

Furthermore, Patherick et al. (2002) stated that fearful cattle had greater response to changes in environment and the energy spent in maintaining additional response came at the expense of growth, thereby reducing FCE.

1.9.5. Reproductive performance

Cattle temperament influences pregnancy rate. Cooke et al. (2017) found that cow temperament influenced conception rates where cows with docile temperament had increased conception rates compared to cows with excitable temperament using chute and exit scores methods. In the same study, pregnancy loss had decreased, and calving rates had increased in cows with docile temperament compared to cows with excitable temperament. Kasimanickam et al. (2014), in a study using Angus beef heifer and exit score to measure temperament, found that heifers with calm temperament had increased pregnancy rates. However, Burrow (2001) found that cattle temperament had close to zero relationship to male and female fertility using cattle of *Bos indicus* and *Bos taurus* crosses and Africander breed raised in pasture. Differences in the results of these studies can be due primarily to differences in breed and method of temperament evaluation. Overall, most studies show that beef cattle temperament significantly influenced reproductive performance.

1.9.6. Meat quality and tenderness

The earliest study to document effect of cattle temperament on meat quality and tenderness was done by Fordyce et al. (1988) using Brahman cross and Shorthorn cattle with the crush score method. Cattle with higher temperament scores (i.e., aggressive temperament) have more bruising and have higher peak shear force indicating tougher, or less tender, beef. Later, Voisinet et al. (1997) found that excitable cattle produce tougher meat and had higher incidences of borderline dark cutters than cattle with calm temperament. Thereafter, additional studies have reported the effects of cattle temperament on meat quality and tenderness. Kadel et al. (2006), King et al. (2006), Behrends et al. (2009), and Da Silva Coutinho et al. (2017) found that cattle with longer flight time or lower exit velocity (calm temperament) produced more tender meat. In addition, Cafe et al. (2011), found cattle with increased chute score (aggressive temperament) has reduced rib fat. However, Turner et al. (2011) found no association of beef cattle temperament on meat quality. Overall, because a majority of the studies reported associations, beef cattle temperament appears to influence meat quality and tenderness. The aggressive cattle produce less tender meat with more incidence of borderline dark cutters and bruising, which is undesirable.

1.10. Consensus on the effect of beef cattle temperament on productivity

A majority of published literature indicates a favorable association of beef cattle temperament on productivity. Cattle that are calm during handling have higher ADG, increased FCE, increased pregnancy rates, and increased immunity and health compared to cattle that become agitated (Burrow and Dillon, 1997; Voisinet et al., 1997; Petherick et al., 2002; Cooke et al., 2009; Kasimanickam et al., 2014; and Hine et al., 2019). However, some researchers found no associations of beef cattle temperament to these traits. Cooke et al. (2012) suggested that temperament had no effect on birth and weaning weight and Burrow (2001) found no relationship of temperament to cattle fertility including growth traits. In addition, Sant'Anna et al. (2014) stated that there is still no consensus about the extent on how beef cattle temperament affects productivity. Despite this, Adamczyk et al. (2013) stated that beef cattle temperament appears to correlate favorably on production traits. The method used for beef cattle temperament evaluation plays a major role in variation of the results, however differences can also be due to different breeds of cattle used, number of animals used, and the degree of handling (intensive or extensive). Therefore, using various objective and subjective methods of temperament evaluation at the same time with the same animals in a large population may provide evidence of the association of beef cattle temperament to productivity. Various methods of beef cattle temperament evaluation have been formulated due to the ambiguous nature of the definition of beef cattle temperament. At present, there is still no gold standard method for evaluation of this very complex trait in beef cattle.

1.11. Effect of dam and sire temperament on offspring performance

Maternal and paternal genetic effects account for genes in the dam and sire that influence phenotype of the offspring (Beckman et al., 2007). Non-genetic influences by the dam are the uterine environment and nourishment, for example, that affects offspring phenotype. In livestock species, it is established that dam has an influence on birth weight and weaning weight due to maternal effects (Burfening and Kress, 1993; Eler et al., 1995; and Franke et al., 2001). Furthermore, differences in birth and weaning weights were observed based on which breed were used as a dam.

Most studies have focused on association or effect of temperament to productivity of the cattle to itself and limited studies have been conducted on maternal and paternal genetic influence of beef cattle temperament on progeny performance. Some breed cattle associations have already incorporated docility EPD in their breeding program due to favorable effects of this trait. However, limited studies were conducted on whether the maternal and paternal temperament may influence offspring productivity in growth. The following are studies to date that investigate the effect of dam and sire temperament on offspring performance.

1.11.1. Dam temperament effects on offspring performance

Research has shown that dam temperament influence offspring productive performance. Vann et al. (2017) found that dam temperament is positively associated with their offspring's ADG to weaning as well as birth weight (BW). In addition, Koch (1972) found that maternal temperament effects accounted to 15 to 20% variation in birth weight and 35 to 45% pre-weaning daily gain. In sheep, Brown et al. (2015) found that ewes with good temperament had increased number of lambs weaned and had lambs with increased yearling weights.

1.11.2. Sire temperament effects on offspring performance

Beef cattle associations, which include the American Angus Association, Northern American Limousin Foundation, and American Simmental Association, have incorporated docility EPD in their breeding program. Kasimacnickan et al. (2018) found significant effect of sire docility EPD scores on calf temperament. Furthermore, calves sired by *Bos taurus* breeds have calmer temperament compared to *Bos taurus* sired calves (Hearnshaw and Moris, 1984; and Parandos da Costa et al., 2002). However, no published study at present has been found that determines the relationship of sire docility EPD (a measure of sire genotype) on calf productive traits. It can be recalled that *Bos taurus* breeds have calmer temperament compared to *Bos indicus* breeds (Voisinet et al., 1997, and Burrow, 2001) and calm temperament is associated with better production performance (Burrow and Dillon, 1997; Voisinet et al., 1997; Fell et al., 1999; Petherick et al., 2002; Cooke et al., Oliphint, 2006; and 2009). Therefore, sire temperament may have an influence on offspring performance simply through genetic inheritance of calmer behavioral attributes, leading to improved productivity.

1.12. Summary

Beef cattle temperament is vital in beef cattle production not only due to handler safety and animal welfare but most importantly its association to productivity. However, the inherent complexity and difficulty in measurement of this trait are the constraints to improve it in beef cattle. Thereby, various methods of beef cattle temperament evaluation have been and continue to be developed. Despite this, most beef breed associations are utilizing a subjective method due to practically. However, no study has been conducted that evaluated the impact of these methods on prediction of genetic merit and genetic parameter estimations, especially considering evaluator bias. As the majority of studies conducted showed favorable association of beef cattle temperament on productivity, there is still no consensus to the magnitude that temperament affects production traits. Lastly, limited studies focus on paternal and maternal genetic influence of beef cattle temperament on progeny performance. In this dissertation, we investigated the impact of subjective methods of temperament evaluation on genetic prediction (heritability and estimated breeding value ranking) and determined the phenotypic and genotypic correlations of objective and subjective methods of temperament evaluation. Furthermore, we determined the effect and relationship of temperament on calf productive and reproductive traits using the FFSS data and subjective methods of temperament evaluations. Lastly, we determined the influence and association of cow temperament at weaning and sire docility EPD on adjusted birth weight (ABW), adjusted 205 weaning weight (205-d WW), weaning average daily gain (ADG), and weaning weight gain (WG) of their calves.

2. EVALUATOR IMPACT ON GENETIC PREDICTONS AND ASSOCIATIONS OF METHODS FOR BEEF CATTLE TEMPERAMENT EVALUATION

2.1. Abstract

The objectives of this study were: 1) to determine evaluator impact on genetic predictions using docility score (DS), temperament score (TS), 12 qualitative behavior assessment attributes (QBA; 6 positive and 6 negative attributes) and temperament index (TI, TI positive and negative) subjective methods; and 2) to determine relationship of movement-based objective method (four-platform standing scale, FPSS) using the standard deviation of FPSS data (SSD) and coefficient of variation of SSD (CVSSD) with subjective methods (across and within evaluators). We hypothesized that evaluator has a significant impact on genetic parameter estimations (heritability and breeding value) using subjective methods. Furthermore, objective methods using FPSS data (SSD, CVSSD) are moderately to highly correlated with subjective methods. Weaning age calves (n = 1,542) were evaluated using DS, TS, QBA scores, and FPSS methods over 4-year period. Fixed effects included evaluator (n = 11 total), primary breed (n = 2), sex (n = 2), day within year (n = 8) and random effect of calf using a repeated measure design (across-evaluator model only). Variance components, heritability ($\hat{h}^2$), and breeding values (EBV) were estimated using pedigree in ASReml 4.2. Evaluator effect on EBV was based on 1) Spearman rank correlation coefficients (r_s) and 2) 3-quartile change in rankings of calves among evaluators per trait. Results of the study showed that evaluator scoring was different in DS, TS, and 12 QBA that ranged from 28.57% to 95% of evaluators ($P < 0.002$). Spearman rank correlation coefficients on EBVs across and within evaluators were significant in DS, TS, TIs (TI, positive, and negative TI), and QBA attributes (except curious) that ranged from -0.68 to 0.88 ($P < 0.05$). Across and within evaluators, negligible 3 quartile change in EBV (0% to 2.27%) was observed using DS, TS, TI positive, and TI negative

while greater 3 quartile changes were observed on positive and negative QBA attributes (0% to 13.95%) and TI (1.56% to 30.05%). Genetic correlations of SSD to DS and TS were 0.44 and 0.62 while genetic correlations of CVSSD to DS and TS were 0.36 and 0.49, respectively. In conclusion, evaluator scoring has significant effect using subjective methods. However, in predicting genetic merit, evaluator has negligible effect for scoring systems already implemented by breed associations.

2.2. Introduction

Beef cattle temperament has been found to be moderately heritable and thereby, will respond to selection (Burrow, 1997). Countries like Australia and the United States have begun selecting beef cattle using a chute test (Benhajali, et al., 2010) and docility score (BIF, 2018) due to the realization of its importance to productivity, handling, safety, and animal welfare (Haskell et al., 2014). Variations in beef cattle response to stressors, human handling, and environmental challenge have an impact on working safety, adaptability, animal productivity, and animal welfare (Friedrich et al., 2014). The interest to improve cattle temperament is reflective of the trend that less labor in beef cattle management has been the industry standard (Benhajali et al., 2010). Handling is more labor intensive and time consuming and, therefore, increases production cost (Grandin, 1989). Furthermore, temperament is considered an economically important trait in cattle as fluctuation in profit associated with changes in this trait have been observed (Golden et al., 2000).

The main challenge in selection for beef cattle temperament is the difficulty in evaluation and subjectivity of measurement (Adamczyk et al., 2013). At present, there is still no gold standard method for evaluation. However, most beef cattle breed associations are using subjective methods of evaluation due to feasibility. Subjective methods include docility and pen scores (Hearnshaw and Morris, 1984; Grandin, 1993), and crush score (Tulloh, 1961; Hearnshaw et al., 1979) or chute score (Grandin, 1993). These methods rely on evaluator's interpretation of cattle behavior. Limited literature exists investigating evaluator effect and how it impacts temperament evaluation, prediction of genetic merit, and genetic parameter estimations. Therefore, the objectives of this study were: 1) to determine evaluator effect on genetic predictions of docility score (DS), temperament score (TS), 12 qualitative behavior attributes (QBA; 6 positive and 6 negative behavioral attributes) and Temperament Index (TI; positive and negative); 2) to determine relationship among subjective and objective (FFSS) methods of beef cattle temperament evaluation using phenotypic and genetic correlations across evaluator; and 3) to compare genetic parameter estimations (heritability and estimated breeding value ranking) differences per trait when evaluator was included in the model.

2.3. Materials and methods

2.3.1. Animals

All cattle were managed according to the Federation of Animal Science Guide for the Care and Use of Agricultural Animals in Agriculture Research and Teaching (FASS, 2010). Over a four-year period, data was collected on 1,542 weaning age calves (year 1: n = 420, year 2: n = 382, year 3: n= 337, and year 4: n = 403) that includes 779 steers and 750 heifers while 13 calves have no data on sex. Calves were produced by the cow herd at the North Dakota State University Central Grasslands Research Extension Center (CGREC), located approximately 14 km NW of Streeter, ND. This cow herd consists of approximately 425 Angus and Hereford-based females (mature cows and heifers) that were bred to either Angus or Hereford bulls. A pedigree including 109,483 animals was formed using the information of dams and records of complete ancestry for registered bulls provided by the American Angus Association and American Hereford Association. All procedures were reviewed and approved by the Institutional Animal Care and Use Committee of North Dakota State University.

2.3.2. Breed composition

Dams of calves used in this study had unknown pedigree and breed composition if born prior to 2012. Some heifers born from 2012 to 2015 were retained at CGREC for use in breeding, where breed type of sire was known, leading to a better estimation of their breed composition. Over the four-year study period (2014 to 2017), dams were mated to either Angus (AN) or Hereford (HH) bulls, except in the first year where only AN bulls were used.

Dams in the breeding population born prior to 2012 had unknown breed type (i.e., 100%UN) based on available records. It was known, however, that dams born in 2012 and 2013 were sired by AN bulls (i.e., 50%AN 50%UN breed type). When mated to AN or HH bulls, these produced either 50%AN 50%UN, 50%HH 50%UN, 75%AN 25%UN, or 50%HH 25%AN 25%UN, respectively. As the study progressed, heifers born in 2014 (50%AN 50%UN or 75%AN 25% UN) and 2015 (75%AN 25% UN or 50%HH 25%AN 25%UN) were introduced as dams and mated to either AN (both) or HH (2015 only) bulls. Over the 4-year period, eight breed types were produced in calves evaluated for temperament. These included 50%AN 50%UN (n = 943), 50%AN 25%HH 25%UN (n = 4), 50%HH 50%UN (n = 34), 50%HH 25%AN 25%UN (n = 150), 50% HH 37.5% AN 12.5% UN (n = 4), 62.5% AN 25% HH12.5% UN (n = 14), 75%AN 25%UN (n = 361), and 87.5%AN 12.5%UN (n = 32). Based on primary breed (50% or greater) this resulted in 1,354 AN and 188 HH influenced calves.

2.3.3. Beef cattle temperament evaluations

The experimental set-up (Figure 1) and execution for temperament evaluation used in this study was previously described by Hulsman Hanna et al. (2019) and Yu et al. (2020). Briefly, docility score (DS) followed BIF guidelines (BIF, 2018) using a scale of 1 to 6 with the head caught in the chute. Temperament score (TS) ranged from 1 to 5, where the intermediate score (3) was removed from the scale to avoid the option of evaluators choosing the median value (as described by Sant'Anna and Paranhos da Costa, 2013). For QBA previously described by Sant'Anna and Paranhos da Costa (2013), evaluators were provided with a single page of 12 attributes per calf, with each attribute having a corresponding 136 mm visual analog scale (VAS) to indicate the level of expression (0 to 136 mm) associated with that attribute for that given calf. The QBA score is the distance of the mark from the far-left side of the VAS (in mm) measured with a digital fractional caliper (General Tools & Instruments, New York, NY). For temperament evaluation using the four-platform standing scale (FPSS; Pacific Industrial Scale, British Columbia, Canada), data was collected on each quadrant with a rubber mat placed on top (approximately 1.22 m wide by 2.44 m long) to improve traction and comfort for the animal. A computer and software connected to FPSS recorded the weight shifts on each foot while calves were standing evenly without movement restriction on FPSS for at least 45 seconds.

Calves were evaluated as they were brought through the working pens based on management group (e.g., young dams vs. old dams). As calves pass through the handling facility, they first entered a squeeze (Moly Manufacturing Inc., Lorraine, KS) where their weaning weight and docility score were recorded. Calves were moved from the chute and entered the four-platform standing scale that measured weight distribution eight to ten times per second. The calf remained on the scale for at least 45 seconds. Once released from the four-platform standing scale, calves entered a working pen where they were evaluated for temperament score and QBA (Figure 2.1). A cattle handler was present in the working pen and slowly walked toward and moved each calf so that evaluators could score specific attributes for TS and QBA. Following evaluation in the working pen, calves were sorted into management pens.

After data collection was completed, records from the FPSS were quality checked and processed to calculate the two statistics that represent temperament: the standard deviation of total weight over 500 records (SSD) and the coefficient of variation of the SSD (i.e., the SSD divided by the mean of those same records). The process by which the FPSS data was calculated were described in detail in Hulsman Hanna et al. (2019) and Yu et al. (2020). Briefly, the standard deviation of FPSS (SSD) data were calculated using these steps:

1. Within each animal's data file, the ideal data point (start point) when the animal was completely standing on the scale was located. A diagram on locating the start point is shown in Figure 2.2.
2. The number of observations after this start point (including the start point) was counted for each animal.
3. The total number of observations was kept to 500 for consistency and to ensure a robust mean and SSD were identified. Priority was given to including as many records and animals as possible as long as the data was reliable.

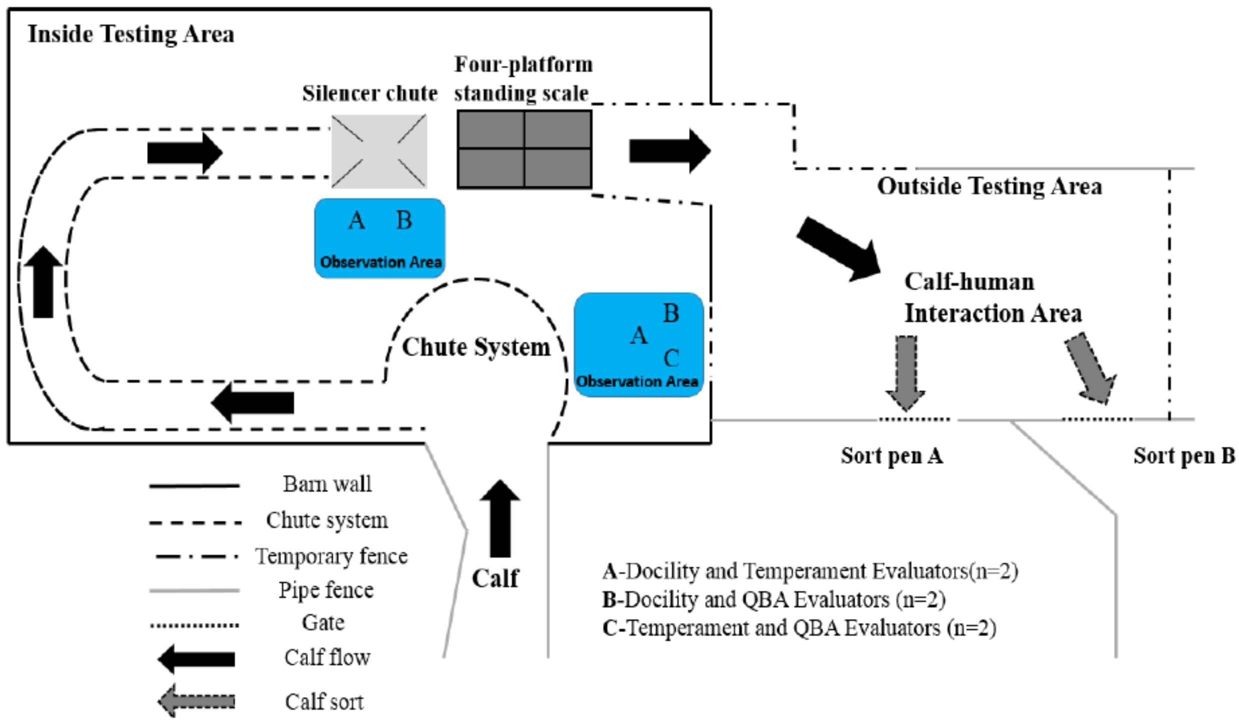


Figure 2.1. Experimental set-up for beef cattle temperament evaluation using docility score, temperament score, qualitative behavioral attributes, and four flatform standing scale (Hulsman Hanna et al., 2019).

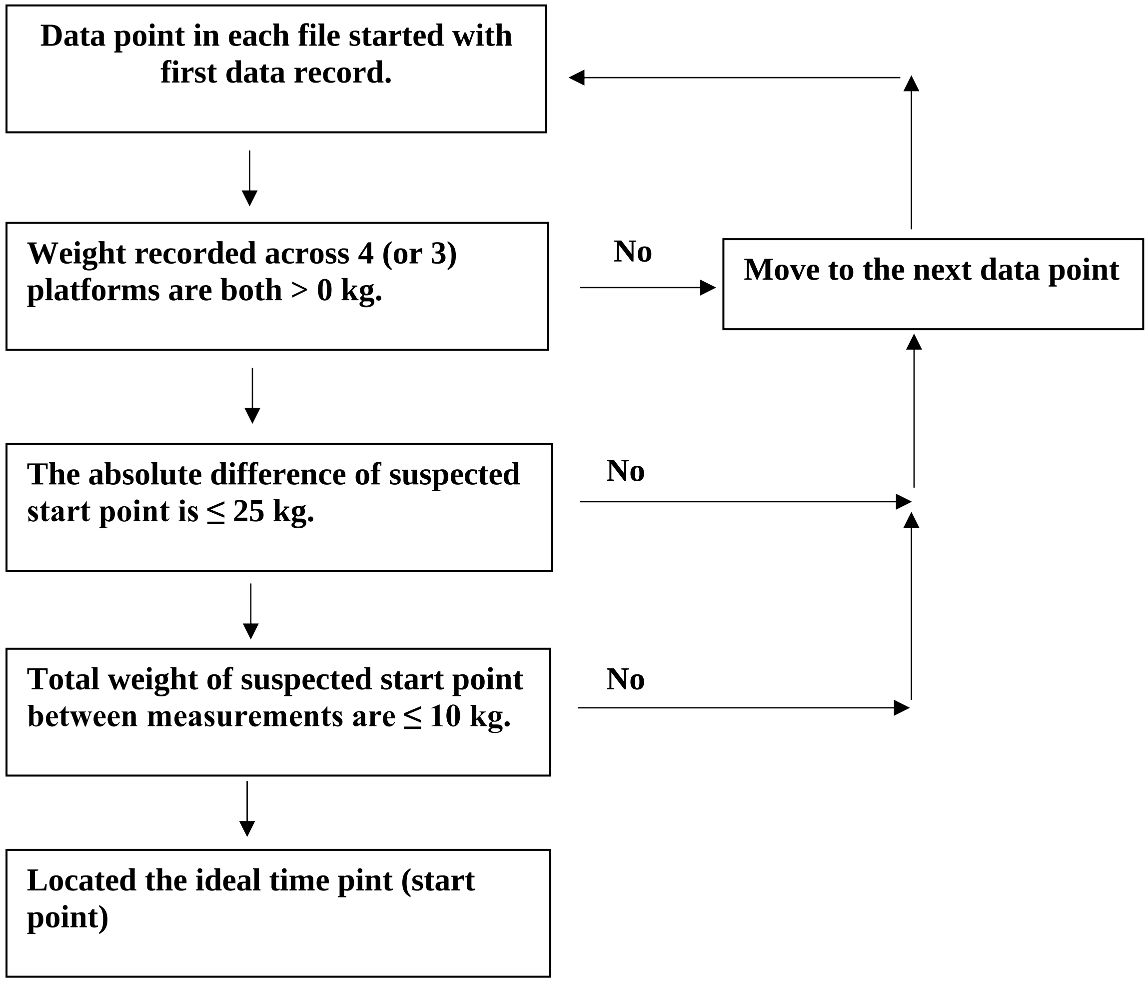


Figure 2.2. Procedure of locating start point for records from the four-platform standing scale to determine ideal number of records in calculating the standard deviation of records for a given animal. Absolute difference indicates absolute weight difference between total weight recorded by FPSS and weaning weight from the silencer chute. Total weight of the suspected start point between measurements are calculated within suspected start point and 5 following records.

2.3.4. Statistical analysis

Principal component analysis (PCA) using PROC PRINCOMP in SAS 9.4 (SAS Institute, Inc., Cary, NC) was conducted using the 12 QBA traits to produce the first principal component, referred to as the temperament index (TI; Sant'Anna and Paranhos da Costa, 2013). The 12 QBA traits consist of 6 positive and 6 negative QBA traits in which temperament index were also produced for each (TI positive and TI negative). Each trait (n = 15) was evaluated for fixed effects of evaluator (n = 4 per trait; 11 evaluators over the 4-year period), sex of the calf (n = 2), breed composition (n = 8), interactions of evaluator by sex of calf, and breed composition by sex of the calf, as well as a fixed covariate based on year, day, and sequence of evaluation (sequence covariate) and age of calve (age covariate). A repeated measures design was used with variance covariance structures tested to capture correlations among the residuals for a given animal.

The final model determined in SAS across traits was utilized to calculate additive genetic variances, permanent environment variances, heritability and repeatability estimates using ASReml 4.2 (Gilmour et al., 2015) to allow for an animal model based on current pedigree, appropriate distribution of data, and model effects. The basic statistical model equation for each trait to fitting animal model was:

$$Y = Xb + Zu + e$$

where Y is the vector of observations (traits), b is the vector for fixed effect, u is the additive genetic effects (animal), X is the incidence matrix of fixed effects, Z is the incidence matrix of additive genetic effects, and e is the residual error.

The impact of evaluator on breeding value estimations was evaluated based on 1) Spearman rank correlation coefficients (r_s) and 2) 3-quartile change in rankings of animals within a method across evaluators, which are procedures found in Hulsman Hanna et al. (2014). Correlation coefficient values greater than or equal to 0.50 is considered highly correlated, greater than or equal to 0.30 and less that 0.50 is moderately correlated, and less than 0.30 is lowly correlated. Bivariate analysis was used to calculate phenotypic and genetic correlation among subjective and objective measures of temperament using ASReml 4.2 (Gilmour et al., 2015). Least square means and standard errors were generated for fixed effects with relevant t-statistics provided through ASReml 4.2 (Gilmour et al., 2015). Pairwise comparisons were controlled for Type I Error using

Tukey-Kramer method by 1) converting the t-statistic to a q-statistic as $q = \sqrt{2} * t$ and 2) by finding the related p-value using the Real Statistics Resource Pack software (Release 7.6) Excel add-in QDIST function with k as the fixed effect degrees of freedom and the df as the residual degrees of freedom (Zaiontz, 2021).

2.4. Results and discussion

2.4.1. Principal component analysis

Principal component analysis was performed to reveal the internal structure of the QBA data that best explains variance per evaluator. This procedure reduces the dimensionally of 12 QBA data into one or two principal components depending on the eigenvalues. Based on Kaiser criterion (Kaiser, 1960), principal components with eigenvalue greater than 1 should be retained for further analysis. Principal component 1 (PC1) and principal component 2 (PC2) had eigenvalues greater than 1 across evaluators (Figure 2.3) when 12 QBA attributes were utilized for PCA. For the positive and negative QBA attributes, PC1 had eigenvalue greater than 1 across evaluators. However, not all evaluators in PC2 in both positive and negative QBA attributes had eigenvalues greater than one. Given this scenario, PC1 for 12 QBA and 6 positive and 6 negative QBA attributes were utilized as temperament indexes (TI, TI positive, and TI negative) in this study.

PC1 accounted for 39.64 to 45.90% variation for the 12 QBA attributes when considering the available evaluators (Table 2.1). For the 6 positive and 6 negative QBA attributes, PC1 accounted for 45.17% to 60.14% and 48.2% to 62.25% variation, respectively. Among these PC1s, negative QBA attributes accounted for the greatest variation followed by positive QBA attributes and 12 QBA attributes. Partitioning the 12 QBAs into two groups (positive and negative) for principal component analysis resulted in increased variation that PC1 captured. Even though PC1 accounts for a high percentage of the variation when all 12 attributes were used, there is still concern if this PC truly explains sufficient attributes of temperament for selection purposes. Various simulation studies with PCA have demonstrated it to substantially overestimate or underestimate the number of factors retained (Zwick and Velicer, 1986). Experts agree that it has deficiencies and that its use is not recommended (Ledesma and Mora, 2007). In a recent study conducted by Yu et al. (2020), exploratory factor analysis (EFA) was utilized to identify two latent variables that account for the 12 QBA attributes. Result of the study prove that EFA is useful in the analysis of the 12 QBA attributes. Even so, separating the QBA based on behavioral similarity (negative vs. positive) did improve PCA outcomes.

Table 2.1. Percentage variation for principal component 1 (PC1) and principal component (PC2) using 12 qualitative behavioral attributes, 6 positive and 6 negative QBA attributes[1].

Evaluators	**Percentage Variation**					
	12 QBA		**6 Positive QBA**		**6 Negative QBA**	
	PC1	**PC2**	**PC1**	**PC2**	**PC1**	**PC2**
1	45.90	10.47	48.13	18.42	54.95	14.20
2	42.98	23.71	57.99	17.50	58.36	18.33
6	39.64	19.85	51.19	22.54	59.37	12.58
7	44.97	15.82	45.17	22.46	62.25	15.18
9	45.38	11.91	47.37	18.68	48.84	16.61
10	45.39	19.54	60.14	17.91	48.20	19.43
11	45.70	18.22	46.09	23.37	53.06	20.73

[1]Qualitative behavioral attributes (QBA) consists of 12 attributes and are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) QBA.

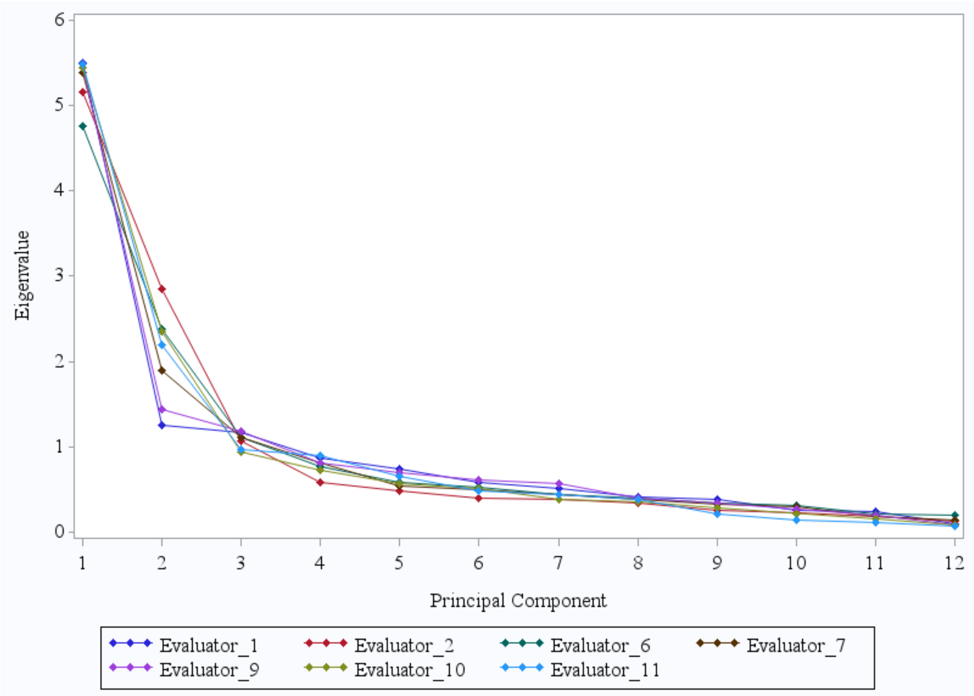


Figure 2.3. Principal component analysis scree plots by evaluator. Eigenvalues greater than 1 contribute to significant variation in the data (Kaiser, 1960).

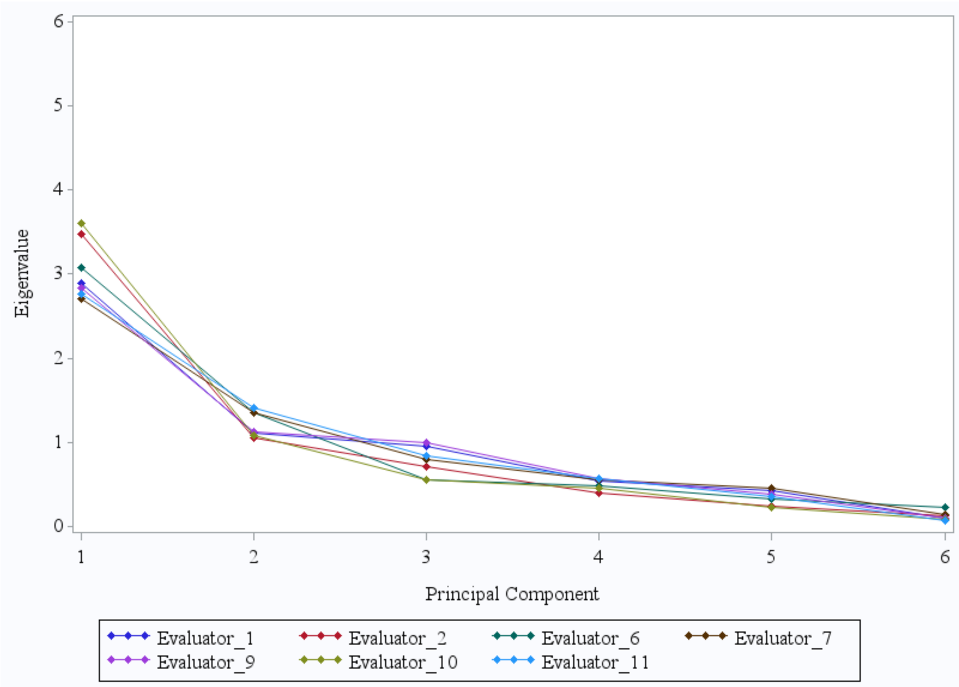


Figure 2.4. Principal component analysis scree plots for positive temperament index by evaluator. Eigenvalues greater than 1 contribute to significant variation in the data (Kaiser, 1960).

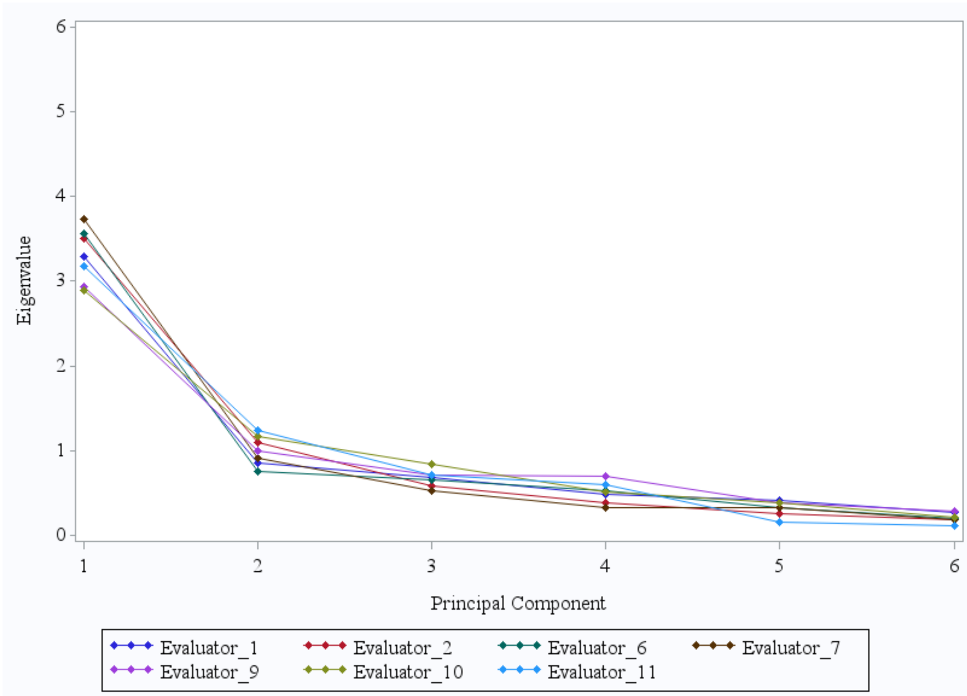


Figure 2.5. Principal component analysis scree plots for negative temperament index by evaluator. Eigenvalues greater than 1 contribute to significant variation in the data (Kaiser, 1960).

The 12 QBAs, positive and negative QBA attributes were plotted into a loading plot across evaluators with PC1 in the x-axis while PC2 in the y-axis to determine pattern of scoring across evaluators for QBA attributes. For the 12 QBA attributes in both PC1 and PC2, each evaluator scored differently (Figure 2.6). Some evaluators were in the positive loading and some were in the negative loading of the plot. In this section, evaluator differences using PC1 is used since this PC explains most of the variation. High positive loading (greater than 0.5) using PC1 is observed for 3 out 7 evaluators (42.86%) for active QBA attribute (QBA1) while 3 out 7 evaluators (42.86%) had high negative loading. For relaxed (QBA2) and calm (QBA5) QBA attributes, 2 out of 7 evaluators (28.57%) had high positive loading while 5 out of 7 evaluators (71.43%) had high negative loading. For fearful (QBA3), agitated (QBA4), irritated (QBA9), and distressed (QBA12) QBA attributes 5 out of 7 evaluators (71.43%) had high positive loading while 2 out of 7 evaluators

(28.57%) had high negative loading. For positively occupied (QBA7), apathetic (QBA10), happy (QBA11) QBA attributes 2 out of 7 evaluators (28.57%) had high positives loading while 1 (14.29%), 2 (28.57%), and 3 (42.86%) out of 7 evaluators had high negative loadings, respectively. Based on the result of this loading plot, there are differences in scoring using the 12 QBA attributes. When comparing negative and positive QBA attributes based on loading plot, the majority of negative QBA attributes (4 out of 6, 66.67%; fearful, agitated, irritated, and distressed) had greater percentage of evaluators (5 out of 7, 71.43%) that scored similarly. For positive QBA attributes, only 2 out of 6 (33.33%; relaxed and calm) QBA attributes had greater percentage of evaluators (5 out of 7, 71.43%) that scored similarly. Based on this result negative QBA are easier for evaluators to score similarly than positive QBA attributes. This result is similar to the study of Yu et al. (2020) using exploratory factor analysis which revealed that positive QBA attributes were difficult to score while negative QBA attributes were easy to score.

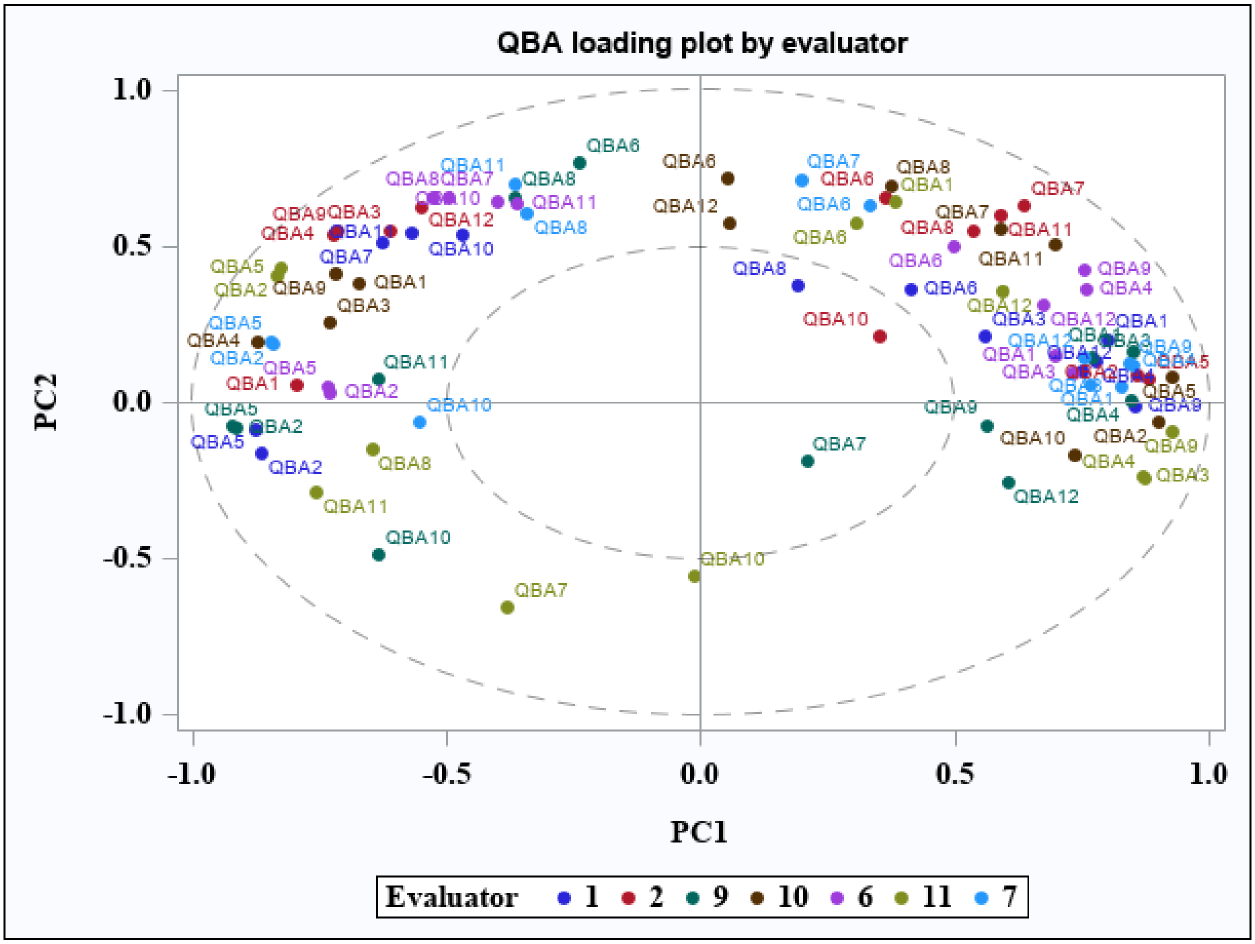


Figure 2.6. Qualitative behavior assessment attributes (12 QBA) loading plot by evaluator. QBA refers to qualitative behavior assessment attribute, QBA1 = active, QBA2 = relaxed, QBA3 = fearful, QBA4 = agitated, QBA5 = calm, QBA6 = attentive, QBA7 = positively occupied, QBA8 = curious, QBA9 = irritated, QBA10 = apathetic, QBA11 = happy, and QBA 12 = distressed.

2.4.2. Statistical modeling

Breed composition was significant in 7 out of 17 (41.18%) models. Upon review, it was determined that breed compositions with smaller sample sizes were driving significance rather than finding true breed or breed composition differences. As AN and HH may have different temperament, the primary breed (n = 2) was instead used as a fixed effect. Interactions of evaluator by sex as well as primary breed by sex were not included in the final model. Majority of models (n = 8 out of 17, 47.06%) indicated these interactions were not significant. Furthermore, it is unlikely all evaluators had time to assess sex of the calf during processing, therefore any statistical differences being found are likely artifacts rather than true differences. Lastly, primary breed by sex was not included in the final model because 9 out 17 (52.94%) models indicated these interactions were not significant. The final model across traits included fixed effects of evaluator, primary breed, sex and day within year as fixed effects, and random effect of calf. Sequence and age covariates were not included as sequence was found to be an indicator of temperament and age covariate did not improve the model, which was previously identified by Hulsman Hanna et al. (2019). Day within year was included in the model to account for contemporary grouping. Analysis in ASReml used variance-covariance structure based on pedigree to account for additive genetic variance (animal) and permanent environmental variance (across evaluator model) to account for repeated measures. For within evaluator model, permanent environment variance was not included in the final model as there was only one record for that evaluator per animal.

2.4.3. Evaluator scoring for subjective measure of temperament

There were 6 evaluators per year. However, evaluators per year varies across years as some evaluators could not return. In total, there were 11 evaluators used in 4 years. If an evaluator could not continue in the project, a new evaluator was selected based on similar temperament evaluation experience. This created an unbalanced design for the study. The evaluators with the number of year(s) of evaluation and number of records available for the traits are presented in Table 2.2 There were five evaluators (1, 3, 5, 9, and 11), two evaluators (6 and 8), 1 evaluator (2), and three evaluators (4, 7, and 10) that had 1 year, 2 years, 3 years, and 4 years of records, respectively. To avoid bias due to small sample sizes, evaluators having 3 or more years of record were used for analysis. Summary statistics indicating minimum, maximum, means and standard deviations for

DS, TS, each of the QBA attributes, and temperament indexes (TI, TI positive, TI negative) per year across evaluators are shown in Table 2.3.

Table 2.2. Record summary per evaluator for docility score (DS), temperament score (TS), qualitative behavior attributes (QBA), and temperament index (TI).

	Evaluator[1]										
Method	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
No. of years[2]	1	3	1	4	1	2	4	2	1	4	1
DS	418	-	382	1,541	419	702	1,534	740	398	-	-
TS	-	1,181	382	1,542	420	-	-	739	-	1,532	336
QBA[3]											
Apathetic	420	1,203	-	-	-	719	1,542	-	402	1,541	337
Calm	420	1,204	-	-	-	719	1,539	-	402	1,542	337
Curious	420	1,205	-	-	-	719	1,538	-	402	1,541	337
Happy	419	1,205	-	-	-	719	1,542	-	402	1,542	337
Pos. occupied	418	1,202	-	-	-	719	1,534	-	402	1,541	337
Relaxed	419	1,205	-	-	-	719	1,542	-	402	1,542	337
Active	420	1,205	-	-	-	719	1,542	-	402	1,542	337
Agitated	419	1,201	-	-	-	719	1,527	-	402	1,542	337
Attentive	419	1,202	-	-	-	718	1,539	-	402	1,539	337
Distressed	419	1,205	-	-	-	719	1,542	-	401	1,542	337
Fearful	420	1,204	-	-	-	718	1,539	-	402	1,542	337
Irritated	419	1,204	-	-	-	719	1,537	-	402	1,540	337
TI	420	1,205	-	-	-	719	1,542	-	402	1,542	337
TI positive	416	1,201	-	-	-	718	1526	-	402	1,538	336
TI negative	416	1,196	-	-	-	716	1515	-	401	1,536	336

[1]Records may varying for a given evaluator if that trait was accidently not scored.
[2]Number of years the evaluator scored as part of the project.
[3]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.

Table 2.3. Summary statistics for temperament traits measured across evaluators for calves over a 4-year period[1].

Evaluation	Year														
	2014			2015			2016			2017			Overall		
	Min	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**
Docility Score[2]	1.00	5.00	1.84 ± 0.77	1.00	6.00	1.91 ± 0.78	1.00	5.00	1.59 ± 0.64	1.00	5.00	1.38 ± 0.64	1.00	6.00	1.68 ± 0.74
Temperament Score[3]	1.00	4.00	1.80 ± 0.89	1.00	5.00	1.96 ± 0.89	1.00	5.00	2.09 ± 1.06	1.00	5.00	1.77 ± 0.92	1.00	5.00	1.90 ± 0.95
QBA[4] attributes															
Apathetic	0.00	133.90	59.58 ± 40.80	0.00	136.00	35.03 ± 48.45	0.00	136.00	13.12 ± 29.22	0.00	136.00	46.41 ± 45.41	0.00	136.00	39.89 ± 45.15
Calm	0.00	136.00	93.98 ± 30.18	0.00	136.00	58.63 ± 39.03	0.00	136.00	55.71 ±38.88	0.00	136.00	75.17 ± 40.44	0.00	136.00	71.94 ± 40.24
Curious	0.00	132.38	50.95 ± 30.53	0.00	133.76	14.32 ±20.98	0.00	136.00	30.36 ± 39.85	0.00	130.07	24.99 ± 27.45	0.00	133.76	30.58 ± 33.06
Happy	0.00	132.84	57.39 ± 35.95	0.00	105.00	9.67 ± 15.80	0.00	136.00	13.82 ± 25.17	0.00	132.85	29.71 ± 34.96	0.00	132.85	28.81 ± 35.13
Positively Occupied	0.00	133.79	51.63 ± 30.46	0.00	133.59	15.09 ± 18.76	0.00	125.55	20.93 ± 30.05	0.00	128.55	23.56 ± 30.55	0.00	133.79	28.52 ± 31.46
Relaxed	0.00	136.00	88.40 ± 32.28	0.00	136.00	55.08 ± 38.30	0.00	136.00	55.90 ± 37.69	0.00	136.00	70.95 ± 38.46	0.00	136.00	68.48 ± 39.14
Active	0.00	135.06	43.32 ± 34.46	0.00	136.00	57.17 ± 37.38	0.00	136.00	71.06 ± 40.13	0.00	131.51	46.41 ± 46.41	0.00	136.00	53.62 ± 37.18
Agitated	0.00	127.96	21.71 ± 19.46	0.00	136.00	31.60 ± 29.53	0.00	136.00	31.01 ± 28.83	0.00	136.00	24.53 ± 26.41	0.00	136.00	26.94 ± 26.48
Attentive	0.00	134.44	70.81 ± 25.78	0.00	135.25	37.68 ± 25.69	0.00	136.00	61.99 ± 41.39	0.00	132.06	43.24 ± 29.57	0.00	135.25	53.46 ± 33.67
Distressed	0.00	107.73	15.08 ± 16.36	0.00	135.62	13.22 ± 20.67	0.00	123.29	12.32 ± 17.11	0.00	115.20	8.56 ± 12.83	0.00	135.62	12.31 ± 17.08
Fearful	0.00	121.81	15.41 ± 15.97	0.00	134.92	23.43 ±23.43	0.00	136.00	36.64 ± 29.89	0.00	22.54	22.54 ± 23.97	0.00	134.92	23.90 ± 24.53
Irritated	0.00	115.71	21.53 ± 19.65	0.00	135.60	20.92 ± 24.68	0.00	136.00	22.60 ± 24.52	0.00	131.31	20.72 ± 23.26	0.00	135.60	21.40 ± 23.00
TI[5]	-7.49	11.03	0.51 ± 2.11	11.18	9.54	-0.279 ± 2.29	-6.48	8.08	-0.26 ± 2.31	-8.05	7.10	-0.05 ± 2.40	-11.19	11.03	0.00 ± 2.30
TI positive	-6.43	5.11	0.89 ±1.68	-3.45	16.91	-0.56 ± 1.61	-3.36	6.70	-0.45 ± 1.55	-3.45	5.71	-0.02 ± 1.83	-6.43	16.91	0.00 ± 1.77
TI negative	-2.55	10.22	0.06 ± 1.70	-2.84	9.85	0.11 ± 1.98	-3.35	8.29	0.12 ± 1.85	-2.70	8.09	-0.28 ± 1.74	-3.35	10.22	-0.00 ± 1.82

[1]Sample size for 2014 = 420, 2015 = 382, 2016 = 337, 2017 = 403, and across years = 1542. Minimum (Min), maximum (max), mean and standard deviation (SD) are reported.

[2]Docility score: scale of 1 to 6 with 1 = calm and 6 = very aggressive.

[3]Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence, and tries to attack the observer.

[4]QBA refers to qualitative behavior assessment, measured on a 136 mm visual analog scale. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression.

[5]TI=Temperament index: the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

Least square means and standard errors for evaluator effect on DS, TS, QBA attributes and TIs across evaluators (n = 11) are presented in Tables 2.3 and 2.4. Evaluators scored differently in all methods of evaluation (DS, TS, QBA (positive and negative), TIs (TI, TI+ and TI-) (*P-value* ≤ 0.002). For DS, differences ranged from 0.18 (3% of the scale) to 1.23 (20.50%) on a scale of 1 to 6 (Table 2.4). Similarly, for TS, differences ranged from 0.20 (5.04%) to 0.64 (16.11%) on a scale of 1 to 5, where 3 was not an option for evaluators (Table 2.4).

Table 2.4. Least squares means and standard errors for evaluator effect on docility score (DS) and temperament score (TS) across evaluator[1].

	Method	
Evaluator	**DS[2]**	**TS[3]**
1	1.59 ± 0.05^{e}	-
2	-	1.70 ± 0.07^{d}
3	2.55 ± 0.05^{a}	2.34 ± 0.07^{a}
4	1.77 ± 0.04^{d}	1.95 ± 0.07^{c}
5	2.00 ± 0.05^{c}	1.95 ± 0.07^{c}
6	2.16 ± 0.04^{b}	-
7	1.52 ± 0.04^{e}	-
8	1.34 ± 0.04^{f}	1.90 ± 0.07^{c}
9	1.32 ± 0.05^{f}	-
10	-	2.15 ± 0.07^{b}
11	-	1.98 ± 0.07^{c}

[a,b,c,d,e]Within a column, different superscript letters differ (*P* < 0.05).
[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, and random effect of animal with known pedigree.
[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive.
[3]Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer.

Table 2.5. Least squares means and standard errors for evaluator effect on qualitative behavior attributes (QBA) and temperament index (TI) across evaluator[1].

Method	**Evaluator**						
	1	**2**	**6**	**7**	**9**	**10**	**11**
QBA[2]							
Positive QBA							
Apathetic	50.25 ± 2.35^{b}	17.90 ± 1.96^{d}	13.37 ± 2.11^{d}	17.84 ± 1.90^{d}	28.88 ± 2.37^{c}	83.03 ± 1.90^{a}	29.55 ± 2.49^{c}
Calm	81.44 ± 2.85^{b,c}	72.71 ± 2.60^{d}	52.40 ± 2.69^{g}	63.35 ± 2.56^{f}	76.95 ± 2.86^{c,d}	67.26 ± 2.56^{e}	91.28 ± 2.94^{a}
Curious	34.74 ± 1.70^{b,c}	36.66 ± 1.16^{b}	14.17 ± 1.38^{e}	23.70 ± 1.07^{d}	32.32 ± 1.73^{b,c,d}	28.73 ± 1.07^{c,d}	72.29 ± 1.87^{a}
Happy	24.02 ± 1.73^{c}	23.61 ± 1.27^{c}	20.19 ± 1.45^{c}	11.60 ± 1.20^{d}	24.25 ± 1.75^{c}	42.76 ± 1.20^{b}	59.46 ± 1.88^{a}
Pos. occupied	44.47 ± 1.37^{a}	34.94 ± 0.87^{b}	13.94 ± 1.07^{c}	10.94 ± 0.78^{c}	9.55 ± 1.40^{c}	47.46 ± 0.78^{a}	31.96 ± 1.52^{b}
Relaxed	87.12 ± 2.78^{a}	69.63 ± 2.52^{c,d}	42.32 ± 2.62^{f}	57.52 ± 2.49^{e}	72.44 ± 2.79^{b,c,d}	67.30 ± 2.49^{d}	83.95 ± 2.87^{a,b}
Negative QBA							
Active	23.82 ± 2.17^{f}	39.26 ± 1.91^{e}	55.93 ± 2.01^{d}	40.08 ± 1.87^{e}	68.03 ± 2.18^{c}	80.70 ± 1.87^{b}	116.15 ± 2.26^{a}
Agitated	22.49 ± 1.88^{d,e}	21.47 ± 1.67^{e}	30.91 ± 1.75^{b}	25.42 ± 1.64^{c,d}	34.41 ± 1.89^{b}	38.89 ± 1.64^{a}	24.08 ± 1.96^{c,d,e}
Attentive	51.26 ± 1.65^{c,d}	45.67 ± 1.20^{d}	45.44 ± 1.38^{d,e}	41.93 ± 1.12^{e}	56.71 ± 1.68^{c}	62.62 ± 1.12^{b}	122.54 ± 1.80^{a}
Distressed	10.65 ± 1.04^{e}	13.35 ± 0.84^{d,e}	22.39 ± 0.92^{a}	14.17 ± 0.81^{c,d}	13.01 ± 1.05^{d,e}	6.64 ± 0.8^{f}	17.43 ± 1.11^{b,c}
Fearful	14.33 ± 1.48^{d}	17.40 ± 1.25^{d}	39.57 ± 1.34^{b}	25.47 ± 1.21^{c}	49.52 ± 1.50^{a}	24.62 ± 1.21^{c}	17.28 ± 1.57^{d}
Irritated	21.32 ± 1.66^{b,c}	24.44 ± 1.47^{a,b}	22.23 ± 1.54^{b,c}	19.63 ± 1.44^{c}	24.75 ± 1.67^{a,b}	26.76 ± 1.44^{a}	26.62 ± 1.72^{a,b}
TI[3]	-0.71 ± 0.13^{c}	-0.13 ± 0.08^{b,c}	0.43 ± 0.10^{a}	0.00 ± 0.07^{b}	0.02 ± 0.13^{a,b}	0.01 ± 0.07^{b}	0.52 ± 0.15^{a}
TI positive	-1.45 ± 0.13^{c}	-0.43 ± 0.12^{b}	0.59 ± 0.12^{a}	-0.17 ± 0.12^{b}	-0.23 ± 0.13^{b}	-0.18 ± 0.12^{b}	0.68 ± 0.13^{a}
TI negative	0.15 ± 0.14^{b,c}	0.26 ± 0.13^{b}	0.01 ± 0.13^{c}	0.19 ± 0.13^{b,c}	0.59 ± 0.14^{a}	0.20 ± 0.13^{b,c}	-0.01 ± 0.14^{c}

^{a,b,c,d,e,f}Within a row, different superscript letters differ ($P < 0.05$).

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, and random effect of animal with known pedigree.

[2]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression.

[3]Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

For the 12 QBA attributes, most evaluators scored differently (Table 2.5). Active, attentive, apathetic, curious, happy, and relaxed attributes had large differences in scores for all evaluators, considering the 136 mm scale. For active, the largest difference between least square means was 92.33 (67.88% of the line between the two evaluator's means), while for attentive, apathetic, curious, happy, and relaxed, the differences were slightly lower with 80.61 (59.27%), 69.66 (52.23%), 58.13 (42.74%), 47.86 (35.19%), and 44.79 (32.94%), respectively. Attributes of calm, positively occupied, and fearful had moderate differences of 38.88 (28.59%), 37.91 (28.88%), and 35.19 (25.87%), respectively. Attributes of agitated, distressed, and irritated had small differences (i.e., less than 15% of the line between the two evaluator's means) of 17.42 (12.81%), 15.74 (11.58%), and 7.13 (5.25%), respectively. Therefore, 4 out of 6 negative-like behaviors had lower differences seen between evaluators (less than 26% of the line differed) meaning their scores were more likely to be similar to each other. All positive-like behaviors had their largest difference be over 28% of the line.

Out of 28 pairs of evaluators for DS, 2 (7.14%) scored similarly. On the other hand, 6 out of 21 pairs (28.57%) of evaluators scored similarly for TS. Therefore, TS had more evaluators score similarly than DS. This also means that it is easier for the evaluators to use TS and were interpreting cattle temperament similarly on that scale. These results suggest that it is easier for the evaluator to use a lesser scale (6-point vs. 4-point scale). According to Randel et al. (2012) these two methods measure different cattle temperament behaviors. It is also possible that the evaluator can easily see the reaction or behavior of the cattle to human approach (TS) similarly than the response of the animal to restraint (DS).

In terms of evaluator pairs, there were 1 (4.76%), 6 (28.57%), 5 (23.81%), 6 (28.57%), 4 (19.05%), and 15 (71.43%) pairs of evaluators out of 21 total pairs that scored similarly for active, agitated, attentive, distressed, fearful, and irritated negative QBA attributes, respectively. For positive QBA attributes, there were 4 (19.05%), 2 (9.52%), 5 (23.81%), 6 (28.57%), 5 (23.81%), and 4 (19.05%) pairs of evaluators out of 21 total pairs that scored similarly using apathetic, calm, curious, happy, positively occupied, and relaxed attributes, respectively. Irritated was the easiest attribute for evaluators to score similarly (i.e., 71.43% of evaluators). Descriptive statistics confirm that irritated had full range of scores available across all years, indicating that evaluators were able to perceive irritated calves better than other attributes. Even so, 6 other QBA attributes had 5 or 6 pairs of evaluators score similarly, which resembles TS. As indicated by mean differences, active attribute had the lowest number of evaluators scoring similarly, with only 1 pair. Therefore, QBA attributes are likely to be influenced by evaluator experience and future work should reduce these to attributes that can be scored similarly.

For TI, most evaluators scores were not different from each other (Table 2.5). Out of 21 pairs of evaluators, there were 11 (52.38%), 5 (23.81%), and 14 (66.67%) pairs of evaluators that scored similarly using TI, TI+, and TI- respectively. Therefore, running PCA per evaluator reduced variability. When looking on average, negative QBA had 29.4% evaluators score similarly compared to 20.6% of evaluators for positive QBA. This aligns with TI outcomes since TI- had higher percent of evaluators score similarly than TI+. It is also evident that TI traits have less evaluator bias, as expected based on PCA, than DS, TS, or QBA attributes on their own.

A previous study by Parham et al. (2019) indicated that experience of the evaluator plays an important role in scoring consistently (i.e., unexperienced evaluators had more variation than experienced evaluators). In our study, all evaluators had experience in handling cattle but differed in terms of experience in evaluating beef cattle temperament and use of subjective methods of temperament evaluation.

2.4.4. Primary breed effect on temperament

When accounting for evaluators in the statistical model, DS, TS, QBA attributes TI, TI+ and TI- did not have significant primary breed effect (*P-value* > 0.05) (Table 2.6). Within evaluator, DS, TS, QBA attributes TI, TI+ and TI- did not have significant primary breed effect (*P-value* > 0.05) except for evaluator 2 for positively occupied QBA attribute (*P-value* ≤ 0.05) (Tables 2.6 to 2.9). Hereford-based calves had increased expression of positively occupied than AN based calves, meaning HH based calves had more docile temperament. Majority of the calves in the study were AN based, creating an unbalanced design and leading to larger standard errors for HH based calves. Even so, it is well established that breed differences affect cattle temperament. For example, *Bos taurus* breeds are generally more docile than *Bos indicus* breeds (Burrow, 2001). Sire breed also had an influence on temperament. *Bos taurus* sired calves were significantly calmer compared to *Bos indicus* sired calves, specifically Brahman influenced sires (Hearnshaw and Morris, 1984). Calves in this study were primarily AN and HH influenced breeds and generally had docile temperament. Based on DS and TS scores, most of the calves (DS = 94% and TS = 86%) on all evaluators' average scores were 1 and 2, meaning calves in this study had docile temperament regardless of breed.

Table 2.6. Least squares means and standard errors for primary breed effect on docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) across evaluators[1].

Method	**Primary Breed**				
	Angus	**N**	**Hereford**	**N**	**P-value[6]**
DS[2]	1.76 ± 0.02	5387	1.80 ± 0.07	747	0.659
TS[3]	1.97 ± 0.03	5382	2.02 ± 0.12	750	0.659
QBA[4]					
Positive QBA					
Apathetic	36.03 ± 0.90	5412	32.77 ± 3.42	752	0.348
Calm	71.38 ± 1.27	5411	73.02 ± 4.75	752	0.733
Curious	33.92 ± 0.61	5410	35.40 ± 1.67	752	0.397
Happy	28.92 ± 0.64	5414	29.91 ± 2.01	752	0.630
Pos. occupied	27.01 ± 0.45	5402	28.21 ± 1.10	751	0.301
Relaxed	68.53 ± 1.21	5413	68.70 ± 4.61	752	0.971
Negative QBA					
Active	58.56 ± 0.93	5415	62.57 ± 3.44	752	0.253
Agitated	27.86 ± 0.84	5397	28.61 ± 3.01	750	0.808
Attentive	59.27 ± 0.62	5405	62.50 ± 1.86	751	0.097
Distressed	13.89 ± 0.46	5413	14.00 ± 1.43	752	0.939
Fearful	26.91 ± 0.66	5410	26.86 ± 2.18	752	0.984
Irritated	22.80 ± 0.76	5407	24.56 ± 2.64	751	0.514
TI[5]	-0.02 ± 0.04	5347	0.06 ± 0.09	747	0.365
TI positive	-0.16 ± 0.06	5386	-0.18 ± 0.21	751	0.939
TI negative	0.13 ± 0.07	5368	0.26 ± 0.24	748	0.574

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, and random effect of animal with known pedigree using repeated measures design.
[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive.
[3]Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer.
[4]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression.
[5]Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).
[6]P-value ≤ 0.05 is significant

Table 2.7. Least squares means and standard errors for primary breed effect on docility score (DS) and temperament score (TS) within evaluators[1].

Evaluator by method	Primary Breed				
	Angus	N	Hereford	N	P-value[4]
DS[2]					
4	1.74 ± 0.03	1353	1.85 ± 0.10	188	0.279
7	1.50 ± 0.03	1349	1.53 ± 0.08	185	0.090
TS[3]					
2	1.60 ± 0.03	1047	1.68 ± 0.11	134	0.519
4	1.90 ± 0.04	1354	1.95 ± 0.13	188	0.685
10	2.11 ± 0.04	1344	2.18 ± 0.15	188	0.668

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, and random effect of animal with known pedigree.
[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive.
[3]Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence, and tries to attack the observer.
[4]P-value ≤ 0.05 is significant

Table 2.8. Least squares means and standard errors for primary breed effect on positive qualitative behavior attributes (QBA) within evaluators[1].

Evaluator by method	**Primary Breed**				
	Angus	**N**	**Hereford**	**N**	**P-value**
QBA[2]					
Positive QBA					
Apathetic					
2	29.02 ± 1.18	1067	24.60 ± 3.93	136	0.282
7	20.71 ± 1.13	1354	17.10 ± 4.36	188	0.415
10	82.15 ± 1.57	1353	84.72 ± 4.80	188	0.270
Calm					
2	76.65 ± 1.64	1068	81.49 ± 5.87	136	0.423
7	66.39 ± 2.66	1351	61.44 ± 2.67	188	0.511
10	67.65 ± 1.66	1364	69.66 ± 6.00	188	0.110
Curious					
2	37.33 ± 1.21	1069	42.12 ± 3.56	136	0.210
7	23.46 ± 0.76	1350	24.23 ± 2.04	188	0.727
10	27.84 ± 0.71	1353	30.49 ± 1.90	188	0.205
Happy					
2	30.05 ± 0.91	1069	35.24 ± 2.61	136	0.076
7	12.80 ± 0.64	1354	14.43 ± 1.77	188	0.391
10	41.31 ±1.09	1354	41.40 ± 3.28	188	0.980
Pos. occupied					
2	35.37 ± 0.97[a]	1066	42.02 ± 2.76[b]	136	0.037
7	11.53 ± 0.64	1347	11.93 ± 2.01	187	0.850
10	46.55 ± 0.84	1353	47.06 ± 2.69	188	0.855
Relaxed					
2	72.74 ± 1.57	1069	73.82 ± 5.77	136	0.856
7	57.48 ± 1.24	1353	58.96 ± 4.44	188	0.745
10	68.37 ± 1.75	1354	69.34 ± 6.21	188	0.879

[a,b,c,d,e,f]Within a row, different superscript letters differ ($P < 0.05$).

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, and random effect of animal with known pedigree.

[2]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression.

Table 2.9. Least squares means and standard errors for primary breed effect on negative qualitative behavior attributes (QBA) within evaluators[1].

Evaluator by method	Primary Breed				
	Angus	N	Hereford	N	P-value[3]
QBA[2]					
Negative QBA					
Active					
2	37.81 ± 0.99	1069	40.84 ± 3.59	136	0.412
7	38.27 ± 0.97	1354	41.95 ± 3.50	188	0.307
10	78.04 ± 1.28	1354	79.61 ± 4.39	188	0.729
Agitated					
2	20.14 ± 0.93	1065	20.80 ± 3.40	136	0.850
7	24.15 ± 1.59	1341	26.95 ± 1.60	186	0.870
10	39.01 ± 1.35	1354	40.87 ± 4.87	188	0.709
Attentive					
2	46.43 ± 0.91	1066	47.92 ± 2.64	136	0.597
7	40.95 ± 0.80	1351	42.36 ± 2.43	188	0.580
10	61.98 ± 0.98	1352	66.99 ± 2.83	187	0.100
Distressed					
2	14.61 ± 0.77	1069	14.87 ± 2.58	136	0.923
7	14.91 ± 0.68	1354	13.99 ± 2.13	188	0.676
10	5.51 ± 0.25	1354	5.87 ± 0.68	188	0.627
Fearful					
2	12.98 ± 0.66	1068	15.14 ± 2.13	136	0.332
7	26.24 ± 0.76	1351	23.65 ± 2.45	188	0.310
10	24.29 ± 0.87	1354	23.67 ± 2.59	188	0.820
Irritated					
2	23.89 ± 1.06	1068	25.03 ± 3.75	136	0.769
7	19.00 ± 0.72	1350	19.85 ± 2.30	187	0.720
10	24.80 ± 1.09	1352	25.54 ± 3.85	188	0.850

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, and random effect of animal with known pedigree.
[2]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression.
[3]P-value ≤ 0.05 is significant

Table 2.10. Least squares means and standard errors for primary breed effect on negative qualitative behavior attributes (QBA) within evaluators[1].

Evaluator by method	**Primary Breed**				
	Angus	**N**	**Hereford**	**N**	**P-value[3]**
TI[2]					
2	-0.22 ± 0.10	1056	-0.15 ± 0.36	136	0.833
7	0.27 ± 0.10	1317	0.31 ± 0.36	184	0.921
10	-0.14 ± 0.09	1347	-0.15 ± 0.32	187	0.970
TI positive					
2	-0.13 ± 0.07	1065	0.14 ± 0.24	136	0.271
7	-0.16 ± 0.07	1339	-0.14 ± 0.24	187	0.922
10	-0.13 ± 0.06	1350	-0.07 ± 0.21	188	0.806
TI negative					
2	0.16 ± 0.08	1060	0.31 ± 0.29	136	0.601
7	0.18 ± 0.08	1330	0.23 ± 0.27	185	0.850
10	0.05 ± 0.07	1349	0.17 ± 0.25	187	0.631

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, and random effect of animal with known pedigree.
[2]Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).
[3]P-value ≤ 0.05 is significant

2.4.5. Sex effect on temperament

When evaluator was included in the statistical model, sex of calves did not have significant effect on DS or TS (Table 2.11). For positive QBA attributes, sex has significant effect on apathetic, calm, and relaxed attributes and for all negative QBA attributes (active, agitated, attentive, distresses and irritated) (*P-value* ≤ 0.05) except fearful. For TI, sex of calves had no significant effect while in TI positive (TI+) and TI negative (TI-), sex of calves had a significant effect. In summary, sex was found to be significant in 10 out of 17 (58.82%) temperament traits in this study. Heifers had higher least squares means (LSMeans) using negative QBA attributes and TI- compared to steers, suggesting that heifers are more temperamental. Heifers had lower LSMeans compared to steers using positive QBA attributes and TI+, further supporting that heifers are more temperamental. Results of this study are consistent with results found in literature where heifers are more excitable than steers (Hearnshaw, 1979; Voisenet et al., 1997; and Riley et al., 2014).

For within evaluator, sex was significant within majority of the evaluators per trait except DS, curious, happy, and positively occupied, attentive, distressed, and fearful QBA attributes (Table 2.11 to Table 2.15). Although sex is not significant in all evaluators per trait, temperament scores have similar numerical trends where heifers had higher scores using DS, TS, negative QBA, and TI- than steers. Using positive QBA and TI+, heifers that lower scores compared than steers except for evaluators 7 for curious, happy, and positively occupied QBA attributes; and evaluator 10 for happy QBA attributes. Results are similar to previous studies that heifers were more temperamental that steers (Voisenet et al., 1997 and Riley et al., 2014). Therefore, sex is an important factor in temperament evaluation and should be included in statistical modelling.

Table 2.11. Least squares means and standard errors for sex effect on docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) across evaluators[1].

Method	Sex				
	Steer	N	Heifer	N	P-value
DS[2]	1.76 ± 0.04	778	1.80 ± 0.04	750	0.154
TS[3]	1.96 ± 0.07	779	2.04 ± 0.07	750	0.154
QBA[4]					
Positive QBA					
Apathetic	35.58 ± 1.87[a]	779	33.22 ± 1.87[b]	750	0.018
Calm	73.71 ± 2.61[a]	779	70.69 ± 2.61[b]	750	0.036
Curious	34.87 ± 0.98	779	34.45 ± 0.99	749	0.577
Happy	29.61 ± 1.14	779	29.21 ± 1.14	750	0.588
Pos. occupied	27.49 ± 0.69	778	27.49 ± 0.69	750	0.693
Relaxed	70.21 ± 2.53[a]	779	67.01 ± 2.53[b]	750	0.019
Negative QBA					
Active	59.32 ± 1.89[a]	779	61.82 ± 1.89[b]	750	0.017
Agitated	27.21 ± 1.66[a]	779	29.27 ± 1.67[b]	750	0.035
Attentive	60.01 ± 1.06[a]	778	61.76 ± 1.07[b]	749	0.017
Distressed	13.16 ± 0.81[a]	779	14.73 ± 0.82[b]	750	0.005
Fearful	26.15 ± 1.22	779	27.62 ± 1.23	750	0.063
Irritated	22.71 ± 1.47[a]	778	24.65 ± 1.47[b]	749	0.029
TI[5]	0.01 ± 0.06	775	0.03 ± 0.06	746	0.804
TI positive	-0.10 ± 0.12[a]	779	-0.24 ± 0.12[b]	749	0.024
TI negative	0.09 ± 0.13[a]	779	0.30 ± 0.13[b]	749	0.007

[a,b,c,d,e,f]Within a row, different superscript letters differ ($P < 0.05$).

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, and random effect of animal with known pedigree.

[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive.

[3]Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer.

[4]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression.

[5]Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

Table 2.12. Least squares means and standard errors for sex effect on docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) within evaluators[1].

Evaluator by method	**Sex**				
	Steer	**N**	**Heifer**	**N**	**P-value**
DS[2]					
4	1.76 ± 0.05	778	1.83 ± 0.06	750	0.105
7	1.49 ± 0.05	776	1.55 ± 0.05	745	0.306
TS[3]					
2	1.60 ± 0.06[a]	613	1.68 ± 0.06[b]	555	0.053
4	1.91 ± 0.07	779	1.94 ± 0.07	750	0.439
10	2.09 ± 0.08[a]	773	2.20 ± 0.08[b]	746	0.027

[a,b,c,d,e,f]Within a row, different superscript letters differ ($P < 0.05$).

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, and random effect of animal with known pedigree.

[2]Docility score: scale of 1 to 6 with 1 = calm and 6 = very aggressive.

[3]Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer.

Table 2.13. Least squares means and standard errors for sex effect on positive qualitative behavior attributes (QBA) within evaluators[1].

Evaluator by method	**Sex**				
	Steer	**N**	**Heifer**	**N**	**P-value**
QBA[2]					
Positive QBA					
Apathetic					
2	28.67 ± 2.21[a]	625	24.95 ± 2.24[b]	565	0.020
7	20.81 ± 2.38[a]	779	17.00 ± 2.38[b]	750	0.004
10	84.16 ± 2.73	778	82.71 ± 2.77	750	0.476
Calm					
2	81.12 ± 3.27[a]	624	77.02 ± 3.28[a]	567	0.054
7	66.39 ± 2.66[a]	778	61.44 ± 2.67[b]	748	0.002
10	69.97 ± 3.30	779	67.34 ± 3.32	750	0.183
Curious					
2	41.19 ± 2.07	625	38.25 ± 2.12	567	0.104
7	23.44 ± 1.22	778	24.24 ± 1.26	747	0.493
10	29.82 ± 1.14	779	28.50 ± 1.18	749	0.246
Happy					
2	33.29 ± 1.53	625	32.01 ± 1.58	567	0.359
7	13.36 ± 1.04	779	13.87 ± 1.07	750	0.588
10	41.00 ± 1.88	779	41.71 ± 1.91	750	0.619
Pos. occupied					
2	39.15 ± 1.64	622	38.24 ± 1.70	567	0.579
7	11.25 ± 1.14	776	12.21 ± 1.15	745	0.248
10	47.49 ± 1.51	778	46.12 ± 1.53	750	0.198
Relaxed					
2	75.42 ± 3.19[a]	625	71.14 ± 3.20[b]	567	0.033
7	60.28 ± 2.45[a]	779	56.16 ± 2.46[b]	749	0.006
10	70.33 ± 3.43	779	67.39 ± 3.45	750	0.165

[a,b,c,d,e,f]Within a row, different superscript letters differ ($P < 0.05$).

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, and random effect of animal with known pedigree.

[2]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression.

Table 2.14. Least squares means and standard errors for sex effect on negative QBA qualitative behavior attributes (QBA) within evaluators[1].

Evaluator by method	Sex				
	Steer	N	Heifer	N	P-value
QBA[2]					
Negative QBA					
Active					
2	37.76 ± 1.99[a]	625	40.89 ± 2.00[b]	567	0.014
7	38.51 ± 1.93[a]	779	41.71 ± 1.94[b]	750	0.006
10	77.26 ± 2.44[a]	779	80.39 ± 2.46[b]	750	0.047
Agitated					
2	18.89 ± 1.89[a]	622	22.04 ± 1.89[b]	566	0.008
7	24.15 ± 1.59[a]	773	26.95 ± 1.60[b]	741	0.009
10	39.58 ± 2.68	779	40.31 ± 2.69	750	0.653
Attentive					
2	45.94 ± 1.58	625	48.41 ± 1.65	564	0.145
7	39.62 ± 1.39[a]	777	43.70 ± 1.41[b]	749	<0.001
10	64.19 ± 1.63	778	64.79 ± 1.67	748	0.653
Distressed					
2	12.92 ± 1.45[a]	625	16.56 ± 1.47[b]	567	<0.001
7	13.64 ± 1.20	779	15.26 ± 1.22	750	0.062
10	5.42 ± 0.42	779	5.96 ± 0.43	750	0.236
Fearful					
2	13.41 ± 1.21	624	14.71 ± 1.23	567	0.155
7	23.53 ± 1.38[a]	776	26.36 ± 1.39[b]	750	0.003
10	23.57 ± 1.48	779	24.40 ± 1.51	750	0.469
Irritated					
2	22.11 ± 2.09[a]	624	26.81 ± 2.10[b]	567	<0.001
7	18.26 ± 1.30[a]	777	20.58 ± 1.31[b]	747	0.011
10	24.37 ± 2.13	778	25.97 ± 2.14	749	0.230

[a,b,c,d,e,f]Within a row, different superscript letters differ ($P < 0.05$).

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, and random effect of animal with known pedigree.

[2]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression.

Table 2.15. Least squares means and standard errors for sex effect on temperament index within evaluators[1].

Evaluator by method[2]	Sex				
	Steer	N	Heifer	N	P-value
TI					
2	-0.01 ± 0.20[a]	617	-0.36 ± 0.20[b]	562	0.005
7	0.11 ± 0.20[a]	761	0.47 ± 0.20[b]	727	0.002
10	-0.07 ± 0.18	775	-0.22 ± 0.18	746	0.150
TI positive					
2	0.10 ± 0.13[a]	622	-0.09 ± 0.13[b]	566	0.036
7	-0.05 ± 0.13[a]	774	-0.24 ± 0.13[b]	739	0.016
10	-0.05 ± 0.12	777	-0.15 ± 0.12	740	0.183
TI negative					
2	0.07 ± 0.16[a]	620	0.40 ± 0.16[b]	563	0.002
7	0.06 ± 0.15[a]	766	0.35 ± 0.15[b]	736	0.003
10	0.06 ± 0.14	777	0.17 ± 0.14	746	0.172

[a,b,c,d,e,f]Within a row, different superscript letters differ ($P < 0.05$).

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, and random effect of animal with known pedigree.

[2]Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

2.4.6. Day within year effect on temperament

Across evaluators, day within year of evaluation had significant effect on all measures of beef cattle temperament in this study (Table 2.16) (*P-value* ≤ 0.05). Within evaluator, day within year of evaluation were significantly different for all temperament traits (Table 2.16 to 2.20). Day within year of evaluation is included in the model to account for differences in environment across years and days that impact temperament evaluation. Results of this study showed that day within year significantly affect temperament evaluation and therefore should be included in statistical modelling of temperament traits. Similarly, significant effect of season (spring and fall) by birth year was found by Hulsman Hanna et al. (2014) when evaluating Nellore-Angus cross steers. Although day within year is different from season by birth year, these shows that in evaluation of beef cattle temperament, these environmental corrections should be accounted due to variation of day-to-day management and weather fluctuations.

Table 2.16. Least squares means and standard errors for day nested within year effect on docility score (DS) temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) across evaluators[1].

Method	Day within year of evaluation							
	2014		2015		2016		2017	
	1	2	1	2	1	2	1	2
DS[2]	2.12 ± 0.06^{a}	1.79 ± 0.05^{b}	1.83 ± 0.05^{b}	1.66 ± 0.05^{b}	1.79 ± 0.06^{b}	1.66 ± 0.05^{b}	1.75 ± 0.05^{b}	1.65 ± 0.05^{b}
TS[3]	1.83 ± 0.09^{b}	1.93 ± 0.09^{a,b}	2.02 ± 0.09^{a,b}	1.94 ± 0.08^{a,b}	2.16 ± 0.09^{a,b}	2.25 ± 0.09^{a}	1.93 ± 0.08^{a,b}	1.90 ± 0.09^{a,b}
QBA[4]								
Positive QBA								
Apathetic	53.01 ± 2.44^{a}	49.05 ± 2.32^{a}	32.85 ± 2.37^{b}	37.70 ± 2.29^{b}	9.44 ± 2.45^{c}	8.14 ± 2.43^{c}	43.32 ± 2.19^{a}	41.70 ± 2.42^{a,b}
Calm	93.73 ± 3.41^{a}	95.43 ± 3.24^{a}	64.63 ± 3.32^{c,d}	65.84 ± 3.20^{b,c}	52.27 ± 3.43^{d}	57.18 ± 3.40^{d}	77.50 ± 3.04^{b}	71.03 ± 3.37^{b,c}
Curious	59.23 ± 1.48^{a}	52.51 ± 1.42^{b}	24.77 ± 1.46^{d,e}	22.65 ± 1.38^{e}	36.02 ± 1.49^{c}	24.17 ± 1.50^{d,e}	30.31 ± 1.30^{c,d}	27.59 ± 1.44^{c,d,e}
Happy	65.40 ± 1.60^{a}	58.68 ± 1.53^{b}	18.44 ± 1.57^{d}	11.05 ± 1.50^{e,f}	9.95 ± 1.62^{e,f}	6.31 ± 1.61^{f}	32.18 ± 1.42^{c}	33.30 ± 1.57^{c}
Pos. occupied	50.59 ± 1.11^{a}	40.77 ± 1.08^{b}	17.19 ± 1.11^{d}	15.87 ± 1.04^{d}	29.79 ± 1.12^{c}	15.42 ± 1.14^{d}	25.04 ± 0.98^{c}	26.21 ± 1.07^{c}
Relaxed	82.97 ± 3.28^{a,b}	87.98 ± 3.12^{a}	64.31 ± 3.20^{c,d}	60.33 ± 3.08^{d}	53.99 ± 3.30^{d}	60.19 ± 3.27^{c,d}	71.89 ± 2.93^{b,c}	67.23 ± 3.25^{b,c}
Negative QBA								
Active	61.44 ± 2.48^{a}	57.99 ± 2.36^{b}	66.90 ± 2.42^{a}	65.70 ± 2.33^{a}	58.99 ± 2.50^{a,b}	66.60 ± 2.47^{a}	49.78 ± 2.21^{b}	57.15 ± 2.45^{b}
Agitated	25.62 ± 2.23^{a,b,c}	22.93 ± 2.12^{c}	32.15 ± 2.17^{a,b}	32.74 ± 2.09^{a}	32.08 ± 2.24^{a,b}	31.99 ± 2.22^{a,b}	24.30 ± 1.97^{b,c}	24.11 ± 2.20^{b,c}
Attentive	86.78 ± 1.54^{a}	79.33 ± 1.47^{b}	52.00 ± 1.51^{c}	50.22 ± 1.43^{c}	55.55 ± 1.55^{c}	56.03 ± 1.55^{c}	50.82 ± 1.35^{c}	56.33 ± 1.50^{c}
Distressed	23.12 ± 1.16^{a}	14.73 ± 1.11^{b,c}	18.93 ± 1.14^{a,b}	8.62 ± 1.09^{d}	12.15 ± 1.17^{c,d}	11.66 ± 1.17^{c,d}	11.07 ± 1.02^{c,d}	11.31 ± 1.13^{c,d}
Fearful	24.27 ± 1.70^{b}	20.64 ± 1.62^{b}	25.59 ± 1.66^{b}	23.65 ± 1.59^{b}	37.17 ± 1.71^{a}	40.68 ± 1.70^{a}	20.79 ± 1.49^{b}	22.28 ± 1.66^{b}
Irritated	28.63 ± 1.98^{a}	19.69 ± 1.88^{b}	28.96 ± 1.94^{a}	17.93 ± 1.86^{b}	26.56 ± 1.99^{a}	23.17 ± 1.98^{a,b}	22.24 ± 1.75^{a,b}	22.25 ± 1.95^{a,b}
TI[5]	1.14 ± 0.10^{a}	0.44 ± 0.10^{b}	-0.21 ± 0.10^{c,d}	-0.39 ± 0.09^{d}	-0.37 ± 0.10^{c,d}	-0.54 ± 0.10^{d}	-0.18 ± 0.09^{c,d}	0.28 ± 0.10^{b}
TI positive	1.35 ± 0.15^{a}	1.17 ± 0.14^{a}	-0.64 ± 0.15^{c,d}	-0.88 ± 0.14^{c,d}	-1.00 ± 0.15^{d}	-1.15 ± 0.15^{d}	0.02 ± 0.14^{b}	-0.22 ± 0.15^{b,c}
TI negative	0.62 ± 0.17^{a}	-0.18 ± 0.16^{b,c}	0.56 ± 0.17^{a}	0.07 ± 0.16^{a,b,c}	0.40 ± 0.17^{a,b}	0.53 ± 0.17^{a}	-0.33 ± 0.15^{c}	-0.11 ± 0.17^{b,c}

[a,b,c,d,e,f]Within a row, different superscript letters differ ($P < 0.05$).

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, and random effect of animal with known pedigree.

[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive.

[3]Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer.

[4]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression.

[5]Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

Table 2.17. Least squares means and standard errors day nested within year effect on docility score (DS) temperament score (TS) within evaluators[1].

Evaluator by method	Day within year of evaluation							
	2014		2015		2016		2017	
	1	2	1	2	1	2	1	2
DS[2]								
4	2.21 ± 0.08[a]	1.93 ± 0.07[b]	1.93 ± 0.07[b]	1.59 ± 0.07[c]	1.80 ± 0.08[b,c]	1.69 ± 0.07[b,c]	1.66 ± 0.07[b,c]	1.57 ± 0.07c
7	1.71 ± 0.07[a]	1.45 ± 0.07[a,b]	1.56 ± 0.07[a,b]	1.37 ± 0.07[b]	1.51 ± 0.07[a,b]	1.57 ± 0.07[a,b]	1.58 ± 0.06[a,b]	1.37 ± 0.07[b]
TS[3]								
2	1.44 ± 0.08[b,c]	1.43 ± 0.08[c]	1.69 ± 0.08[a,b,c]	1.83 ± 0.08[a]	-	-	1.70 ± 0.07[a,b]	1.75 ± 0.08[a]
4	2.01 ± 0.10[a,b]	2.04 ± 0.09[a,b]	2.12 ± 0.10[a]	1.86 ± 0.09[a,b]	1.90 ± 0.10[a,b]	1.97 ± 0.10[a,b]	1.78 ± 0.09[a,b]	1.70 ± 0.10[b]
10	1.86 ± 0.11[c]	2.11 ± 0.11[b,c]	2.02 ± 0.11[b,c]	1.90 ± 0.10[c]	2.41 ± 0.11[a,b]	2.74 ± 0.11[a]	2.05 ± 0.10[b,c]	2.06 ± 0.11[b,c]

[a,b,c,d,e,f]Within a row, different superscript letters differ ($P < 0.05$).

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, year by day of evaluation, and random effect of animal with known pedigree.

[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive.

[3]Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer.

Table 2.18. Least squares means and standard errors day nested within year effect on positive qualitative behavior attributes (QBA) within evaluators[1].

Evaluator by method	Day within year of evaluation							
	2014		2015		2016		2017	
	1	2	1	2	1	2	1	2
QBA[2]								
Positive QBA								
Apathetic								
2	48.11 ± 2.99^{a}	28.85 ± 2.85^{b}	22.11 ± 2.93^{b,c}	13.82 ± 2.73^{c}	-	-	30.48 ± 2.57^{b}	17.49 ± 2.86^{c}
7	22.90 ± 3.09^{b,c}	21.50 ± 2.94^{b,c,d}	15.08 ± 3.02^{c,d,e}	11.62 ± 2.91^{d,e}	1.90 ± 3.11^{e}	7.16 ± 3.05^{e}	41.51 ± 2.75^{a}	29.58 ± 3.06^{b}
10	104.97 ± 3.99^{a,b}	116.40 ± 3.80^{a}	89.21 ± 3.96^{b,c}	121.26 ± 3.73^{a}	33.72 ± 4.01^{d}	31.16 ± 3.99^{d}	75.78 ± 3.45^{c}	94.97 ± 3.87^{b}
Calm								
2	102.13 ± 4.26^{a}	86.31 ± 4.05^{b}	65.66 ± 4.15^{c}	66.59 ± 3.91^{c}	-	-	79.21 ± 3.71^{b,c}	74.52 ± 4.12^{b,c}
7	82.14 ± 3.60^{a}	71.03 ± 3.41^{a,b}	67.31 ± 3.52^{b,c}	58.61 ± 3.37^{b,c}	54.16 ± 3.61^{c}	52.54 ± 3.56^{c}	70.89 ± 3.16^{a,b}	54.64 ± 3.53^{c}
10	101.15 ± 4.43^{a}	104.32 ± 4.20^{a}	48.20 ± 4.34^{c}	50.97 ± 4.16^{c}	57.32 ± 4.45^{b,c}	44.66 ± 4.38^{c}	72.70 ± 3.91^{b}	69.91 ± 4.36^{b}
Curious								
2	69.13 ± 3.00^{a}	37.90 ± 2.89^{b}	34.09 ± 3.00^{b}	21.87 ± 2.74^{c}	-	-	35.53 ± 2.56^{b}	39.82 ± 2.82^{b}
7	27.77 ± 1.98^{a}	29.55 ± 1.92^{a}	17.35 ± 2.01^{b}	16.79 ± 1.86^{b}	23.96 ± 1.99^{a,b}	22.09 ± 2.03^{a,b}	27.06 ± 1.72^{b}	26.16 ± 1.90^{a,b}
10	66.73 ± 1.88^{b}	76.57 ± 1.83^{a}	7.22 ± 1.93^{d}	10.39 ± 1.77^{d}	42.28 ± 1.90^{c}	9.91 ± 1.94^{d}	12.66 ± 1.64^{d}	7.56 ± 1.81^{d}
Happy								
2	65.15 ± 2.26^{a}	42.97 ± 2.18^{b}	28.06 ± 2.27^{c}	13.99 ± 2.06^{d}	-	-	23.46 ± 1.92^{c}	22.24 ± 2.11^{c,d}
7	30.22 ± 1.64^{a}	14.18 ± 1.58^{b}	11.09 ± 1.66^{b,c}	6.33 ± 1.54^{c}	8.75 ± 1.65^{b,c}	8.68 ± 1.67^{b,c}	14.23 ± 1.42^{b}	15.43 ± 1.58^{b}
10	97.76 ± 2.77^{a}	105.21 ± 2.64^{a}	11.36 ± 2.76^{d}	5.56 ± 2.59^{d,e}	4.48 ± 2.79^{d,e}	-1.26 ± 2.78^{d,e}	46.73 ± 2.40^{c}	61.00 ± 2.69^{b}
Pos. occupied								
2	77.03 ± 2.49^{a}	46.97 ± 2.43^{b}	35.03 ± 2.54^{c}	16.92 ± 2.28^{d}	-	-	27.36 ± 2.13^{c}	28.86 ± 2.31^{c}
7	24.25 ± 1.65^{a}	9.98 ± 1.57^{b,c}	13.64 ± 1.63^{b}	23.58 ± 1.54^{a}	2.89 ± 1.65^{c}	3.05 ± 1.64^{c}	8.48 ± 1.43^{b,c}	7.95 ± 1.60^{b,c}
10	71.87 ± 2.16^{a}	72.27 ± 2.05^{a}	13.71 ± 2.13^{e}	12.34 ± 2.02^{e}	59.62 ± 2.17^{b}	40.42 ± 2.15^{d}	50.12 ± 1.88^{c}	54.10 ± 2.10^{b,c}
Relaxed								
2	93.93 ± 4.11^{a}	84.13 ± 3.91^{a,b}	62.36 ± 4.00^{c}	59.91 ± 3.78^{c}	-	-	67.42 ± 3.60^{c}	71.92 ± 3.99^{b,c}
7	70.63 ± 3.30^{a}	61.11 ± 3.14^{a,b,c}	62.28 ± 3.24^{a,b,c}	50.05 ± 3.10^{c}	54.34 ± 3.32^{b,c}	51.70 ± 3.27^{b,c}	63.50 ± 2.91^{a,b}	52.15 ± 3.25^{b,c}
10	90.99 ± 4.65^{a,b}	93.60 ± 4.41^{a}	54.21 ± 4.56^{d,e}	57.79 ± 4.36^{c,d,e}	57.93 ± 4.67^{c,d,e}	51.46 ± 4.60^{e}	74.03 ± 4.09^{b,c}	70.86 ± 4.57^{c,d}

[a,b,c,d,e,f]Within a row, different superscript letters differ ($P < 0.05$). Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, year by day of evaluation, and random effect of animal with known pedigree.

[2]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression.

Table 2.19. Least squares means and standard errors for day nested within year effect on negative qualitative behavior attributes (QBA) within evaluators[1].

Evaluator by method	Day within year of evaluation							
	2014		2015		2016		2017	
	1	2	1	2	1	2	1	2
QBA[2]								
Negative QBA								
Active								
2	33.45 ± 2.58^{b,c}	27.19 ± 2.45^{c}	34.30 ± 2.51^{b,c}	52.64 ± 2.37^{a}	-	-	35.74 ± 2.25^{b}	52.64 ± 2.50^{a}
7	43.47 ± 2.58^{a,b}	33.67 ± 2.45^{c}	34.39 ± 2.53^{b,c}	37.00 ± 2.43^{a,b,c}	44.43 ± 2.60^{a,b}	46.53 ± 2.56^{a}	38.49 ± 2.28^{a,b,c}	42.90 ± 2.54^{a,b,c}
10	78.99 ± 3.36^{b}	96.23 ± 3.19^{a}	89.56 ± 3.30^{a,b}	79.81 ± 3.15^{b}	86.64 ± 3.38^{a,b}	96.10 ± 3.33^{a}	56.65 ± 2.94^{c}	46.59 ± 3.29^{c}
Agitated								
2	27.78 ± 2.43^{a}	16.90 ± 2.32^{b}	23.87 ± 2.37^{a,b}	17.85 ± 2.24^{b}	-	-	17.15 ± 2.13^{b}	19.25 ± 2.36^{a,b}
7	24.10 ± 2.22^{a,b}	29.58 ± 2.11^{a}	31.14 ± 2.18^{a}	29.15 ± 2.07^{a}	26.33 ± 2.23^{a}	25.97 ± 2.20^{a}	15.84 ± 1.93^{b}	22.30 ± 2.18^{a,b}
10	22.99 ± 3.60^{e}	28.55 ± 3.42^{d,e}	38.65 ± 3.53^{b,c,d}	48.41 ± 3.38^{a,b}	50.14 ± 3.62^{a,b}	56.17 ± 3.56^{a}	41.47 ± 3.17^{b,c}	33.15 ± 3.54^{c,d,e}
Attentive								
2	72.93 ± 2.47^{a}	58.30 ± 2.45^{b}	35.40 ± 2.55^{c}	29.21 ± 2.27^{c}	-	-	34.10 ± 2.14^{c}	53.11 ± 2.28^{b}
7	62.11 ± 2.04^{a}	54.24 ± 1.94^{a}	44.12 ± 2.02^{b}	43.77 ± 1.90^{b}	36.93 ± 2.05^{b,c}	34.24 ± 2.04^{b,c}	25.56 ± 1.76^{d}	32.30 ± 1.97^{d,c}
10	90.51 ± 2.48^{a}	95.07 ± 2.37^{a}	33.61 ± 2.47^{e}	34.99 ± 2.31^{e}	77.61 ± 2.49^{b}	68.51 ± 2.50^{b,c}	54.14 ± 2.14^{d}	61.43 ± 2.39^{c,d}
Distressed								
2	24.93 ± 1.96^{a}	16.03 ± 1.86^{b,c}	19.96 ± 1.92^{a,b}	10.68 ± 1.79^{c,d}	-	-	8.53 ± 1.69^{d}	8.32 ± 1.87^{d}
7	19.38 ± 1.73^{a,b}	7.75 ± 1.65^{c}	19.61 ± 1.71^{a}	11.92 ± 1.62^{c}	16.35 ± 1.74^{a,b,c}	14.53 ± 1.73^{a,b,c}	12.51 ± 1.50^{b,c}	13.55 ± 1.68^{a,b,c}
10	14.96 ± 0.72^{a}	14.71 ± 0.71^{a}	4.73 ± 0.75^{b,c}	1.60 ± 0.68^{c,d}	0.22 ± 0.72^{d}	0.33 ± 0.75^{d}	5.46 ± 0.64^{b}	3.50 ± 0.70^{b,c,d}
Fearful								
2	21.30 ± 1.66^{a}	14.95 ± 1.59^{b,c}	17.93 ± 1.63^{b}	10.04 ± 1.52^{c,e}	-	-	7.34 ± 1.42^{e}	12.81 ± 1.58^{b,c,e}
7	23.92 ± 1.96^{a}	16.24 ± 1.86^{b}	27.25 ± 1.93^{a}	26.90 ± 1.83^{a}	28.51 ± 1.97^{a}	29.63 ± 1.95^{a}	21.81 ± 1.70^{a,b}	25.29 ± 1.91^{a}
10	14.18 ± 2.20^{c,d}	18.79 ± 2.10^{c,d}	21.06 ± 2.19^{c}	17.31 ± 2.06^{c,d}	33.62 ± 2.21^{b}	54.68 ± 2.20^{a}	21.34 ± 1.90^{c}	10.87 ± 2.13^{d}
Irritated								
2	35.95 ± 2.74^{a}	20.46 ± 2.61^{b}	25.88 ± 2.68^{b}	19.05 ± 2.52^{b}	-	-	20.21 ± 2.38^{b}	25.22 ± 2.65^{b}
7	21.24 ± 1.85^{a,b}	15.83 ± 1.76^{b}	27.52 ± 1.82^{a}	17.49 ± 1.73^{b}	19.21 ± 1.86^{b}	19.08 ± 1.84^{b}	16.68 ± 1.61^{b}	18.35 ± 1.80^{b}
10	22.75 ± 2.89^{a,b}	24.83 ± 2.75^{a,b}	24.94 ± 2.84^{a,b}	17.72 ± 2.72^{b}	33.99 ± 2.91^{a}	27.81 ± 2.87^{a,b}	31.26 ± 2.54^{a}	18.07 ± 2.84^{b}

^{a,b,c,d,e,f}Within a row, different superscript letters differ ($P < 0.05$).

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, year by day of evaluation, and random effect of animal with known pedigree.

[2]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression.

Table 2.20. Least squares means and standard errors for day nested within year effect on negative qualitative behavior attributes (QBA) within evaluators[1].

Evaluator by method[2]	Day within year of evaluation							
	2014		2015		2016		2017	
	1	2	1	2	1	2	1	2
TI								
2	0.91 ± 0.26[a]	0.52 ± 0.25[a,b]	-0.75 ± 0.25[c,d]	-1.04 ± 0.24[d]	-	-	-0.16 ± 0.23[b,c]	-0.60 ± 0.25[c,d]
7	0.03 ± 0.26[b,c]	-0.17 ± 0.25[b,c,d]	0.63 ± 0.26[c,d,e]	0.67 ± 0.25[d,e]	0.74 ± 0.26[e]	0.76 ± 0.26[e]	-0.56 ± 0.23[a]	0.25 ± 0.26[b]
10	1.59 ± 0.23[a]	1.51 ± 0.22[a]	-1.03 ± 0.23[d]	-0.69 ± 0.22[c,d]	-1.12 ± 0.23[d,e]	-2.00 ± 0.23[e]	-0.03 ± 0.21[b,c]	0.60 ± 0.23[a,b]
TI positive								
2	2.05 ± 0.18[a]	0.52 ± 0.17[b]	-0.50 ± 0.17[c]	-1.17 ± 0.16[d]	-	-	-0.39 ± 0.15[b,c]	-0.48 ± 0.17[c]
7	0.91 ± 0.18[a]	0.13 ± 0.17[b]	-0.20 ± 0.17[b,c]	-0.70 ± 0.17[c]	-0.73 ± 0.18[b,c]	-0.77 ± 0.18[b,c]	0.40 ± 0.16[b]	-0.22 ± 0.18[b]
10	1.80 ± 0.16[a]	2.10 ± 0.15[a]	-1.32 ± 0.16[d,e]	-1.05 ± 0.15[d,e]	-0.75 ± 0.16[c,d]	-1.54 ± 0.16[e]	-0.11 ± 0.14[b]	0.09 ± 0.16[b]
TI negative								
2	1.00 ± 0.21[a]	-0.05 ± 0.20[b,c]	0.50 ± 0.20[a,b]	0.05 ± 0.19[b,c]	-	-	-0.32 ± 0.18[c]	0.25 ± 0.20[a,b,c]
7	0.60 ± 0.21[a,b]	-0.17 ± 0.20[c]	0.64 ± 0.20[a]	0.18 ± 0.19[c]	0.37 ± 0.21[a,b,c]	0.32 ± 0.21[a,b,c]	-0.38 ± 0.18[b,c]	0.07 ± 0.20[a,b,c]
10	-0.20 ± 0.18[c,d]	0.27 ± 0.17[b,c]	0.05 ± 0.18[b,c]	-0.16 ± 0.17[c,d]	0.69 ± 0.19[a,b]	1.17 ± 0.18[a]	-0.09 ± 0.16[c]	-0.83 ± 0.18[d]

[a,b,c,d,e,f]Within a row, different superscript letters differ (*P* < 0.05).

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, year by day of evaluation, and random effect of animal with known pedigree.

[2]Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

2.4.7. Genetic parameter estimations

Genetic parameter estimates for all 17 traits across and within evaluators are presented in Tables 2.21 to 2.24. Heritability estimates ($\hat{h}^2$) for across evaluator model for the 17 traits ranged from 0.000 ± 0.000 to 0.261 ± 0.045 using fixed effect of evaluator in the model (Tables 2.21 to 2.24). Of these traits, $\hat{h}^2$ for TI was 0.000 ± 0.000 while $\hat{h}^2$ for QBA attributes ranged was 0.009 ± 0.007 to 0.261 ± 0.045. The additive genetic variance for TI was 0.000 ± 0.000, therefore $\hat{h}^2$ could not be estimated. As TI is the PC1 from the PCA of positive and negative QBA attributes, the eigenvalue scores were likely in opposite directions and allowed the TI trait itself to have an average close to zero. This leads to issues with estimating genetic variance from the population as well. Furthermore, genetic correlation between positive and negative QBA attributes were negative, further supporting why TI yielded $\hat{h}^2$ of zero. On the other hand, TI positive and TI negative, as separate traits, had $\hat{h}^2$ of 0.261 ± 0.044 and 0.234 ± 0.048, respectively. Estimates of heritability when including evaluator in the model followed previous reports in general (e.g., Kim et al., 2018).

Table 2.21. Genetic parameters estimation ($\hat{\sigma}_a^2$, $\hat{\sigma}_{pe}^2$, $\hat{\sigma}_e^2$, $\hat{\sigma}_p^2$, $\hat{h}^2$, and $\hat{c}^2$) within and across evaluators for docility score (DS) and temperament score (TS).

Evaluator by method	**N**	$\hat{\boldsymbol{\sigma}}_a^2$	$\hat{\boldsymbol{\sigma}}_{pe}^2$	$\hat{\boldsymbol{\sigma}}_e^2$	$\hat{\boldsymbol{\sigma}}_p^2$	$\hat{\boldsymbol{h}}^2$	$\hat{\boldsymbol{c}}^2$
DS[1]	6,134	0.063 ± 0.017	0.123 ± 0.016	0.236 ± 0.005	0.422 ± 0.010	0.148 ± 0.039	0.293 ± 0.037
4	1,541	0.056 ± 0.029	-	0.376 ± 0.000	0.491 ± 0.019	0.235 ± 0.066	-
7	1,534	0.055 ± 0.029	-	0.465 ± 0.031	0.520 ± 0.019	0.107 ± 0.055	-
TS[2]	6,132	0.206 ± 0.046	0.317 ± 0.040	0.337 ± 0.007	0.860 ± 0.024	0.239 ± 0.051	0.369 ± 0.047
2	1,181	0.121 ± 0.045	-	0.415 ± 0.042	0.536 ± 0.023	0.226 ± 0.081	-
4	1,541	0.193 ± 0.057	-	0.660 ± 0.054	0.854 ± 0.032	0.227 ± 0.064	-
10	1,532	0.282 ± 0.074	-	0.721 ± 0.066	1.004 ± 0.038	0.282 ± 0.069	-

$\hat{\sigma}_a^2$ = estimated additive genetic variance, $\hat{\sigma}_{pe}^2$ = estimated permanent environment variance, $\hat{\sigma}_e^2$ = residual variance, $\hat{\sigma}_p^2$ = estimated phenotypic variance, $\hat{h}^2$ = estimated heritability, and $\hat{c}^2$ = proportion of phenotypic variance due to permanent environmental effect. Genetic parameters and variances were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, and random effect of animal with known pedigree.

[1]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive.

[2]Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer.

Table 2.22. Genetic parameters estimation ($\hat{\sigma}_a^2$, $\hat{\sigma}_{pe}^2$, $\hat{\sigma}_e^2$, $\hat{\sigma}_p^2$, $\hat{h}^2$, and $\hat{c}^2$) across and within evaluators for positive qualitative behavior assessment (QBA) attributes.

Evaluator by Method[1]	**N**	$\hat{\sigma}_a^2$	$\hat{\sigma}_{pe}^2$	$\hat{\sigma}_e^2$	$\hat{\sigma}_p^2$	$\hat{h}^2$	$\hat{c}^2$
Positive QBA							
Apathetic	6,164	178.541 ± 34.008	22.267 ± 28.186	806.215 ± 16.941	1,007.000 ± 20.590	0.177 ± 0.032	0.022 ± 0.028
2	1,203	130.841 ± 64.454	-	629.538 ± 62.207	760.380 ± 32.205	0.172 ± 0.083	-
7	1,542	283.220 ± 57.682	-	409.046 ± 47.898	692.270 ± 27.487	0.409 ± 0.075	-
10	1,541	215.660 ± 90.234	-	1,374.980 ± 93.282	1,590.600 ± 58.781	0.136 ± 0.056	-
Calm	6,163	333.673 ± 64.540	333.970 ± 54.216	649.723 ± 13.655	1,317.400 ± 34.306	0.253 ± 0.046	0.254 ± 0.042
2	1,204	349.124 ± 112.985	-	1,026.470 ± 105.063	1,375.600 ± 58.730	0.254 ± 0.079	-
7	1,539	301.080 ± 73.614	-	741.984 ± 66.249	1,043.100 ± 39.824	0.289 ± 0.066	-
10	1,542	483.736 ± 113.287	-	1,065.090 ± 100.197	1,548.800 ± 59.505	0.312 ± 0.068	-
Curious	6,162	23.083 ± 11.658	1.933 ± 12.889	733.227 ± 15.410	758.240 ± 13.896	0.030 ± 0.015	0.003 ± 0.017
2	1,205	61.198 ± 52.306	-	906.876 ± 60.905	968.070 ± 39.999	0.031 ± 0.041	-
7	1,538	15.822 ± 20.818	-	494.859 ± 26.506	510.680 ± 18.609	0.06 ± 0.047	-
10	1,541	9.738 ± 16.230	-	475.765 ± 23.073	485.500 ± 17.648	0.063 ± 0.054	-
Happy	6,166	46.704 ± 8.296	0.000 ± 0.000	650.662 ± 13.230	697.370 ± 12.913	0.067 ± 0.012	0.000 ± 0.000
2	1,205	26.427 ± 33.034	-	550.867 ± 38.202	577.290 ± 23.835	0.046 ± 0.057	-
7	1,542	16.797 ± 13.437	-	311.701 ± 16.749	328.500 ± 11.972	0.051 ± 0.041	-
10	1,542	94.329 ± 44.706	-	699.969 ± 46.852	794.300 ± 29.284	0.119 ± 0.055	-
Pos. occupied	6,153	4.843 ± 3.906	0.000 ± 0.000	534.204 ± 10.355	539.050 ± 9.832	0.009 ± 0.007	0.000 ± 0.000
2	1,202	14.264 ± 36.575	-	764.763 ± 47.149	779.030 ± 32.109	0.018 ± 0.047	-
7	1,534	40.281 ± 16.048	-	221.195 ± 16.064	261.480 ± 9.735	0.154 ± 0.060	-
10	1,541	76.158 ± 27.199	-	359.720 ± 26.765	435.880 ± 16.247	0.175 ± 0.061	-
Relaxed	6,166	322.140 ± 59.108	268.412 ± 48.891	644.326 ± 13.539	1,234.900 ± 31.492	0.261 ± 0.045	0.217 ± 0.041
2	1,205	354.302 ± 108.019	-	879.487 ± 97.938	1,233.800 ± 53.150	0.287 ± 0.083	-
7	1,542	258.808 ± 61.768	-	619.670 ± 55.377	878.480 ± 33.531	0.295 ± 0.066	-
10	1,542	500.758 ± 124.877	-	1,254.680 ± 112.326	1,755.400 ± 66.984	0.285 ± 0.067	-

$\hat{\sigma}_a^2$ = estimated additive genetic variance, $\hat{\sigma}_{pe}^2$ is estimated maternal permanent environment variance, $\hat{\sigma}_e^2$ = residual variance, $\hat{\sigma}_p^2$ = estimated phenotypic variance, $\hat{h}^2$ = estimated heritability, and $\hat{c}^2$= proportion of phenotypic variance due to permanent environmental effect. Genetic parameters and variances were calculated using ASReml 4.2 (Gilmour et al., 2015) following the final model that included) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, and random effect of animal (with and without pedigree) as well as fitting additive genetic and permanent environment using pedigree (across evaluator only).

[1]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.

Table 2.23. Genetic parameters estimation ($\hat{\sigma}_a^2$, $\hat{\sigma}_{pe}^2$, $\hat{\sigma}_e^2$, $\hat{\sigma}_p^2$, $\hat{\sigma}_{ape}^2$, $\hat{h}^2$, $\hat{r}^2$ and $\hat{c}^2$) across and within evaluators for negative qualitative behavior assessment (QBA) attributes.

Evaluator by method[1]	**N**	$\hat{\sigma}_a^2$	$\hat{\sigma}_{pe}^2$	$\hat{\sigma}_e^2$	$\hat{\sigma}_p^2$	$\hat{h}^2$	$\hat{c}^2$
Negative QBA							
Active	6,167	173.144 ± 34.084	140.995 ± 28.833	501.359 ± 10.533	815.500 ± 19.024	0.212 ± 0.040	0.173 ± 0.036
2	1,205	133.800 ± 43.301	-	361.032 ± 39.630	494.830 ± 21.272	0.270 ± 0.084	-
7	1,542	165.241 ± 38.608	-	361.845 ± 34.072	527.090 ± 20.254	0.314 ± 0.068	-
10	1,542	234.983 ± 66.757	-	727.284 ± 61.791	962.270 ± 36.434	0.244 ± 0.066	-
Agitated	6,147	123.710 ± 26.952	163.316 ± 23.738	355.661 ± 7.488	642.690 ± 15.575	0.193 ± 0.040	0.254 ± 0.037
2	1,201	122.375 ± 36.639	-	313.274 ± 33.577	435.650 ± 18.717	0.281 ± 0.080	-
7	1,527	91.785 ± 29.138	-	341.571 ± 27.635	433.360 ± 16.367	0.212 ± 0.065	-
10	1,542	316.621 ± 73.804	-	710.864 ± 65.578	1,027.500 ± 39.373	0.308 ± 0.067	-
Attentive	6,156	36.252 ± 13.680	14.170 ± 13.625	612.485 ± 12.881	662.910 ± 12.331	0.055 ± 0.021	0.021 ± 0.021
2	1,202	0.000 ± 0.000	-	844.168 ± 34.739	844.170 ± 34.739	0.000 ± 0.000	-
7	1,539	53.783 ± 27.163	-	365.212 ± 27.336	419.000 ± 15.565	0.128 ± 0.064	-
10	1,539	60.292 ± 35.259	-	611.948 ± 38.633	672.240 ± 24.687	0.090 ± 0.052	-
Distressed	6,165	21.726 ± 7.340	54.367 ± 7.298	177.861 ± 3.737	253.950 ± 5.313	0.086 ± 0.028	0.214 ± 0.028
2	1,205	56.534 ± 23.854	-	269.841 ± 23.670	326.380 ± 13.713	0.173 ± 0.071	-
7	1,542	45.705 ± 17.183	-	242.658 ± 17.283	288.360 ± 10.701	0.159 ± 0.058	-
10	1,542	0.000 ± 0.000	-	79.635 ± 2.890	79.635 ± 2.890	0.000 ± 0.000	-
Fearful	6,162	56.808 ± 15.780	106.596 ± 14.888	305.677 ± 6.424	469.080 ± 10.282	0.121 ± 0.033	0.227 ± 0.032
2	1,204	34.555 ± 17.630	-	215.107 ± 18.001	249.660 ± 10.444	0.138 ± 0.070	-
7	1,539	64.983 ± 22.564	-	289.251 ± 21.996	354.230 ± 13.241	0.183 ± 0.062	-
10	1,542	58.717 ± 26.812	-	440.808 ± 28.531	499.530 ± 18.388	0.118 ± 0.053	-
Irritated	6,158	92.271 ± 21.917	145.186 ± 19.620	276.487 ± 5.813	513.940 ± 12.575	0.180 ± 0.041	0.283 ± 0.038
2	1,204	137.776 ± 45.925	-	447.220 ± 43.462	585.000 ± 24.846	0.236 ± 0.075	-
7	1,537	56.110 ± 19.348	-	261.700 ± 19.144	317.810 ± 11.847	0.177 ± 0.059	-
10	1,540	189.234 ± 49.930	-	498.942 ± 45.112	688.180 ± 26.289	0.275 ± 0.069	-

$\hat{\sigma}_a^2$ = estimated additive genetic variance, $\hat{\sigma}_{pe}^2$ = estimated maternal permanent environment variance, $\hat{\sigma}_e^2$ = residual variance, $\hat{\sigma}_p^2$ = estimated phenotypic variance, $\hat{h}^2$ = estimated heritability, and $\hat{c}^2$ = proportion of phenotypic variance due to permanent environmental effect. Genetic parameters and variances were calculated using ASReml 4.2 (Gilmour et al., 2015) following the final model that included) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, and random effect of animal with known pedigree as well as fitting additive genetic and permanent environment using pedigree (across evaluator only).

[1]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.

Table 2.24. Genetic parameters estimation ($\hat{\sigma}_a^2$, $\hat{\sigma}_{pe}^2$, $\hat{\sigma}_e^2$, $\hat{\sigma}_p^2$, $\hat{h}^2$, and $\hat{c}^2$) within and across evaluators for temperament index (TI)[1].

Evaluation by method[2]	N	$\hat{\sigma}_a^2$	$\hat{\sigma}_{pe}^2$	$\hat{\sigma}_e^2$	$\hat{\sigma}_p^2$	$\hat{h}^2$	$\hat{c}^2$
TI	6,167	0.000 ± 0.000	0.000 ± 0.000	5.116 ± 0.094	5.116 ± 0.094	0.000 ± 0.000	0.000 ± 0.000
2	1,205	1.419 ± 0.412	-	3.376 ± 0.374	4.795 ± 0.207	0.296 ± 0.081	-
7	1,542	1.719 ± 0.395	-	3.552 ± 0.347	5.271 ± 0.206	0.326 ± 0.070	-
10	1,542	1.411 ± 0.316	-	2.792 ± 0.275	4.204 ± 0.163	0.336 ± 0.070	-
TI positive		0.703 ± 0.127	0.494 ± 0.104	1.502 ± 0.032	2.699 ± 0.067	0.261 ± 0.044	0.183 ± 0.040
2	1201	0.533 ± 0.206	-	1.971 ± 0.196	2.504 ± 0.107	0.213 ± 0.080	-
7	1526	0.785 ± 0.186	-	1.702 ± 0.164	2.488 ± 0.096	0.316 ± 0.070	-
10	1538	0.607 ± 0.147	-	1.417 ± 0.131	2.025 ± 0.078	0.300 ± 0.068	-
TI negative		0.763 ± 0.164	1.171 ± 0.144	1.323 ± 0.028	3.257 ± 0.090	0.234 ± 0.048	0.359 ± 0.045
2	1196	0.824 ± 0.265	-	2.527 ± 0.250	3.352 ± 0.143	0.246 ± 0.076	-
7	1515	0.888 ± 0.245	-	2.736 ± 0.228	3.624 ± 0.138	0.245 ± 0.064	-
10	1536	0.844 ± 0.197	-	1.828 ± 0.174	2.671 ± 0.103	0.316 ± 0.069	-

[1]$\hat{\sigma}_a^2$ = estimated additive genetic variance, $\hat{\sigma}_{pe}^2$ = estimated permanent environment variance, $\hat{\sigma}_e^2$ = residual variance, $\hat{\sigma}_p^2$ = estimated phenotypic variance, $\hat{h}^2$ = estimated heritability, and $\hat{c}^2$= proportion of phenotypic variance due to permanent environmental effect. Genetic parameters and variances were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of evaluator, primary breed, sex, year by day of evaluation, and random effect of animal with known pedigree.

[2]Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

The proportion of phenotypic variance due to permanent environmental effects (c^2) ranged from 0.000 ± 0.000 to 0.361 ± 0.048 across evaluators (Tables 2.22 to 2.25). This indicates that there is low to moderate repeatability of scoring an animal for that given trait. As noted with heritability, the same issues were encountered for c^2 of TI, further supporting that it is not an appropriate measure of temperament from the QBA. On the other hand, measures of temperament that were moderately repeatable included TS and DS (Table 2.21), calm and relaxed QBA (Table 2.22) and all negative QBA except for attentive (Table 2.23). It was clear, through the repeatability measure, that negative QBA attributes were more repeatable among evaluators than positive QBA (Table 2.24), further supporting comparisons made based on evaluator least squares means. Between TI positive and TI negative, the latter is more repeatable. Therefore, the use of TI negative is more appropriate between the two.

When considering evaluators with multiple years of observations, differences among genetic parameter estimates could be seen easily on methods with larger scales (e.g., QBA scores; Tables 2.21 to 2.24). Even so, when negative QBA were combined into TI negative, the repeatability across evaluators was higher than DS, indicating that other methods may be viable for the production setting even if individual scores on given attributes varied.

Variability in subjective measures of temperament depends on differences in measuring protocols or recording methods (Haskell et al., 2014) as well as the population being measured. The QBA scale utilized a 136 mm scale, while DS and TS utilized discrete scales. Furthermore, DS and TS had differences in sample sizes per scale due to differences in levels used by both methods. In the case of the current population, most (n = 811, 52.6%) of the calves were scored with 1 followed by 2 (n = 643, 41.70%). Few calves were scored 3 (n = 76, 4.93%) or 4 (n = 12, 0.78%), and none for 5 and 6. TS had 4 levels with most of the calves scored as 1 (n = 649, 42.09%)

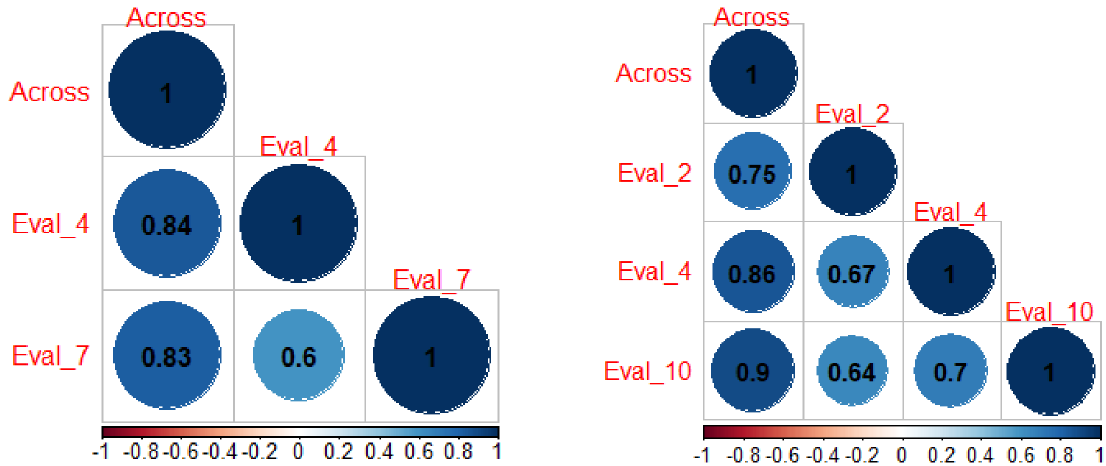
or 2 (n = 676, 43.84%), followed by 4 (n = 210, 13.62%) and very few calves were scored by 5 (n = 7, 0.45%). Therefore, this population was less temperamental than some may be. Breed differences also exist, where crosses of *Bos indicus* and *Bos taurus* are likely to have more temperamental cattle. The $\hat{h}^2$ for DS in our study was comparable to other $\hat{h}^2$ found in literature (Fordyce et al., 1996; Phocas et al., 2006; and Hoppe et al., 2010)

2.4.8. Estimated breeding value comparisons

Spearman Rank correlation coefficients (r_s) on estimated breeding value (EBV) across and within evaluators are presented in Figures 2.7 to 2.11. All Spearman rank correlations were significant (*P-value* $\leq$ 0.05) when comparing specific evaluator EBV to the respective across evaluator model. Furthermore, evaluator to evaluator EBV within all subjective measures of temperament were significant except for evaluators 2 and 10 for curious QBA attribute (*P-value* = 0.058). All r_s were positively correlated except for TI, but this was driven primarily by the nature of TI having a mean close to zero. Correlations further support the repeatability differences seen among evaluators for a given trait and across traits.

Correlations and repeatability estimates do not provide an understanding of rank changes among animals. As these temperament scores are being captured for selection purposes in breed associations, the rank of individuals based on genetic merit becomes important. Due to this, EBV can be ordered and placed into quartiles based on rank within the population. For this study, focus was placed on changes of 2-quartiles (i.e., moderate re-ranking) and 3-quartiles (i.e., extreme re-ranking) as a single quartile re-rank could likely happen when animals rank around quartile thresholds. For example, more than 91% of EBV ranked the same or only had 1 quartile change when comparing evaluators to the across evaluator model for DS and TS (Table 2.25). This percentage dropped some (at least 81% fell in this category) when comparing evaluators to each other within a given temperament evaluation method (Table 2.25). Considering that evaluators may influence genetic merit predictions resulting in moderate to extreme re-ranks, emphasis was placed on methods that did not meet 90% of EBV staying within 1 quartile when comparing ranks (i.e., no more than 10% moderate or extreme re-ranking). Ideally, this would be less – such as 1 to 5%.

When comparing evaluator specific EBV from evaluators with multiple years of observations to the across evaluator model, DS and TS had minimal 2 and 3-quartiles changes (1.75% to 8.10%, Table 2.25). On the other hand, evaluator-to-evaluator EBV rank comparison showed much higher levels of re-ranking (18.03% for DS, 11.61% to 14.40% for TS; Table 2.25), indicating that including evaluator in the model ensured consistency of rank. This was even more pronounced in QBA attributes and respective TI (Tables 2.26 to 2.28). In terms of extreme re-ranking, less was seen with DS and TS, overall, than many QBA attributes (Tables 2.25 to 2.28). The concern would be the number of top-ranking animals that moved from first quartile ranking to 3^{rd} or 4^{th} quartile ranking because of evaluator differences. Further summary of the data is required to understand this.



DS **TS**

Figure 2.7. Spearman rank correlation coefficients for docility score (DS) and temperament score (TS) estimated breeding values across and within evaluator. Eval_2, Eval_4, Eval_7, and Eval_10 refers to evaluators 2, 4, 7, and 10, respectively.
Docility score: scale of 1 to 6 with 1 = calm and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation jumps against the fence and tries to attack the observer. Estimated breeding values used to calculate correlation coefficients when the model included fixed effects of primary breed, sex, evaluator, day within year and random effect of calf.

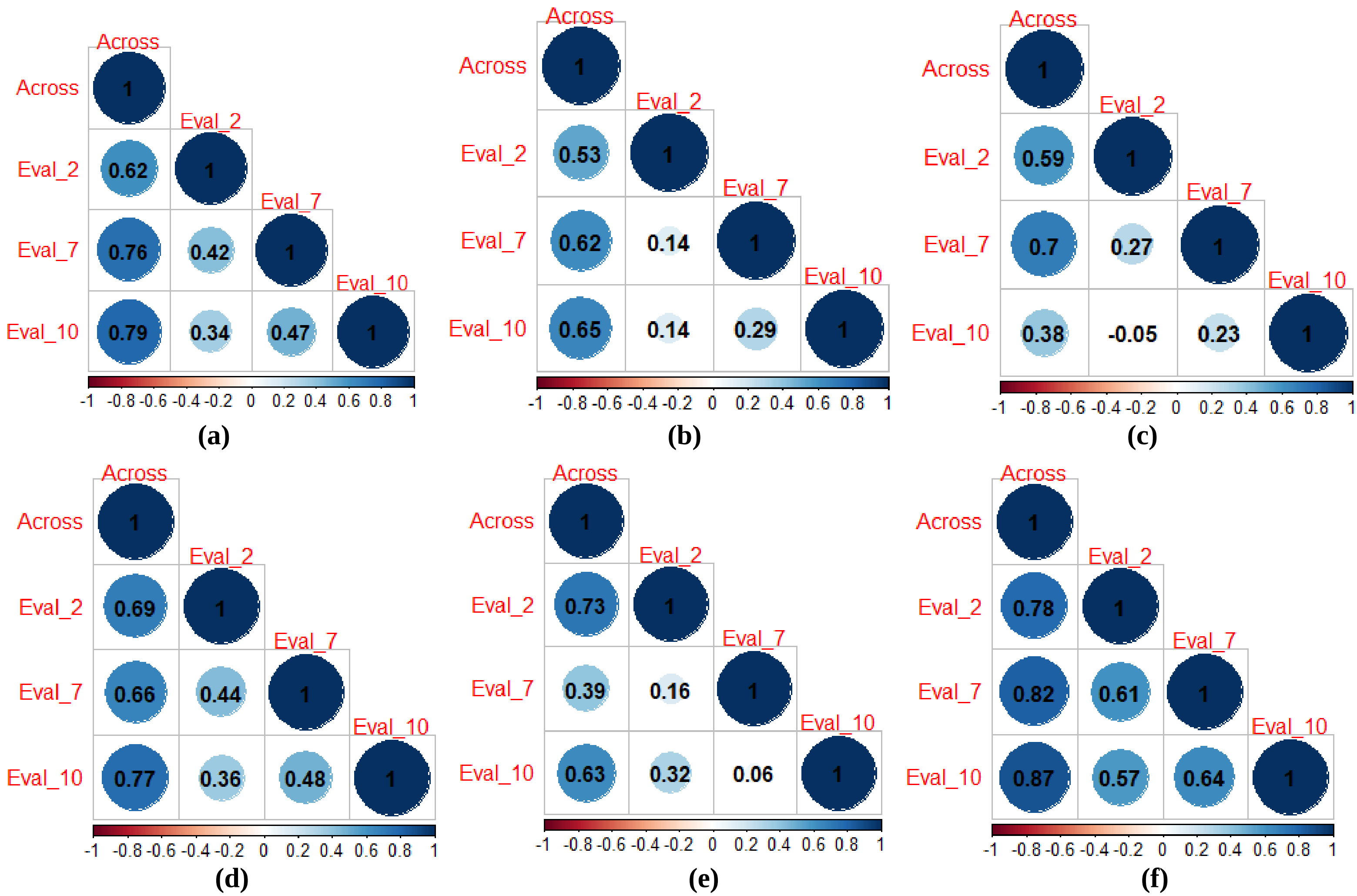


Figure 2.8. Spearman rank correlation coefficients for positive qualitative behavior attributes (QBA). Eval_2, Eval_7, and Eval_10 refers to evaluators 2, 7, and 10, respectively. a = apathetic, b = calm, c = curious, d = happy, e = positively occupied, and f = relaxed) estimated breeding values across and within evaluator. Qualitative behavior attributes (QBAs) are measured on a 136 mm visual analog scale. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Estimated breeding values used to calculate correlation coefficients when the model included fixed effects of primary breed, sex, evaluator, day within year and random effect of calf.

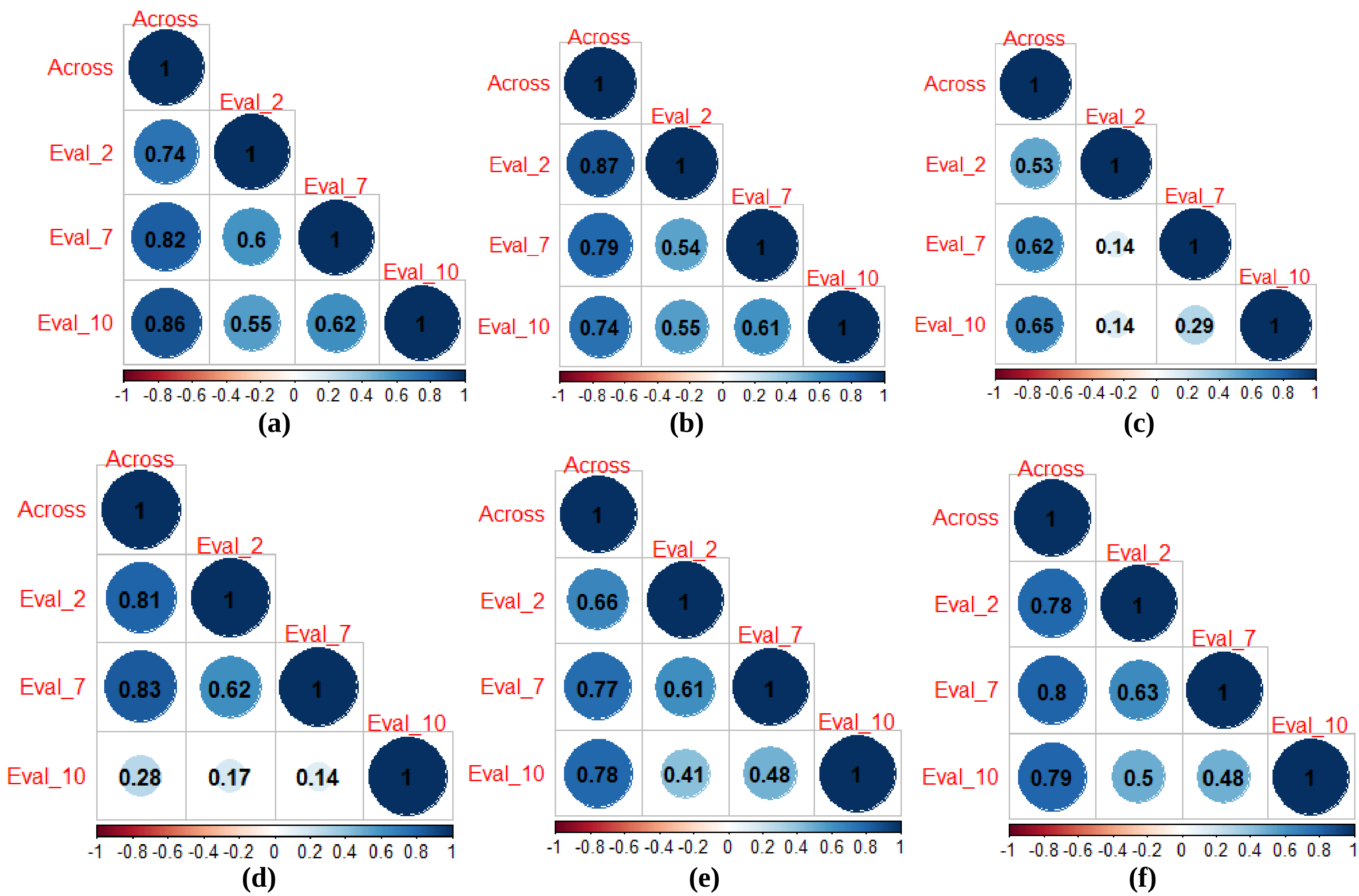


Figure 2.9. Spearman rank correlation coefficients for negative qualitative behavior attributes. Eval_2, Eval_7, and Eval_10 refers to evaluators 2, 7, and 10, respectively. a = active, b = agitated, c = attentive, d = distressed, e = fearful, and f = irritated) estimated breeding values across and within evaluator. Qualitative behavior attributes (QBAs) are measured on a 136 mm visual analog scale. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Estimated breeding values used to calculate correlation coefficients when the model included fixed effects of primary breed, sex, evaluator, day within year and random effect of calf.

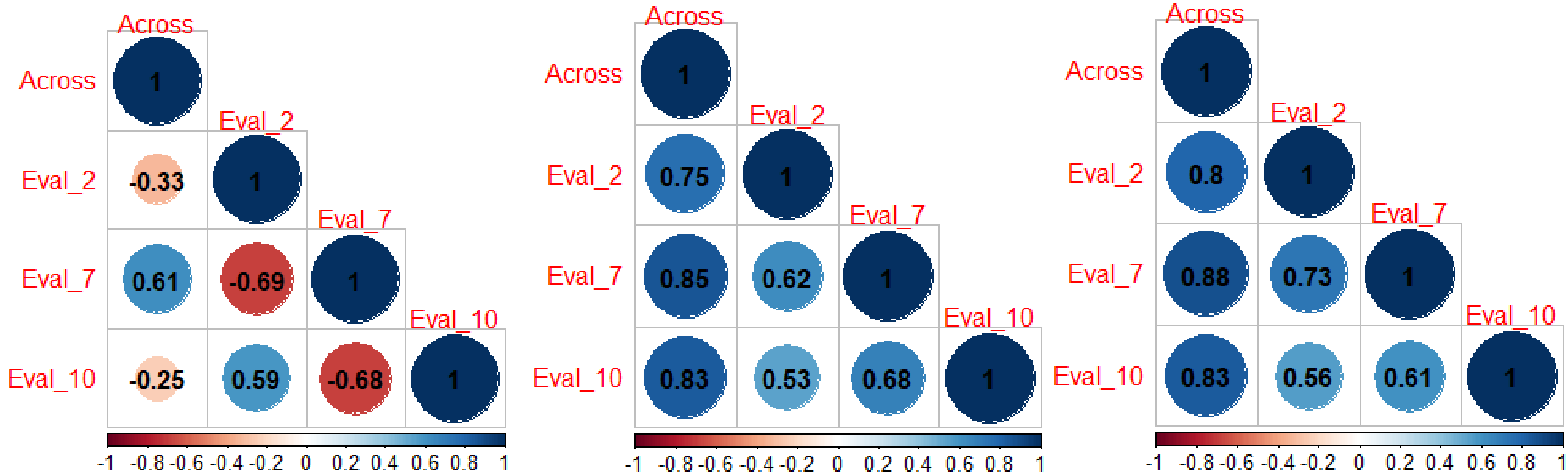


Figure 2.10. Spearman rank correlation coefficients for temperament indexes (TIs). Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). Eval_2, Eval_7, and Eval_10 refers to evaluators 2, 7, and 10, respectively.

Table 2.25. Comparison of the percentage of individuals with estimated breeding values for docility and temperament scores that changes *n* quartiles between any two analyses.

Evaluation	Percentage of individuals that changed n quartiles[1]				
	0	1	2	3	Sum of 2 and 3 quartiles
Docility score[2]					
Across vs. 4	58.37	36.96	4.41	0.26	4.67
Across vs. 7	53.70	39.49	6.36	0.45	6.81
4 vs. 7	40.34	41.63	14.79	3.24	18.03
Temperament score[3]					
Across vs. 2	51.10	40.79	7.26	0.84	8.10
Across vs. 4	62.00	34.44	3.44	0.13	3.57
Across vs. 10	65.11	33.14	1.75	0.00	1.75
2 vs 4	48.12	39.69	10.44	1.75	12.19
2 vs. 10	43.97	41.63	12.91	1.49	14.40
4 vs 10	50.91	37.48	10.70	0.91	11.61

[1]The number of quartile changes was calculated by first assigning an animal's quartile for any given analysis, then finding the difference of each animal's quartile between the two analyses (evaluators in this case) compared. Percentage was calculated by dividing the number of individuals within that category by the total number of animals.

[2]Docility score: scale of 1 to 6 with 1 = calm and 6 = very aggressive.

[3]Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation jumps against the fence and tries to attack the observer.

Table 2.26. Comparison of the percentage of individuals with estimated breeding values for positive qualitative behavior attributes (QBA) that changes *n* quartiles between any two analyses.

Evaluation	Percentage of individuals that changed n quartiles[1]				
	0	1	2	3	Sum of 2 and 3 quartiles
Positive QBA[2]					
Apathetic					
Across vs. 2	43.51	41.70	12.65	2.14	14.79
Across vs. 10	54.93	37.74	7.07	0.26	7.33
Across vs. 7	52.14	39.30	7.85	0.71	8.56
2 vs.10	30.67	42.87	21.73	4.73	26.46
2 vs. 7	39.43	39.23	14.72	6.61	21.33
10 vs. 7	36.77	42.09	17.77	3.37	21.14
Calm					
Across vs. 2	57.65	35.21	6.74	0.39	7.13
Across vs. 10	63.10	33.72	3.18	0.00	3.18
Across vs. 7	60.96	35.73	3.31	0.00	3.31
2 vs.10	43.90	40.01	13.75	2.33	16.08
2 vs. 7	46.30	41.57	10.38	1.75	12.13
10 vs. 7	46.69	41.83	10.31	1.17	11.48
Curious					
Across vs. 2	45.98	39.23	11.80	2.98	14.78
Across vs. 10	35.80	38.65	19.84	5.71	25.55
Across vs. 7	51.49	36.19	11.54	0.78	12.32
2 vs.10	24.14	37.44	24.46	13.95	38.41
2 vs. 7	38.07	35.73	16.86	9.34	26.2
10 vs. 7	34.31	34.24	22.76	8.69	31.45
Happy					
Across vs. 2	50.13	38.13	10.96	0.78	11.74
Across vs. 10	53.76	38.20	7.59	0.45	8.04
Across vs. 7	47.67	39.88	10.96	1.49	12.45
2 vs.10	38.13	37.81	18.42	5.64	24.06
2 vs. 7	38.26	41.05	15.82	4.86	20.68
10 vs. 7	41.57	39.43	14.72	4.28	19.00
Positively occupied					
Across vs. 2	53.44	36.25	8.95	1.36	10.31
Across vs. 10	46.89	39.88	11.87	1.36	13.23
Across vs. 7	35.34	40.99	18.35	5.32	23.67
2 vs.10	35.28	38.65	19.33	6.74	26.07
2 vs. 7	28.86	37.09	25.49	8.56	34.05
10 vs. 7	25.29	39.36	25.42	9.92	35.34
Relaxed					
Across vs. 2	54.80	37.42	7.46	0.32	7.78
Across vs. 10	62.71	34.37	2.92	0.00	2.92
Across vs. 7	56.03	38.72	5.06	0.19	5.25
2 vs.10	41.18	41.57	14.98	2.27	17.25
2 vs. 7	42.09	43.39	12.26	2.27	14.53
10 vs. 7	45.07	40.99	12.39	1.56	13.95

[1]The number of quartile changes was calculated by first assigning an animal's quartile for any given analysis, then finding the difference of each animal's quartile between the two analyses (evaluators in this case) compared. Percentage was calculated by dividing the number of individuals within that category by the total number of animals.

[2]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.

Table 2.27. Comparison of the percentage of individuals with estimated breeding values for negative qualitative behavior attributes (QBA) that changes *n* quartiles between any two analyses.

Evaluation	Percentage of individuals that changed n quartiles[1]				
	0	1	2	3	Sum of 2 and 3 quartiles
Negative QBA[2]					
Active					
Across vs. 2	51.95	38.13	9.53	0.39	9.92
Across vs. 10	62.39	34.37	3.11	0.13	3.24
Across vs. 7	56.03	38.72	5.19	0.06	5.25
2 vs.10	42.93	39.30	15.30	2.46	17.76
2 vs. 7	45.40	38.26	14.40	1.95	16.35
10 vs. 7	44.68	40.27	12.78	2.27	15.05
Agitated					
Across vs. 2	54.54	36.06	8.63	0.78	9.41
Across vs. 10	63.42	33.14	3.37	0.06	3.43
Across vs. 7	51.36	42.67	5.84	0.13	5.97
2 vs.10	43.71	39.36	14.14	2.79	16.93
2 vs. 7	43.39	40.92	13.94	1.75	15.69
10 vs. 7	41.76	39.04	16.99	2.20	19.19
Attentive					
Across vs. 2	41.50	39.04	15.95	3.50	19.45
Across vs. 10	46.30	39.69	12.58	1.43	14.01
Across vs. 7	44.10	42.15	12.19	1.56	13.75
2 vs.10	28.73	37.09	23.80	10.38	34.18
2 vs. 7	28.99	38.72	21.21	11.09	32.3
10 vs. 7	33.01	40.21	19.65	7.13	26.78
Distressed					
Across vs. 2	58.82	34.57	6.23	0.39	6.62
Across vs. 10	31.45	38.33	23.02	7.20	30.22
Across vs. 7	60.89	33.72	4.99	0.39	5.38
2 vs.10	27.89	37.03	26.52	8.56	35.08
2 vs. 7	47.34	37.48	13.42	1.75	15.17
10 vs. 7	29.05	35.73	25.03	10.18	35.21
Fearful					
Across vs. 2	49.16	38.39	10.38	2.08	12.46
Across vs. 10	41.76	39.04	16.99	2.20	19.19
Across vs. 7	43.84	49.94	6.03	0.19	6.22
2 vs.10	35.86	41.57	17.77	4.80	22.57
2 vs. 7	40.86	48.18	9.92	1.04	10.96
10 vs. 7	36.77	47.02	13.68	2.53	16.21
Irritated					
Across vs. 2	57.00	35.15	7.07	0.78	7.85
Across vs. 10	55.58	37.42	6.42	0.58	7.00
Across vs. 7	58.50	35.47	5.45	0.58	6.03
2 vs.10	39.95	40.01	16.08	3.96	20.04
2 vs. 7	47.08	39.43	10.89	2.59	13.48
10 vs. 7	39.04	40.79	16.08	4.09	20.17

[1]The number of quartile changes was calculated by first assigning an animal's quartile for any given analysis, then finding the difference of each animal's quartile between the two analyses (evaluators in this case) compared. Percentage was calculated by dividing the number of individuals within that category by the total number of animals.

[2]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.

Table 2.28. Comparison of the percentage of individuals with estimated breeding values for temperament index, and for positive and negative temperament indexes that changes *n* quartiles between any two analyses.

Evaluation by method[2]	Percentage of individuals that changed n quartiles[1]				
	0	**1**	**2**	**3**	**Sum of 2 and 3 quartiles**
Temperament index					
Across vs. 2	19.26	33.85	26.65	20.23	46.88
Across vs. 10	22.18	33.33	25.81	18.68	44.49
Across vs. 7	44.68	40.08	13.68	1.56	15.24
2 vs.10	14.54	27.58	28.29	29.59	57.88
2 vs. 7	15.06	27.64	27.26	30.05	57.31
10 vs. 7	14.54	27.58	28.29	29.59	57.88
TI Positive					
Across vs. 2	52.14	39.23	8.30	0.32	8.62
Across vs. 10	58.50	36.38	5.06	0.06	5.12
Across vs. 7	61.28	35.08	3.57	0.06	3.63
2 vs.10	40.08	40.92	16.34	2.66	19.00
2 vs. 7	43.77	42.48	11.48	2.27	13.75
10 vs. 7	48.44	39.88	10.44	1.23	11.67
TI Negative					
Across vs. 2	58.11	35.67	5.71	0.52	6.23
Across vs. 10	59.66	35.28	4.93	0.13	5.06
Across vs. 7	64.20	33.07	2.72	0.00	2.72
2 vs.10	41.63	41.44	14.66	2.27	16.93
2 vs. 7	52.40	38.07	8.69	0.84	9.53
10 vs. 7	44.42	40.40	13.29	1.88	15.17

[1]The number of quartile changes was calculated by first assigning an animal's quartile for any given analysis, then finding the difference of each animal's quartile between the two analyses (evaluators in this case) compared. Percentage was calculated by dividing the number of individuals within that category by the total number of animals.
[2]Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

2.4.9. Phenotypic and genetic correlations of subjective and objective methods

Phenotypic and genetic correlations between subjective and objective (SSD and CVSSD) methods of beef cattle temperament evaluation are presented in Figures 2.11 and 2.12. Phenotypic and genetic correlation between TI and other methods of temperament evaluation were not included in the figure due to lack of convergence. Phenotypic and genetic correlations across all methods of temperament evaluation ranged from -0.69 to 0.96 and -0.99 to 0.99, respectively.

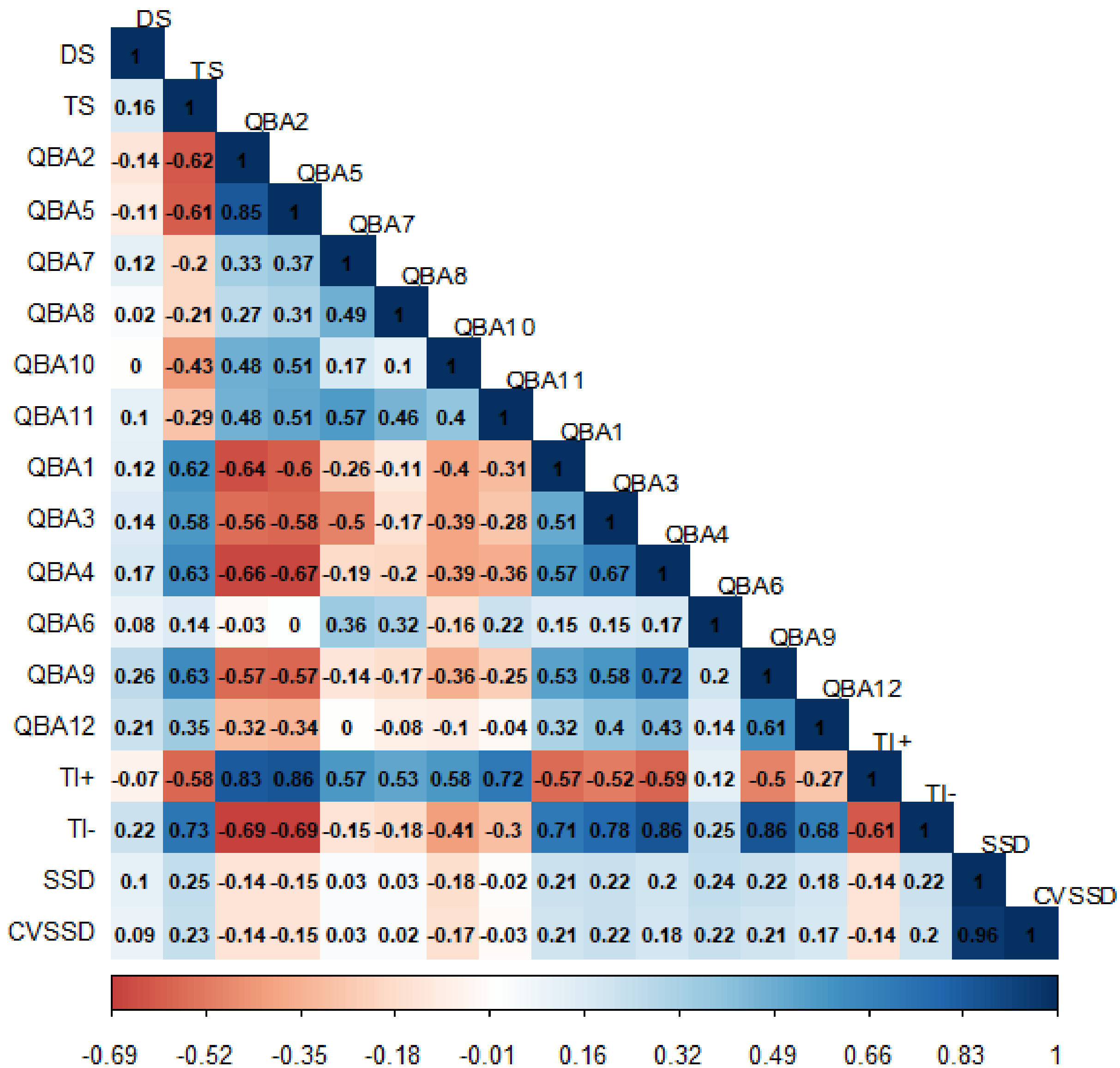


Figure 2.11. Phenotypic correlations of subjective and objective measures of temperament. Subjective methods: Docility score (DS), temperament score (TS), Qualitative Behavioral Attributes (QBA) are grouped by positive (QBA2 = relaxed, QBA5 = calm, QBA7 = positively (pos.) occupied, QBA8 = curious, and QBA10 = apathetic, QBA11= happy) and negative (QBA1 = active, QBA3 = fearful, QBA4 = agitated, QBA6 = attentive, QBA9 = irritated, and QBA12 = distressed) like behavior. Docility score: scale of 1 to 6 with 1 = calm and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation jumps against the fence and tries to attack the observer. [2]Temperament index (TI): the first principal component score generated from QBA scores, TI positive (TI+): first principal component score generated from positive QBA scores, TI negative (TI-): first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). Objective methods, SSD: Standard deviation of four platform standing scale (FPSS) (Pacific Industrial Scale, British Columbia, Canada), and CVSSD: coefficient of variation of SSD.

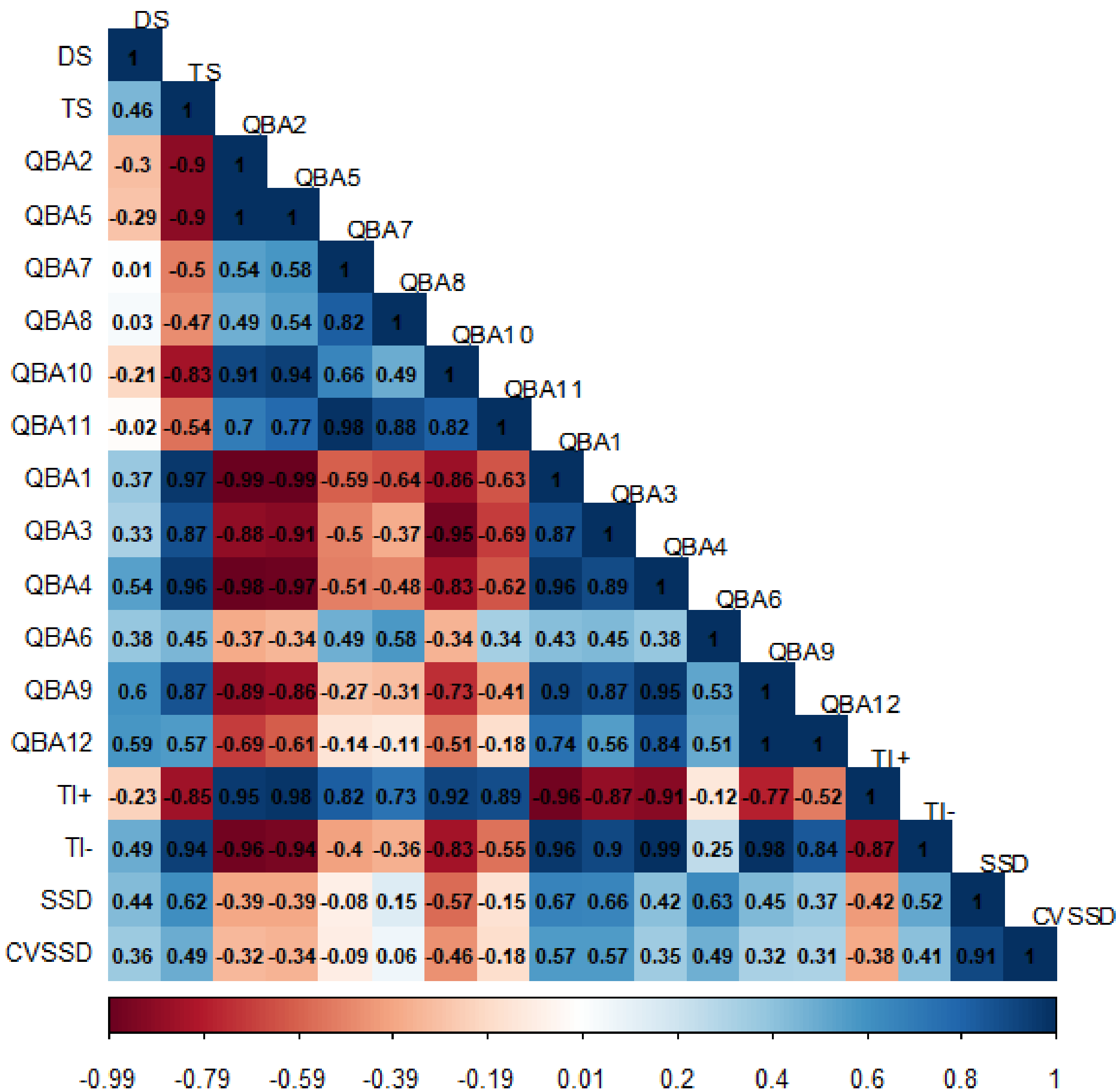


Figure 2.12. Genetic correlations of subjective and objective measures of temperament. Subjective methods: Docility score (DS), temperament score (TS), Qualitative Behavioral Attributes (QBA) are grouped by positive (QBA2 = relaxed, QBA5 = calm, QBA7 = positively (pos.) occupied, QBA8 = curious, and QBA10 = apathetic, and QBA11 = happy) and negative (QBA1 = active, QBA3 = fearful, QBA4 = agitated, QBA6 = attentive, QBA9 = irritated, and QBA12 = distressed) like behavior. Docility score: scale of 1 to 6 with 1 = calm and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation jumps against the fence and tries to attack the observer. [2]Temperament index (TI): the first principal component score generated from QBA scores, TI positive (TI+): first principal component score generated from positive QBA scores, TI negative (TI-): first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). Objective methods, SSD: Standard deviation of four platform standing scale (FPSS) (Pacific Industrial Scale, British Columbia, Canada), and CVSSD: coefficient of variation of SSD.

2.4.9.1. Docility score

Genetic correlations using DS, moderate positive correlations were found to TS, TI negative, SSD, and CVSSD while low negative correlation to TI positive. Correlations of DS to negative QBA attributes were moderate to high (0.33 to 0.60) while correlations of DS to positive QBA attributes were very low (close to zero) to low negative correlations. This means that using TS, TI, TI negative, SSD, CVSSD, and negative QBA (irritated, distressed, and agitated) yield improvement of beef cattle temperament in the same direction as using DS. However, the use TI positive and positive QBA attributes scoring are lowly associated in opposite direction to no association with DS. Based on the result of this study, DS is related to negative QBA attributes specifically to irritated, distressed, and agitated but not to positive QBA attributes. Overall, DS maybe measuring different aspects of cattle temperament compared to TS and QBA attributes which are unrestraint methods. In a study by Yu et al. (2020), DS was excluded in exploratory factor analysis since this method is a restraint method compared to TS and QBA attributes.

2.4.9.2. Temperament score

Compared to other measures of temperament, TS generally had high genetic correlations to both positive and negative QBA attributes, TI positive, TI negative, SSD, and CVSSD except to DS with moderate correlation. The reason why TS have high genetic correlation to other methods including both positive and negative QBA attributes except DS maybe because DS is a restraint procedure while all other are unrestraint. According to Haskell et al. (2014) restraint methods access the behavior of cattle in a handling facility while unrestraint methods access the behavior of cattle to human approach. Therefore, DS maybe measuring different traits or attributes of beef cattle temperament. Genetic correlation between DS and TS in our study is similar to the result of study of Curley et al. (2006) with moderate genetic correlation between the two traits.

However, is different from the study of Burrow and Corbet (2000) which reported low genetic correlation between pen score (similar to TS in our study) and chute score (similar to DS in our study). Based on the result of this study TS highly related in positive and negative directions to negative and positive QBA attributes respectively except to curious and attentive QBA attributes which are moderately correlated genetically. Therefore, QBA attributes can be use as scoring method in place of TS.

2.4.9.3. Positive and negative QBA attributes

Within positive and negative QBA attribute, moderate to high genetic correlations were found. Low to moderate negative genetic correlations were found between positive and negative QBA attributes except between attentive and positively occupied, happy and curious QBA attributes which had moderate to high genetic correlation. It is expected that between positive and negative QBA attribute, all pairs will be negatively correlated since there calmer cattle will have high positive QBA attributes and low negative QBA attributes scores. The positive genetic correlations between attentive and positively occupied, happy and curious QBA attributes in our study may be due to difficulty of evaluators in using these QBA attributes in temperament scoring. With greater number of high and moderate correlations within negative QBA attributes than positive QBA attributes evaluators scores were more in agreement within negative QBA attribute than evaluator score within positive QBA attributes. With positive correlations found between positive and negative QBA attributes some evaluators may not have scored the cattle temperament correctly especially when using positively occupied, happy and curious attributes to attentive attributes. Positively occupied, happy, and curious were positive QBA attributes that evaluators may not differentiate to attentive which is a negative QBA attribute. Furthermore, positive correlations between positive and negative QBA attributes revealed the attributes in QBA that evaluators find difficult to use.

Compared to TI positive high positive genetic correlation was found (0.73 to 0.98) while to TI negative moderate to high negative correlations was found (-0.36 to -0.96). Compared to objective methods (SSD, CVSSD), low to moderate negative correlations were found except for curious attribute with low positive genetic correlation. The high genetic correlations of positive and negative QBA attributes to TI positive and TI negative is expected since TI positive and TI negative are produced using PCA of positive and negative QBA attributes respectively. Therefore, TI positive and TI negative can be used in place of positive and negative QBA attributes respectively.

Genetic correlations of both QBA positive and QBA negative to SSD and CVSSD revealed that QBA positive generally had low to moderate negative correlation to both SSD and CVSSD while QBA negative had moderate to high positive correlation to both SSD and CVSSD. This revealed that QBA negative attributes were more closely similar to SSD and CVSSD specifically active, fearful, and attentive negative QBA attributes.

2.4.9.4. Temperament index positive and negative

Using genetic correlation, TI positive was highly correlated to QBA positive while TI negative was highly correlated to QBA negative. This is because QBA positive attributes were used to produce TI positive and QBA negative attributes were used to produce TI negative using PCA. When comparing the opposites, (i.e., TI positive and QBA negative, and TI negative and QBA positive) high negative correlations were observed in negative directions except for positively occupied, curious, and attentive attributes which were low to moderately correlated.

TI positive and TI negative had high genetic correlation to TS while low and moderate correlations on TS. Compared to SSD and SSD, TI positive and TI negative had moderate to high genetic correlations while compared to CVSSD, moderate correlations were observed. TI positive and TI negative were more similar to QBA positive and negative, including TS, and SSD and CVSSD while lesser extent DS to because of low to moderate correlation. Between TI positive and TI negative, TI negative is more similar to other measures of temperament with higher correlation values. Therefore, the use of TI negative is better compared to TI positive in place of unrestraint temperament evaluation.

2.4.9.5. Four flatform standing scale

SSD compared to CVSSD have greater genetic correlation values to other measures of temperament meaning SSD had was more similar to the other methods as compared to CVSSD. CVSSD used the average weight of the calves as an adjusted factor because weight of the calf may bias measurement of the FFSS especially in heavier calves. It seems that the adjusted weight did not improved measurement of FFSS. Lanier, et al. (2002), reported that weight of cattle had no significant effect on temperament and may support the result of our study.

SSD had high genetic correlations to TS and TI negative while CVSSD had moderate genetic correlation to DS, TS, and TI negative. SDD had moderate to high genetic correlation to negative QBA attributes and low to moderate genetic correlation to positive QBA attributes except apathetic. Similarly, CVSSD had moderate to high genetic correlation to negative QBA attributes and low to moderate genetic correlation to positive QBA attributes. SSD had very high genetic correlation to CVSSD which indicated almost perfect relationship because CVVSD is derived from SSD. The moderate to high genetic correlations of SSD and CVSSD to DS and TS revealed that these novel methods can be use as in place for DS and TS subjective methods of temperament evaluation. More appropriately to TS and TI negative given high genetic correlation to these methods.

2.5. Conclusion

In conclusion, evaluator scoring was different using subjective methods of temperament evaluation. However, in predicting genetic merit, evaluator has less effect for scoring systems already implemented by breed associations (DS, TS) considering evaluator is included in the model. Therefore, DS and TS (similar to pen score) are applicable subjective methods of beef cattle temperament evaluation. The use of 12 QBA attributes and TI as methods had an impact of genetic predictions however, portioning the 12 QBA into positive and negative QBA produce TI positive and TI negative using PCA had negligible impact on genetic prediction similar to DS and TS. SSD and CVSSD as novel objective methods can be use in place of DS and TS, but more appropriately with TS which had higher association based on genetic correlation analysis. Lastly, our study found that QBA attributes are closely associated to TS. Therefore, QBA attributes measure the temperament of cattle to human approach while unrestrained.

3. GENETIC ASSOCIATIONS BETWEEN BEEF CATTLE TEMPERAMENT AND TRAITS RELATED TO PRODUCTIVE AND REPRODUCTIVE TRAITS

3.1. Abstract

The objective was to determine the effect and relationship of temperament on calf productive and heifer reproductive traits using the novel Four Platform Standing Scale (FPSS) and subjective methods of temperament evaluations. Temperament evaluation utilized FPSS data to produce standard deviation of weight over time (SSD), and coefficient of variation of SSD (CVSSD), docility score (DS), temperament score (TS), qualitative behavioral assessment (QBA) attributes and temperament indexes (TI, TI positive, TI negative). Traits included adjusted birth weight (ABW; n = 1530, adjusted 205 weaning weight (205-d WW; n = 1523), pre-weaning average daily gain (ADG; n = 1530), and weight gain (WG; n= 1523), heifer pregnancy (HPG; n = 431), calving success (CS; n= 343), and weaning success (WS; n = 267). The final statistical model determined by SAS software (SAS Institute, Cary, NC, USA) for each trait was utilized in ASReml 4.2 (Gilmour et al., 2015) with the appropriate statistical distribution based on that trait. Least square means and standard errors were generated for fixed effects with relevant t-statistics provided through ASReml 4.2 (Gilmour et al., 2015). Pairwise comparisons were controlled for Type I Error using Tukey-Kramer method. Genetic and phenotypic correlations between calf temperament to calf productive and heifer reproductive traits were estimated using ASReml 4.2 (Gilmour et al., 2015) by bivariate animal model using pedigree. Result of this study showed that calf temperament influenced productive traits where there is an increased ABW, 205-d WW, ADG, and WG with calmer temperament calves. Majority of our models showed low genetic correlation of calf temperament on ABW, 205-d WW, pre-wean ADG, and WG. In conclusion, calves with

calmer temperament had an effect on ABW, 205-d WW, pre-wean ADG, and WG. Selection of calves with calmer temperament leads to improvement of these productive traits.

3.2. Introduction

Cattle temperament has an important role in production as it can influence important production traits such as average daily gain, feed conversion efficiency, pregnancy rate, and immunity. Cattle that are calm during handling have greater average daily gain, increased feed efficiency, increased pregnancy rates, and immunity and health compared to cattle that become agitated (Voisinet et al., 1997; Petherick et al., 2002; Burrow and Dillon, 1997; Cooke et al., 2009; Kasimanickam et al., 2014; and Hine et al., 2019). Cattle with excitable temperament were associated with impaired feedlot performance, poor carcass characteristics and meat quality traits (Cafe et al., 2011; and Francisco et al., 2015). Temperament is associated with the degree of stress the cattle will experience during production and transport (Sebastian et al., 2011; Burdick et al., 2011). It is therefore important to select cattle with calm temperament to improve production and reproductive traits.

As most literature has suggested association of beef cattle temperament to production, reproductive, and meat quality traits, there are still some studies that reported no associations of these traits. Cooke et al. (2012) suggested that temperament had no effect on birth and weaning weight and Burrow (2001) found no relationship of temperament to cattle fertility including growth traits. Furthermore, there is still no consensus about the extent on how beef cattle temperament affects productivity (Sant'Anna et al., 2014). Differences in results can be due to differences in breed of cattle, degree of handling (i.e., intensive or extensive), and methods of temperament evaluation. Breeds of cattle differ in production performance and temperament, and the degree of handling may mask the true temperament of the animal due to habituation or acclimatization

(Burrow and Dillon, 1997; King et al., 2006; Parham et al., 2019). Evidence suggests that methods of temperament evaluation capture different aspects of cattle temperament like reactivity, agitation, or fear (Sant'Anna et al., 2014). Haskell et al. (2014) reported that chute test measures both reactivity of cattle to human handling and restraint while exit velocity measures fearfulness or escape behavior (Curley et al., 2006). Lastly, limited studies were conducted that focus on genetic relationship of cattle temperament on production traits. Hence, this study was conducted.

The general objective of this study was to determine the effect and relationship of temperament on beef cattle production and reproductive traits using the novel Four Platform Standing Scale (FPSS; Yu et al., 2020) objective method and subjective methods of temperament evaluations that include docility score (DS), and temperament score (TS), and 12 qualitative behavioral assessment (QBA) attributes (Sant'Anna, and Paranhos da Costa, 2013). Specific objectives of this study were: (1) To determine the effect of calf temperament on calf productive traits (birth weight, weaning weight, preweaning average daily gain, and preweaning weight gain) and heifer reproductive traits (heifer pregnancy, calving success, weaning success, and reproductive success) using objective and subjective methods of temperament evaluations; (2) To determine phenotypic and genetic relationship of temperament to calf productive and heifer reproductive traits using objective and subjective methods of temperament evaluations; and (3) To estimate genetic parameters and variance components of calf productive and heifer reproductive traits when calf temperament is included in the model.

3.3. Materials and methods

3.3.1. Animals

All cattle were managed according to the Federation of Animal Science Societies Guide for the Care and Use of Agricultural Animals in Agriculture Research and Teaching (FASS, 2010).

All procedures were reviewed and approved by the Institutional Animal Care and Use Committee of North Dakota State University. Details of animals used in this study were described in materials and methods section of Chapter 2 of this dissertation under Animals.

3.3.2. Temperament evaluations

Temperament evaluation was conducted using objective and subjective methods of beef cattle temperament evaluation. The objective method utilized the FPSS data to produce standard deviation of weight over time (SSD), and coefficient of variation of SSD (CVSSD) as measure of temperament. Subjective methods used were DS (BIF, 2018), TS (Sant'Anna and Paranhos da Costa, 2013), 12 QBA attributes (Sant'Anna and Paranhos da Costa, 2013), and temperament indexes (TI) that include TI positive and TI negative. Details of these procedures were described in the Materials and Methods section of Chapter 2 of this dissertation under Beef Cattle Temperament Evaluations.

For a given animal, the average score across the 4 evaluators for each method of temperament evaluation was used for this study. At times, an evaluator missed scoring a given animal. Any animal with less than 3 evaluator scores were not used in this study. Using the average score per animal, each animal was assigned into a discrete category based on the original scale (DS, TS, and QBA) or quartile placement (TI, TI positive, TI negative), which is provided in Table 3.1.

3.3.3. Data collection

Birth weight (BW) was recorded immediately after birth raised with dams on pasture unless health or mothering ability of the dam dictated intervention was needed. Weaning weight (WW) was recorded based on weight obtained on the date of weaning. Birth weight and weaning weight used

Table 3.1. Description of criteria for assigning new categories for DS and TS[1].

Categorical Scores	**DS**	**TS**	**QBA**	**TI, TI+, TI-, SSD, CVSSD**
1	≤ 1.5	≤ 1.67	≤ 34	≤ Q1
2	> 1.5 to ≤ 2.5	> 1.67 to ≤ 2.67	> 34 to ≤ 68	> Q1 to ≤ Q2
3	> 2.5 to ≤ 3.5	-	> 68 to ≤ 102	> Q2 to ≤ Q3
4	> 3.5 to ≤ 4.5	> 2.67 to ≤ 3.67	>102	> Q3 to ≤ Q4
5	> 4.5 to ≤ 5.5	> 3.67	-	-
6	> 5.5	-	-	-

[1]DS: docility score, TS: temperament score, QBA: qualitative behavior attributes, TI: temperament index using 12 QBA attributes, TI+: TI using 6 positive QBA attributes, TI-: TI using 6 negative QBA attributes, SSD: standard deviation of the Four Flatform Standing Scale (FPSS) data (SSD), CVSSD: coefficient of variation of the SSD (CVSSD) "-" indicates not available.

in this study were adjusted based on age of dam using adjustment factors set by BIF (2018) (Table 3.2).

The equation for 205-d WW is based on average daily gain for 205-days using the following formula by BIF (2018):

$$Adj205WW = \frac{Weaning\ weight - Birth\ weight}{Weaning\ age} x\ 205 + Birth\ weight + Age\ of\ dam\ \text{Adj.}$$

Pre-weaning average daily gain (ADG) was calculated using the difference of adjusted birth weight and adjusted weaning weight (weight gain, WG) divided by age at weaning in days. During the four-year period, records of heifer calves that were bred were obtained. Reproductive traits such as heifer pregnancy (HPG), calving success (CS), weaning success (WS) and reproduction success (RS) were assigned based on conception, calving, and weaning records for first year of breeding. Binomial traits such as HPG, CS, and WS were assigned a score of "0" and "1" for failure and success, respectively. Reproductive success was a multinomial trait and indicated based on levels of: being open or not pregnant (1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (3), and being pregnant, having the calf, and successfully weaning the calf (4).

Table 3.2. Adjustment factors for birthweight and weaning weight[1].

Age of Dam (yr.)	BW (lb.)	WW (lb.)	
	All	Male	Female
2	8	60.00	54.00
3	5	40.00	36.00
4	2	20.00	18.00
5 to 10	0.00	0.00	0.00
>=11	3.00	20.00	18.00

[1]BIF guidelines, 2018, BW: Birth weight, WW: Weaning weight.

3.3.4. Statistical analysis

The final model for calf productive and heifer reproductive traits were determined using SAS software (SAS Institute, Cary, NC, USA). Fixed effects related to systematic environment were evaluated for fit, including categorical temperament measures (independent of each other), primary breed, sex, and relevant interactions. For each trait, these fixed effects were modeled with random effect of calf and relevant fixed covariates (e.g., age of dam, weaning weight, birth weight and days to weaning) using the MIXED or GENMOD procedure of (SAS Institute, Cary, NC, USA) based on trait distribution to determine the final model. A threshold for the model term to be included in the final model was set at significance in more than half (greater than 9) models. The final model was then fit with pedigree using ASReml 4.2 (Gilmour et al., 2015) to allow for an animal model based on current pedigree, appropriate distribution of data, and model effects.

Least square means and standard errors were generated for fixed effects with relevant t-statistics provided through ASReml 4.2 (Gilmour et al., 2015). Pairwise comparisons were controlled for Type I Error using Tukey-Kramer method by 1) converting the t-statistic to a q-statistics as $q = \sqrt{2} * t$ and 2) by finding the related p-value using the Real Statistics Resource Pack software (Release 7.6) Excel add-in QDIST function with k as the fixed effect degrees of freedom and the df as the residual degrees of freedom (Zaiontz, 2021).

3.3.5. Phenotypic and genetic correlations

The degree and direction of relationship between temperament on calf productive traits and heifer reproductive traits were determined using genetic and phenotypic correlations estimated through the animal model previously described in ASReml 4.2 (Gilmour et al., 2015) by bivariate analysis. Seed values for additive genetic variances and covariances as well as residual variances were used based on univariate estimates using ASReml 4.2 (Gilmour et al., 2015). Correlation coefficient values greater than or equal to 0.50 is considered highly correlated, greater than or equal to 0.30 and less that 0.50 is moderately correlated, and less than 0.30 is lowly correlated similar to Chapter 2 of this dissertation.

3.4. Results and discussion

3.4.1. Summary statistics

Record summary of productive and reproductive traits are presented in Table 3.3. As 1,542 calves had temperament scores collected, there were 12 and 19 records missing for BW and weaning ADG, and WW and WG, respectively. Records for reproductive traits were lower due to sex wherein less than half of the calves were heifers and the remaining were not used for breeding. Summary statistics that include minimum, maximum, mean, and standard deviations for productive and reproductive traits are presented in and Tables 3.4 and 3.5.

Record summary of calf temperament scores distribution using methods of temperament evaluation over the 4-year period is presented in Table 3.5. Using docility (DS) and temperament score (TS), majority of the calves had temperament scores of 1 and 2 (DS; n = 1,454, 94.29%; and TS; n = 1,325, 85.93%). Similarly, majority of the calves had scores of 1 and 2 using positive QBA of apathetic (n = 1,319, 85.54%), curious (n = 1,477, 95.78%), happy (n = 1,437, 95.78%), and positively occupied (n = 1,504, 97.54%) except calm and relaxed, which majority had scores of 3

Table 3.3. Record summary of productive traits measured across 4-year data.

Traits	Year[2]				Overall
	1	2	3	4	
Productive					
Birth weight	420	379	335	396	1530
Weaning weight	420	372	335	396	1523
Weaning ADG[1]	420	379	335	396	1530
Weight gain	420	372	335	396	1523
Reproductive					
Heifer pregnancy	78	131	97	125	431
Calving success	76	113	65	89	343
Weaning success	74	76	45	72	267
Reproductive success	77	131	97	125	430

[1]ADG = average daily gain.
[2]Sample size per year 1 =2014, 2 = 2015, 3 = 2016, 4 = 2017.

and 4 (n = 893, 57.91%; and n = 844, 57.73% respectively). Majority of the calves had scores of 1 and 2 also for negative QBA attributes using active (n = 1,108, 71.85%), agitated (n = 1,476, 95.72%), attentive (n = 1,159, 75.16%), distressed (n = 1,538, 99.74%), fearful (n = 1,490, 96.63%), and irritated (n = 1,497, 97.08%). Temperament scores using TI (TI positive and negative), SSD, and CVSSD were evenly distributed. Overall, these scores indicated that calves in this study are generally docile in temperament. According to Voisinet et al. (1997) and Burrow (2001), *Bos taurus* breeds have calmer temperament as compared to *Bos indicus* breeds including crosses. Within *Bos taurus* breeds, Tulloh (1961) found that Hereford and Angus have lower temperament scores than Shorthorns. In addition, Angus and Hereford sired calves have decrease temperament scores as compared to Simmental and Limousin sired calves using Angus and Hereford as dams (Graham, et al., 2001). Lastly, Hoppe et al. (2010) demonstrated German Angus and Hereford cattle received the smallest behavior scores compared with Charolais, Limousin, or German Simmental using chute score and flight speed. These findings align with our generally calm population of Angus and Hereford sired calves.

Table 3.4. Summary statistics for productive and reproductive traits measured across 4-year data.

Trait	Year					
	Statistic[1]	**1**	**2**	**3**	**4**	**Overall**
Birth weight, lb	Min	54	44	40	56	40
	Max	121	127	109	125	127
	Mean ± SD	86.14 ± 11.51	85.39 ± 12.04	81.10 ± 11.32	87.51 ± 11.20	85.20 ± 11.74
Weaning weight, lb	Min	284.7	348.4	329.1	360	284.7
	Max	798.1	831.8	810.6	949.1	949.1
	Mean ± SD	584.22 ± 68.36	613.19 ± 67.20	638.64 ± 63.90	707.17 ± 66.67	635.24 ± 81.38
Weight gain, lb	Min	197.7	258.4	260.1	269	197.7
	Max	718.1	730.1	711.8	841.1	841.1
	Mean ± SD	498.09 ± 66.48	527.84 ± 63.41	557.53 ± 60.62	619.67 ± 62.71	550.04 ± 78.50
Weaning ADG, lb/d	Min	0.96	1.26	1.27	1.31	0.96
	Max	3.5	3.44	3.46	4.1	4.1
	Mean ± SD	2.34 ± 0.33	2.49 ± 0.31	2.63 ± 0.31	2.94 ± 0.32	2.60 ± 0.39
Pregnancy success	Mean ± SD	0.97± 0.16	0.58 ± 0.50	0.67 ± 0.47	0.72 ± 0.45	0.71 ± 0.45
Calving success	Mean ± SD	0.95 ± 0.22	0.65 ± 0.48	0.66 ± 0.48	0.84 ± 0.37	0.77 ± 0.42
Weaning success	Mean ± SD	0.96 ± 0.20	0.99 ± 0.11	1.00 ± 0.00	1.00 ± 0.00	0.99 ± 0.12
Reproductive success	Mean ± SD	2.86 ± 0.58	1.73 ± 1.48	1.60 ± 1.36	1.87 ± 1.36	1.94 ± 1.37

[1]Minimum (Min), maximum (max), mean and standard deviation (SD) are reported, lb: pound, lb/d: pound per day, ADG: average daily gain. Success traits (pregnancy, calving, weaning and reproductive) always ranged from 0 to 1.

Table 3.5. Record summary of calf temperament scores distribution using methods of temperament evaluation over the 4-year period.

Method[1]	Score[2]						Total
	1	2	3	4	5	6	
DS	811	643	76	12	-	-	1542
TS	649	676	-	210	7	-	1542
QBA							
Positive QBA							
Apathetic	670	649	202	21	-	-	1542
Calm	261	388	561	332	-	-	1542
Curious	873	604	64	1	-	-	1542
Happy	925	512	105	0	-	-	1542
Pos. occupied	975	529	38	0	-	-	1542
Relaxed	262	436	623	221	-	-	1542
Negative QBA							
Active	348	760	390	44	-	-	1542
Agitated	1115	361	62	4	-	-	1542
Attentive	286	873	377	6	-	-	1542
Distressed	1450	88	4	0	-	-	1542
Fearful	1210	280	51	1	-	-	1542
Irritated	1256	241	43	2	-	-	1542
TI	387	384	386	385	-	-	1542
TI positive	386	384	385	387	-	-	1542
TI negative	386	385	383	388	-	-	1542
SSD	399	380	382	381	-	-	1542
CVSSD	415	366	382	379	-	-	1542

[1]DS = Docility score, score (1-6), TS: Temperament score, QBA: Qualitative behavioral attributes, QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior, TI: Temperament index: the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.), SSD: standard deviation of total weight over time recorded by four-platform standing scale, CVSSD: coefficient of variation based on the SSD.
[2]Score of 6 is only relevant to DS, Score of 5 is only relevant to TS and score of 3 is excluded for TS; TI, TI positive, TI negative, SSD, and CVSSD are based on quartile ranking.

3.4.2. Statistical modelling

Summary of statistical model parameterization for each trait is presented in Table 3.6. Final models by trait are described below.

Table 3.6. Statistical model parameterization for calf productive traits and dam reproductive traits.

Traits[1]	Fixed effects[2]					Fixed effect interactions[3]				Covariates[4]			
	MT	PB	Sex	Year	WW	MT*PB	MT*Sex	MT*Year	PB*Sex	BW	WW	BA	WA
Productive													
ABW	✓	✓	✓	✓	*	x	x	x	x	*	*	*	*
205-d WW	✓	✓	✓	✓	*	x	x	x	x	*	x	*	*
ADG	✓	✓	✓	✓	*	x	x	x	x	*	*	*	x
WG	✓	✓	✓	✓	*	x	x	x	x	*	*	*	*
Reproductive													
HPG	✓	✓	*	✓	x	x	*	x	*	*	*	✓	*
CS	✓	✓	*	✓	x	x	*	x	*	*	*	✓	*
WS	✓	✓	*	✓	x	x	*	x	*	*	*	✓	*
RS	✓	✓	*	✓	x	x	*	x	*	*	*	✓	*

[1] Productive traits: adjusted birth weight (ABW), adjusted 205 weaning weight (205-d WW), pre-weaning average daily gain (ADG), weight gain (WG); and reproductive traits: heifer pregnancy (HPG), calving success (CS), weaning success (WS), and reproductive success (RS).
[2] Fixed effects: method of temperament measurement (MT), primary breed (PB).
[3] Fixed effect interactions: method of temperament measurement with primary breed (MT*PB), sex (MT*Sex), year (MT*Year), and primary breed with sex (PB*Sex).
[4] Fixed covariates: birth weight (BW), weaning weight (WW), breeding age (BA), and weaning age (WA).
Symbols: (✓) indicates included in the final model, (x) indicates not included in the final model, and (*) indicates not evaluated.

3.4.2.1. Adjusted birth weight (ABW)

Out of 19 models, the number of models each effect was significant for temperament measures (11, 57.89%), primary breed (9, 47.37%), sex (15, 78.95%), year (12, 63.16%), and interaction of temperament with primary breed (1, 5.26%), sex (4, 21.05%), and year (7, 36.84%). This resulted in the final reduced model included fixed effects of temperament measure, primary breed, and sex using the criteria that 9 or more models must be significant for a given term.

3.4.2.2. Adjusted 205 weaning weight (205-d WW)

Similarly, the number of models each effect was significant for temperament measure (1, 5.26%), sex (19, 100%), and interactions of temperament measures and primary breed (1, 5.26%), and sex (1, 5.26%). Interactions were dropped in the model due to 1 out of 17 models resulting in a significant effect. Temperament measure was added as a fixed effect since the main effect in this study. Primary breed was added as a blocking factor in the model. Fitting weaning age as a fixed covariate was modelled however, did not improve the model as compared to fitting BW as a fixed covariate. The final model included fixed effect of temperament measures, primary breed, sex, year, and random effect of calf.

3.4.2.3. Pre-weaning ADG

Significant model terms for pre-weaning ADG were fixed effects of temperament measures (4, 21.05%), primary breed (6, 31.58%), sex (19, 100%), year (19, 100%), and interactions of temperament measures to primary breed (1, 5.26%), sex (2, 10.53%), and year (3, 15.79%). The final model included fixed effect of temperament measures, primary breed, sex, year, and random effect of calf.

3.4.2.4. Weight gain

Significant model terms for WG were fixed effects of temperament measures (2, 10.53%), sex (14, 73.68%), year (19, 100%), and interactions of temperament measures to primary breed (2, 10.53%), sex (2, 10.53%), and year (2, 10.53%). The interactions were dropped in the model since very few were significant out of 19 models. The final model included fixed effect of temperament measures, primary breed, sex, year and random effect of calf. Temperament measures and primary breed were added since temperament measures was the main effect on this study while primary breed was considered a blocking factor.

3.4.2.5. Heifer pregnancy

Model terms that were significant included fixed effect of temperament measures (2, 10.53%), and interaction of temperament measures, and weaning weight (2, 10.53%). Weaning weight and interactions were dropped because only 2 out of 19 models had significant effect while primary breed and year were added as blocking factor in the final model. The final model included fixed effect of temperament measure, primary breed and year, fixed covariate of breeding age and random effect of calf.

3.4.2.6. Calving success

Significant model terms for calving success were primary breed (2, 10.53%), interactions of temperament measures and primary breed (4, 21.05%) and weaning weight (1, 5.26%). Interactions were dropped in the model due few models had significant result. The final model included fixed effect of primary breed and year, fixed covariate of breeding age and random effect of calf.

3.4.2.7. Weaning success

Significant terms in the model included fixed effect of weaning weight (3, 15.79%). Primary breed and sex were added to the model to account for contemporary grouping or as blocking factor. Weaning weight was dropped in the model because 3 out of 19 model had significant effect. The final model included primary fixed effects of breed, sex, fixed covariate of breeding age and random effect of calf.

3.4.2.8. Reproductive success

Model terms that were significant included temperament measures (2, 10.53%), primary breed (1, 5.26%), weaning weight (1, 5.26%), and interaction of temperament measures and weaning weight (2, 10.53%). Interactions and weaning weight were dropped in the model because of few numbers of significant effect out of 19 models. The final model included. The final model included primary fixed effects of breed, sex, fixed covariate of breeding age and random effect of calf.

3.4.3. Effect of beef cattle temperament on productive traits

Least square means and standard errors by temperament category are reported in Tables 3.7 to 3.11. Significant effects calf temperament were observed to BW, WW, ADG, and WG. It is expected that that CVSSD showed no significant effect on production traits while SSD had an effect on WW, ADG, and WG. Coefficient of variation of the SSD (CVSSD) is an adjusted version of SSD based on the mean weight of calves. Therefore, SSD may not indicate temperament of the calf since calves with heavier weights have increased SSD. Effects of sex, year, and primary breed on ABW, 205-d WW, ADG, and WG are presented in appendix A3.1 to A3.13. Sex and year had significant effect on ABW, 205-d WW, ADG, and WG while primary breed had no significant effect.

Table 3.7. Least squares means and standard errors for calf docility score (DS) and temperament score (TS) effect on calf adjusted birth weight, adjusted 205 weaning weight (205-d WW), weaning average daily gain (ADG), and weight gain (WG)[1].

Method	Calf Productive Traits							
	ABW	**N**	**205-d WW**	**N**	**ADG**	**N**	**WG**	**N**
DS[2]	**P-value = 0.485**		**P-value = 0.709**		**P-value =0.773**		**P-value = 0.679**	
1	87.12 ± 1.22	803	633.19 ± 6.85	800	547.72 ± 6.93	803	547.72 ± 6.93	800
2	87.24 ± 1.21	640	636.73 ± 6.78	636	551.58 ± 6.86	640	551.58 ± 6.86	636
3	85.37 ± 1.64	76	636.86 ± 9.22	76	550.62 ± 9.36	76	550.62 ± 9.36	76
4	87.98 ± 3.23	11	641.50 ± 18.32	11	556.00 ± 18.54	11	556.00 ± 18.54	11
5	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-
TS[3]	**P-value = 0.019**		**P-value = 0.653**		**P-value =0.794**		**P-value =0 .864**	
1	88.10 ± 1.22[a]	644	633.75 ± 6.89	641	549.43 ± 6.97	644	549.43 ± 6.97	644
2	86.62 ± 1.21[b]	670	635.22 ± 6.84	667	549.38 ± 6.92	670	549.38 ± 6.92	670
4	85.90 ± 1.34[b]	209	639.40 ± 7.55	208	552.88 ± 7.65	209	552.88 ± 7.65	209
5	88.25 ± 3.71[a,b]	7	626.28 ± 21.08	7	542.93 ± 21.35	7	542.93 ± 21.35	7

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement (DS, TS), primary breed, sex, year, and random effect of animal with known pedigree (ABW, ADG, and WG); and fixed effects of methods of temperament measurement (DS, TS), primary breed, sex, year, weaning age; covariate of birth weight; and random effect of animal with known pedigree (205-d WW). "-" indicates no data.

[2]Docility score: scale of 1 to 6 with 1 = docile and 6 = very aggressive.

[3]Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer.

[abc]Superscripts within a column and a given scoring method that are different, differ ($P < 0.05$). "-" indicates no data.

Table 3.8. Least squares means and standard errors for calf positive Qualitative Behavior Assessment (QBA) attributes effect on calf adjusted birth weight (ABW), adjusted 205 weaning weight (205-d WW), weaning average daily gain (ADG), and weight gain (WG)[1].

Positive QBA[2]	Calf Productive Traits							
	ABW	N	205-d WW	N	ADG	N	WG	N
Apathetic	**P-value = 0.028**		**P-value = 0.086**		**P-value = 0.171**		**P-value = 0.865**	
1	86.25 ± 1.23^{b}	664	640.47 ± 6.90	660	2.65 ± 0.04	664	554.25 ± 7.00	660
2	87.48 ± 1.22^{a,b}	644	631.34 ± 6.85	641	2.61 ± 0.03	644	546.51 ± 6.94	641
3	88.99 ± 1.40^{a}	201	629.35 ± 7.86	201	2.60 ± 0.04	201	545.46 ± 7.96	201
4	89.76 ± 2.56^{a,b}	21	628.10 ± 14.43	21	2.63 ± 0.07	21	546.35 ± 14.65	21
Calm	**P-value = <0.001**		**P-value = 0.527**		**P-value = 0.466**		**P-value = 0.735**	
1	84.87 ± 1.30^{c}	259	639.60 ± 7.39	257	2.64 ± 0.04	259	551.78 ± 0.04	257
2	86.48 ± 1.26^{b,c}	385	633.06 ± 7.11	383	2.61 ± 0.04	385	547.05 ± 0.04	383
3	87.76 ± 1.22^{a,b}	556	635.04 ± 6.91	553	2.63 ± 0.04	556	550.21 ± 0.04	553
4	89.16 ± 1.29^{a}	330	633.50 ± 7.31	330	2.64 ± 0.04	330	550.73 ± 0.04	330
Curious	**P-value = 0.726**		**P-value = 0.525**		**P-value = 0.728**		**P-value = 0.479**	
1	87.13 ± 1.21	863	635.46 ± 6.83	856	2.63 ± 0.03	863	550.14 ± 6.90	856
2	86.96 ± 1.25	602	633.89 ± 7.00	602	2.62 ± 0.04	602	548.40 ± 7.09	602
3	88.19 ± 1.74	64	643.94 ± 9.83	64	2.64 ± 0.28	64	558.97 ± 9.96	64
4	80.90 ± 9.56	1	602.27 ± 54.15	1	2.43 ± 0.28	1	512.74 ± 54.95	1
Happy	**P-value = 0.157**		**P-value = 0.700**		**P-value = 0.629**		**P-value = 0.448**	
1	86.57 ± 1.22	916	634.13 ± 6.86	909	2.62 ± 0.03	916	548.14 ± 6.93	909
2	87.94 ± 1.30	509	636.34 ± 7.33	509	2.64 ± 0.04	509	551.98 ± 7.42	509
3	88.87 ± 1.62	105	640.40 ± 9.14	105	2.65 ± 0.05	105	557.64 ± 9.26	105
4	-	-	-	-	-	-	-	-
Pos. occupied	**P-value = 0.024**		**P-value = 0.016**		**P-value = 0.237**		**P-value = 0.024**	
1	87.02 ± 1.21^{a}	964	630.87 ± 6.82^{b}	957	2.65 ± 0.03	964	545.69 ± 6.88^{b}	909
2	87.77 ± 1.30^{a}	528	642.08 ± 7.31^{a}	528	2.64 ± 0.04	528	557.21 ± 7.39^{a}	509
3	83.22 ± 2.12^{b}	38	656.38 ± 11.97^{a}	38	2.65 ± 0.05	38	567.72 ± 12.15^{a}	105
4	-	-	-	-	-	-	-	-
Relaxed	**P-value = <0.001**		**P-value = 0.917**		**P-value = 0.664**		**P-value = 0.990**	
1	85.14 ± 1.30^{b}	260	637.14 ± 7.38	258	2.62 ± 0.04	260	549.68 ± 7.49	258
2	86.87 ± 1.25^{b}	433	635.69 ± 7.06	430	2.62 ± 0.04	433	549.97 ± 7.16	430
3	87.47 ± 1.22^{a,b}	616	634.44 ± 6.89	614	2.62 ± 0.04	616	549.48 ± 6.98	614
4	89.80 ± 1.35^{a}	221	633.28 ± 7.65	221	2.65 ± 0.04	221	551.00 ± 7.75	221

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of positive QBA, primary breed, sex, year, and random effect of animal with known pedigree (ABW, ADG, and WG); and fixed effects of positive QBA, primary breed, sex, year, weaning age; covariate of birth weight; and random effect of animal with known pedigree (205-d WW). [2]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression.

[abc]Superscripts within a column and a given scoring method that are different, differ ($P < 0.05$). "-" indicates no data.

Table 3.9. Least squares means and standard errors for calf negative Qualitative Behavior Assessment (QBA) attributes effect on calf adjusted birth weight (ABW), adjusted 205 weaning weight (205-d WW), weaning average daily gain (ADG), and weight gain (WG)[1].

Negative QBA[2]	Calf Productive Traits							
	ABW	**N**	**205-d WW**	**N**	**ADG**	**N**	**WG**	**N**
Active	**P-value = 0.001**		**P-value = 0.500**		**P-value = 0.924**		**P-value = 0.865**	
1	89.19 ± 1.29[a]	345	631.01 ± 7.26	344	2.62 ± 0.04	345	547.98 ± 7.35	344
2	87.14 ± 1.20[b]	753	636.45 ± 6.80	749	2.63 ± 0.03	753	550.81 ± 6.88	749
3	86.08 ± 1.26[b]	389	635.20 ± 7.11	387	2.62 ± 0.04	389	549.10 ± 7.21	387
4	84.22 ± 1.86[b]	43	640.60 ± 10.56	43	2.64 ± 0.05	43	552.90 ± 10.72	43
Agitated	**P-value = 0.013**		**P-value = 0.894**		**P-value = 0.777**		**P-value = 0.951**	
1	87.69 ± 1.18[a]	1104	634.57 ± 6.71	1100	2.62 ± 0.03	1104	549.76 ± 6.79	1100
2	86.22 ± 1.26[b]	361	635.63 ± 7.14	358	2.62 ± 0.04	361	549.31 ± 7.23	358
3	84.13 ± 1.72[b]	61	638.68 ± 9.69	61	2.64 ± 0.05	61	551.17 ± 9.85	61
4	86.60 ± 4.73[a,b]	4	648.86 ± 26.94	4	2.76 ± 0.14	4	563.99 ± 27.23	4
Attentive	**P-value = 0.232**		**P-value = 0.177**		**P-value = 0.112**		**P-value = 0.117**	
1	88.37 ± 1.35	283	641.40 ± 7.60	280	2.67 ± 0.04	283	556.84 ± 7.66	280
2	86.84 ± 1.21	866	632.80 ± 6.75	862	2.61 ± 0.03	866	547.13 ± 6.84	862
3	86.92 ± 1.29	375	636.44 ± 7.20	375	2.63 ± 0.04	375	551.06 ± 7.31	375
4	85.55 ± 4.04	6	646.51 ± 22.89	6	2.67 ± 0.12	6	558.84 ± 23.20	6
Distressed	**P-value = 0.453**		**P-value = 0.310**		**P-value = 0.164**		**P-value = 0.230**	
1	87.13 ± 1.19	1439	635.37 ± 6.63	1433	2.63 ± 0.03	1439	550.02 ± 6.71	1433
2	87.00 ± 1.57	87	634.18 ± 8.82	86	2.62 ± 0.05	87	548.93 ± 8.94	86
3	80.78 ± 5.18	4	591.81 ± 29.24	4	2.35 ± 0.15	4	500.41 ± 29.67	4
4	-	-	-	-	-	-		-
Fearful	**P-value = 0.003**		**P-value = 0.462**		**P-value = 0.230**		**P-value = 0.211**	
1	87.73 ± 1.18[a]	1200	635.89 ± 6.71	1194	2.63 ± 0.03	1200	551.24 ± 6.78	1194
2	85.50 ± 1.29[b]	279	634.36 ± 7.29	278	2.61 ± 0.04	279	547.35 ± 7.37	278
3	85.27 ± 1.81[a,b]	50	627.24 ± 10.28	50	2.59 ± 0.05	50	539.70 ± 10.40	50
4	101.30 ± 9.57[a,b]	1	699.97 ± 54.33	1	3.09 ± 0.28	1	628.38 ± 55.05	1
Irritated	**P-value = 0.077**		**P-value = 0.411**		**P-value = 0.817**		**P-value = 0.740**	
1	87.50 ± 1.18	1245	634.29 ± 6.67	1239	2.62 ± 0.03	1245	549.37 ± 6.75	1239
2	85.71 ± 1.32	240	640.57 ± 7.44	239	2.64 ± 0.04	240	553.08 ± 7.53	239
3	85.78 ± 1.87	43	631.60 ± 10.57	43	2.62 ± 0.05	43	546.21 ± 10.72	43
4	87.46 ± 6.65	2	657.10 ± 37.80	2	2.77 ± 0.20	2	568.86 ± 38.25	2

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of negative QBA, primary breed, sex, year, and random effect of animal with known pedigree (ABW, ADG, and WG); and fixed effects of negative QBA, primary breed, sex, year, weaning age; covariate of birth weight; and random effect of animal with known pedigree (205-d WW). [2]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression.
[abc]Superscripts within a column and a given scoring method that are different, differ ($P < 0.05$). "-" indicates no data.

Table 3.10. Least squares means and standard errors for calf temperament index effect on calf adjusted birth weight (ABW), adjusted 205 weaning weight (205-d WW), weaning average daily gain (ADG), and weight gain (WG)[1].

Method	**Calf Productive Traits**							
	ABW	**N**	**205-d WW**	**N**	**Pre-wean ADG**	**N**	**WG**	**N**
TI	**P-value = 0.058**		**P-value = 0.124**		**P-value = 0.016**		**P-value = 0.150**	
1	87.80 ± 1.26	385	633.35 ± 7.03	383	2.63 ± 0.04[a,b]	385	549.13 ± 7.13	383
2	86.88 ± 1.26	381	641.33 ± 7.09	377	2.66 ± 0.04[a]	381	555.24 ± 7.17	377
3	87.56 ± 1.25	383	635.02 ± 7.02	382	2.62 ± 0.04[a,b]	383	549.90 ± 7.10	382
4	85.92 ± 1.27	381	632.21 ± 7.11	381	2.59 ± 0.04[b]	381	545.50 ± 7.21	381
TI Positive	**P-value = <0.001**		**P-value = 0.411**		**P-value = 0.759**		**P-value = 0.587**	
1	85.40 ± 1.26[c]	385	636.05 ± 7.13	383	2.62 ± 0.04	385	549.01 ± 7.22	383
2	86.61 ± 1.26[b,c]	378	638.25 ± 7.13	374	2.64 ± 0.04	378	552.14 ± 7.22	374
3	88.22 ± 1.25[a,b]	383	631.19 ± 7.10	382	2.62 ± 0.04	383	547.12 ± 7.18	382
4	88.65 ± 1.28[a]	384	635.33 ± 7.24	384	2.63 ± 0.04	384	551.71 ± 7.34	384
TI Negative	**P-value = <0.001**		**P-value = 0.779**		**P-value = 0.759**		**P-value = 0.468**	
1	88.93 ± 1.26[a]	382	637.52 ± 7.18	381	2.64 ± 0.04	382	553.62 ± 7.25	381
2	87.24 ± 1.25[a,b]	382	635.49 ± 7.09	379	2.63 ± 0.04	382	550.54 ± 7.17	379
3	87.09 ± 1.26[b]	379	633.18 ± 7.18	378	2.61 ± 0.04	379	547.67 ± 7.26	378
4	85.57 ± 1.24[b]	387	634.41 ± 7.05	385	2.61 ± 0.04	387	547.58 ± 7.14	385

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement (TI, TI+, TI-), primary breed, sex, year, and random effect of animal with known pedigree (ABW, ADG, and WG); and fixed effects of methods of temperament measurement (TI, TI+, TI-), primary breed, sex, year, weaning age; covariate of birth weight; and random effect of animal with known pedigree (205-d WW). Quartile values per trait (1 = min, 2 = 25%, median, 3 = 75%, and 4 = max).

[2]Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

[abc]Superscripts within a column and a given scoring method that are different, differ (*P* < 0.05). "-" indicates no data.

Table 3.11. Least squares means and standard errors for calf four flatform standing scale (SSD) and coefficient of variation of SDD (CVSSD) data effect on calf adjusted birth weight (ABW), adjusted 205 weaning weight (205-d WW), weaning average daily gain (ADG), and weight gain (WG)[1].

Method[2]	**Calf Productive Traits**							
	ABW	**N**	**205-d WW**	**N**	**Pre-wean ADG**	**N**	**WG**	**N**
SSD	**P-value = 0.614**		**P-value = <0.001**		**P-value = <0.001**		**P-value = <0.001**	
1	86.93 ± 1.27	395	628.95 ± 7.07[b]	394	2.59 ± 0.04[b,c]	395	543.41 ± 7.15[b]	394
2	86.71 ± 1.27	378	627.20 ± 7.08[b]	377	2.59 ± 0.04[c]	378	541.58 ± 7.16[b]	377
3	87.00 ± 1.26	380	635.95 ± 7.02[a,b]	378	2.63 ± 0.04[b,c]	380	550.30 ± 7.09[b]	378
4	87.67 ± 1.26	377	645.73 ± 7.02[a]	374	2.69 ± 0.04[a]	377	561.19 ± 7.11[a]	374
CVSSD	**P-value = 0.970**		**P-value = 0.878**		**P-value = 0.823**		**P-value = 0.885**	
1	87.32 ± 1.27	409	634.91 ± 7.11	408	2.62 ± 0.04	409	549.80 ± 7.19	408
2	87.02 ± 1.27	365	636.63 ± 7.16	364	2.64 ± 0.04	365	551.39 ± 7.24	364
3	87.01 ± 1.26	380	633.42 ± 7.08	378	2.62 ± 0.04	380	548.08 ± 7.17	378
4	87.09 ± 1.27	376	635.84 ± 7.14	373	2.63 ± 0.04	376	550.19 ± 7.21	373

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement (SSD, CVSSD), primary breed, sex, year, and random effect of animal with known pedigree (ABW, ADG, and WG); and fixed effects of methods of temperament measurement (SSD, CVSSD), primary breed, sex, year, weaning age; covariate of birth weight; and random effect of animal with known pedigree (205-d WW). Quartile values per trait (1 = min, 2 = 25%, median, 3 = 75%, and 4 = max).
[2]SSD: standard deviation of total weight over time recorded by four-platform standing scale, CVSSD: coefficient of variation based on the SSD.
[abc]Superscripts within a column and a given scoring method that are different, differ ($P < 0.05$). "-" indicates no data.

3.4.3.1. Adjusted birth weight (AWD)

Overall, including temperament measure as a fixed effect was significant for 10 out of 19 models. Among these significant measures of temperament, there was a decreasing pattern of calf ABW as the calf becomes temperamental. For example, ABW decreased as scores for TS, active, agitated, fearful QBA attributes, and negative TI increased (i.e., became more agitated, active, fearful, etc.). In some cases, however, this relationship was not clearly seen because sample size in a given category was low, leading to large standard errors. Therefore, our study shows that higher ABW likely result in calmer temperaments of that calf. However, most literature have suggested that temperament had no effect on BW (Burrow, 2001; and Prayaga et al., 2005). Birth weight is influenced genetically both by the sire and dam and environmental factors and therefore, calf temperament may not have an effect on BW. However, studies have shown that calf temperament had an effect on ADG and WW (Turner et al., 2011; Francisco et al., 2012; and Sant' Anna et al., 2012) which is highly correlated with BW (Prayaga et al., 2005). Therefore, temperament of calf can influence BW.

Steers had increased birth weight as compared heifers in all measure of temperament (Appendix table A3.2), which is similar to published literature (Holland and Odde, 1992; and Kertz et al., 1997). Primary breed had no significant effect on birth weight, meaning birth weights were similar to both Angus and Hereford influenced breeds in this study as described in the primary breed effect discussion of Chapter 2.

3.4.3.2. Adjusted 205 weaning weight (205-d WW)

Among measures of temperament, positively occupied (*P-value* = 0.016) QBA attributes (Table 3.8) and SSD (*P-value* < 0.01) (2 out of 19 methods) (Table 3.11) had significant association with 205-d WW. Moreover, pairwise comparisons using Tukey-Kramer to control type

I error showed significant effect. Based on the result of this study, calf temperament had an effect on WW. Weaning weight increases as temperament score increases using SSD and positively occupied increases. Increased in positively occupied score means calmer temperament while increased in SSD means temperamental. Result of this study showed contradicting results, calf with calm temperament (increase positively occupied QBA attribute score) had increased 205-d WW while temperamental calf (increased SSD score) had increased 205-d WW. Outcome of this study is similar to literature using positively occupied QBA attributes but not using SSD. Literature suggested that calmer cattle has increase WW and temperamental cattle has decrease WW. For example, Sant'Anna et al. (2012) found that cattle that had slower flight speed meaning calmer temperament has better weaning weight than faster flight speed. In addition, Fordyce et al. (1985) found that temperamental cattle have lower live weights. Furthermore, there is a decrease in weaning weight in excitable calves as compared to calves that are calm (Francisco et al., 2012) using chute and exit velocity.

3.4.3.3. Pre-weaning ADG

Temperament had an effect on pre-weaning ADG based on Temperament index (TI) (*P-value* = 0.016) and SSD (*P-value* < 0.001) as shown in Tables 3.10 and 3.11. Furthermore, pairwise comparisons using Tukey-Kramer to control type I error showed significant effect. There was an increase in pre-weaning ADG when SSD scores increases while decrease in pre-weaning ADG while TI score increases. Result of this study showed different results based on temperament evaluation methods. Increase in TI and SSD scores showed decrease and increase pre-weaning ADG, respectively. Using TI, temperamental calf had decreased pre-weaning ADG while using SSD, temperamental calf had increased pre-weaning ADG. Result of this study using TI is similar to the results in published papers. Based on literature, calmer beef cattle had increased ADG as compared to beef cattle that were temperamental (Voisinet et al., 1997; Fell et al., 1999, and Patherick et al., 2002). However, these studies measured ADG from feedlot to finishing which was different from this study. Calf pre-weaning ADG most rely on dam performance to produce milk and during this stage of calf life is when there is less human handling that may affect ADG when calf is temperamental. Breed of cattle and method of temperament evaluation used in this study may also affected the results. Burrow and Dillon (1997) used cross of *Bos indicus* and *Bos taurus* cattle and flight time to measure temperament and found that flight time/exit velocity had an effect on ADG where the slow cattle grow faster in feedlot compared to faster cattle. Lastly, Fell et al. (1999) used flight time, endocrine, and immunological assays to measure temperament, found that nervous cattle with faster flight time had significantly lower ADG than the calm cattle.

3.4.3.4. Weight gain

Significant effect of temperament on WG was observed using SSD (*P-value* < 0.001) (Table 3.11) and positively occupied (*P-value* = 0.024) QBA attribute (Table 3.8). Similar to WW, these methods captured effect of calf temperament on this production trait with contradicting results. Using SSD, there was a significant increase in WG with temperamental calf while significant increase in WG with calmer calf using positively occupied QBA attribute. The result of this study specifically using positively occupied QBA attribute is similar to the results of studies published. Studies have shown that beef cattle with calm temperament had higher liveweight (Fordyce et al., 1988) and weight gain (Gauly et al., 2001). Using SSD yielded different result from what is found in literature, however, genetic correlation analysis in this study showed similar results. Other methods in this study showed no significant effect of calf temperament on WG. One possible reason that may explain why there was no significant result is that WG in this study was measured from birth weight to weaning weight. Studies on weight gain starts from feedlot to finishing and during that period there are more human handling or stressor that may affect WG.

3.4.4. Phenotypic and genetic correlations

Phenotypic and genetic correlations of productive traits between temperament measurements per category are presented in Figures 3.1 and 3.2. Phenotypic and genetic correlations between calf temperament and calf productive traits using subjective and objective methods of temperament evaluation ranged from -0.14 to 0.33, and -0.63 to 0.36, respectively. In this section, genetic correlation is discussed since fitting the animal model in the analysis yield more accurate results. Low to high correlation genetic correlation was found between calf temperament and calf productive traits. Based on the results of these study, ABW was affected by calf temperament negatively with calmer temperament calves had increased ABW. For 205-d WW, pre-wean ADG, and WG, calf temperament had positive genetic correlations to these traits. However, genetic correlations of calf temperament to these calf productive traits were mostly low with 18, 17, 15, and 18 out of 19 models for ABW, 205-d WW, pre-wean ADG, and WG respectively. These suggest that calf temperament had no association with these productive traits due to close to zero and low correlations.

3.4.4.1. Calf temperament and adjusted birth weight

Negative correlations were found between ABW and calf temperament using DS, TS, all negative QBAs (QBA1, QBA4, QBA6, QBA12, QBA3, and QBA9), and TI. This means that temperamental calves had decreased ABW since increased in scores using these methods indicates aggressive temperament. Positive correlations were found using positive QBAs (QBA10, QBA5, QBA8, QBA11, and QBA2), and TI positive, except QBA7. Positive correlation of calf temperament to positive QBA attributes means that calmer calf had increased ABW since

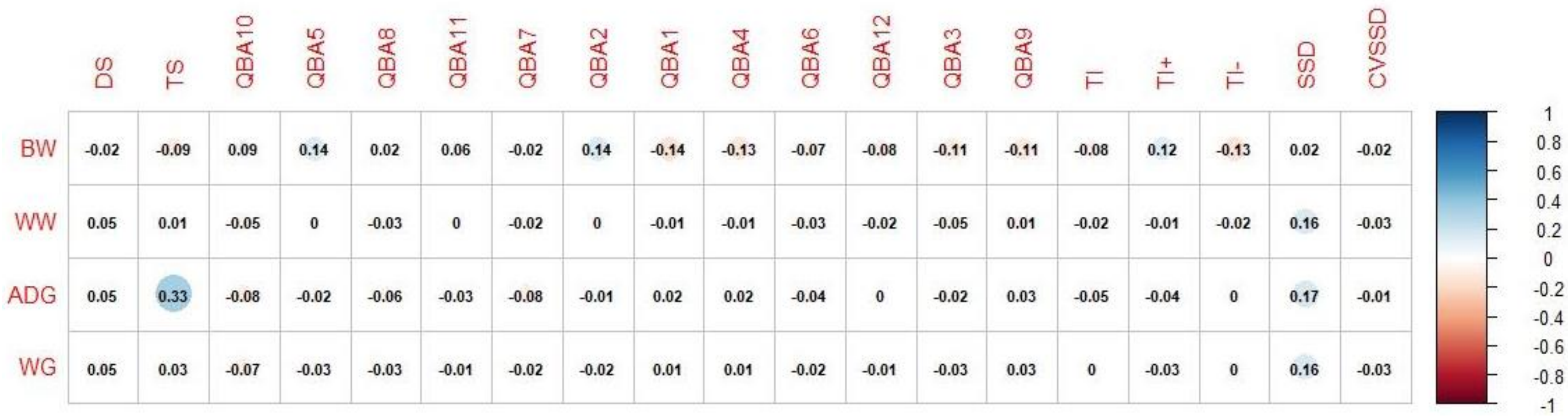


Figure 3.1. Phenotypic correlations between calf production trait to temperament using subjective and objective methods. Estimated using ASReml 4.2 (Gilmour et al., 2015) effects of primary breed, sex year, random effect of animal with known pedigree. Calf production traits: BW: adjusted birth weight, WW: adjusted 205 Weaning weight, ADG: pre-weaning average daily gain, WG: weight gain (WW-BW). Subjective methods: Docility score (DS), temperament score (TS), Qualitative Behavioral Attributes (QBA) are grouped by positive (QBA2 = relaxed, QBA5 = calm, QBA7 = positively (pos.) occupied, QBA8 = curious, and QBA10 = apathetic, QBA11= happy) and negative (QBA1 = active, QBA3 = fearful, QBA4 = agitated, QBA6 = attentive, QBA9 = irritated, and QBA12 = distressed) like behavior. Docility score: scale of 1 to 6 with 1 = calm and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation jumps against the fence and tries to attack the observer. [2]Temperament index (TI): the first principal component score generated from QBA scores, TI positive (TI+): first principal component score generated from positive QBA scores, TI negative (TI-): first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). Objective methods, SSD: Standard deviation of four platform standing scale (FPSS) (Pacific Industrial Scale, British Columbia, Canada), and CVSSD: coefficient of variation of SSD.

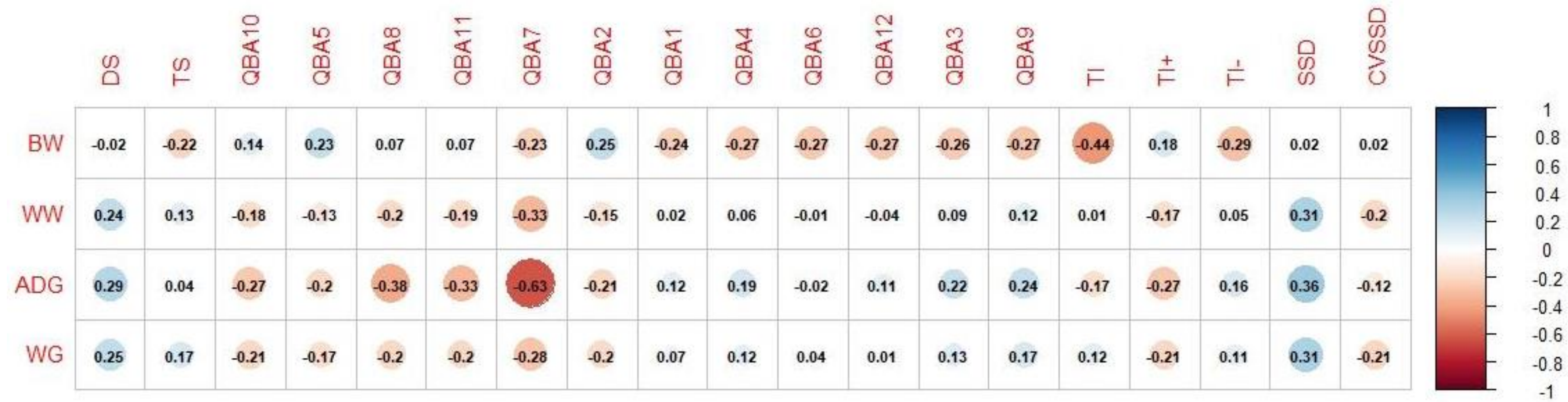


Figure 3.2. Genetic correlations between calf production trait to temperament using subjective and objective methods.
Estimated using ASReml 4.2 (Gilmour et al., 2015) effects of primary breed, sex year, random effect of animal with known pedigree. Calf production traits: BW: adjusted birth weight, WW: adjusted 205-d weaning weight, ADG: pre-weaning average daily gain, WG: weight gain (WW-BW). Subjective methods: Docility score (DS), temperament score (TS), Qualitative Behavioral Attributes (QBA) are grouped by positive (QBA2 = relaxed, QBA5 = calm, QBA7 = positively (pos.) occupied, QBA8 = curious, and QBA10 = apathetic, QBA11= happy) and negative (QBA1 = active, QBA3 = fearful, QBA4 = agitated, QBA6 = attentive, QBA9 = irritated, and QBA12 = distressed) like behavior. Docility score: scale of 1 to 6 with 1 = calm and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation jumps against the fence and tries to attack the observer. [2]Temperament index (TI): the first principal component score generated from QBA scores, TI positive (TI+): first principal component score generated from positive QBA scores, TI negative (TI-): first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). Objective methods, SSD: Standard deviation of four platform standing scale (FPSS) (Pacific Industrial Scale, British Columbia, Canada), and CVSSD: coefficient of variation of SSD.

increased in positive QBA scores means calmer temperament. However, these correlations ranged from very low (insignificant) to moderate genetic correlations. Very low genetic correlations (close to zero) were found using DS, QBA8, QBA11, SSD and CVSSD. Relationship of BW to calf temperament was insignificant using these methods. Low genetic correlation (-0.29 to 0.25) was observed using TS, positive QBA attributes (QBA10, QBA5, QBA7, QBA2), negative QBA attributes (QBA1, QBA4, QBA6, QBA12, QBA3, QBA9), TI+ and TI-. Lastly, moderate correlations were found using TI. Among these measures, TS, negative QBAs, and TI- had tendency to be negatively correlated to BW while TI was negatively correlated to birth weight. Most literature suggested that beef cattle temperament reported no association to birth weight. Results of this present study revealed both similar and different results due to differences in the method of temperament evaluations. Temperament evaluations using DS, positive QBA attributes, SSD and CVSSD in this study had similar results with most literature. For example, Prayaga and Henshall (2005) reported -0.08 genetic correlations between temperament using flight time and birth weight, Burdick et al. (2009) found out 0.01 correlation of birth weight to calf temperament using exit velocity, and Garza-Brenner et al. (2019) found very low correlations (insignificant) with 0.05, -0.01, and 0.03 correlations of birth weight to calf temperament using pen score, exit velocity, and temperament score respectively. Based on these literature, cattle temperament may not have an effect on birth weight. Using TS, negative QBAs, and TI, calf temperament had tendency to be negatively correlated to BW while using TI, calf temperament is negatively correlated to BW. However, findings of this study showed using QBA attributes, specifically negative QBA attributes, TI negative, and TI were negatively correlated to BW. QBA attributes method agreed with traditional methods (chute score, temperament score, and flight speed) however, additional studies are needed to assess the inter- and intra-observers' reliability (Sant'Anna and Paranhos da Costa, 2013).

3.4.4.2. Calf temperament and adjusted 205 weaning weight

Based on the result of our study, increased 205-d WW is associated with increased calf temperament score in 16 out of 19 measures of temperament. Low to moderate negative genetic correlation that ranged from -0.13 to -0.33 were found using positive QBA attributes which means that increased in score (calmer) would mean decrease in pre-weaning 205-d WW. Low positive genetic correlation was found using negative QBA attributes which range from 0.02 to 0.12 except QBA6 and QBA12 but close to zero (insignificant). Positive genetic correlation using negative QBA attributes means that increased score (aggressive) wound mean increase in 205-d WW. Using traditional methods, low positive genetic correlation was found using TS and DS respectively. TI and TI positive showed close to zero (insignificant) genetic correlation. CVSSD is the only method that had negative genetic correlation but is low. Most of these genetic correlations were low except for SSD (0.31) and QBA7 (-0.33) which are moderate.

Result of this study is different to majority of published literature. Traditional methods (DS, TS) and objective method (SSD) used in this study suggest positive genetic correlation which is different from most literature that suggest negative correlation or no correlation of WW to temperament. According to Torres-Vasquez and Spangler (2016), there is a negative genetic correlation of cattle temperament to weaning weight is -0.12 indicating that selection for higher WW would result in selecting animals with calmer temperament. The study of Torres-Vasquez and Spangler (2016) utilized 25,037 animals which increased accuracy of genetic correlation. The difference in the direction (positive and negative genetic correlation) using SSD and CVSSD in this may indicate inaccuracies given that they are both from FPSS data. Other literature also suggest negative genetic correlations but were low. Genetic correlation of WW to calf temperament using flight score and crush score were –0.08 and –0.19 respectively (Sant'Anna et al., 2013). However, Burrow (2001) found no genetic correlation between WW and flight speed score (0.00) and in addition, Henshall (2005) did not find significant genetic correlations between flight times and WW using Bos indicus cattle.

3.4.4.3. Calf temperament and pre-weaning ADG

Majority (16 out of 19) of the methods used in this study showed that pre-weaning ADG increased with calves that are temperamental and vice versa. Low to high negative genetic correlation that ranged from -0.02 to -0.63 were found using positive QBA attributes which means that increased in score (calmer) would mean decrease in pre-weaning ADG. Low positive genetic correlation was found using negative QBA attributes which range from 0.11 to 0.24 except QBA6 (-0.02) which means that increased score using negative QBA attributes (aggressive temperament) wound mean increase in pre-weaning ADG. Using traditional methods, low and moderate positive genetic correlation was found using TS and DS respectively. This also suggests that aggressive cattle have increased pre-weaning ADG. TI, QBA6, and CVSSD showed low negative genetic correlation that ranged from -0.02 to -0.17. Most of the genetic correlations in this study were low. Moderate correlations were found to DS, positive QBAs (QBA8, QBA11, and SSD) with -0.38, -0.33, 0.36 respectively while high correlations were found to QBA7 (-0.63). Overall, with majority of the methods used in this study, pre-weaning ADG had increased to calves that are temperamental.

The result of this study is different from most literature and maybe due to number of animals used in this study that may have an effect on accuracy. Majority of literature suggest negative genetic correlations of temperament to ADG. With 25,691 Nellore cattle, Sant'Anna et al., 2014 found that the genetic correlation of ADG to beef cattle temperament were -0.18, -0.17, -0.31, and -0.20 using temperament score, movement score, crush score, and flight speed respectively. Negative genetic correlation using these methods indicates that docile temperament (lower scores) was genetically associated with higher ADG and vice versa. Negative genetic correlation between these traits varies from low to high and are different among breeds and method of evaluation. Hoppe et al. (2010) reported negative low to high genetic correlation between chute score and ADG using wide range of cattle breeds (-0.13 for German Angus, -0.16 for Charolais, -0.27 for Limousin, -0.34 for German Simmental and -0.58 for Hereford). Burrow (2001) reported low genetic correlation (-0.02) using flight speed scores in composite tropical beef cattle. These negative genetic correlations, however, are similar our study using TI, attentive QBA attributes, and CVSSD. Another possible reason is that in most of these studies ADG was computed from birth to yearling weights which is different from our study. Prayaga and Henshall (2005) reported different genetic correlation between pre-weaning and post-weaning ADG with temperament using flight time and reported zero (0 or no association) genetic correlation between and flight time and pre-weaning ADG while -0.12 genetic correlation with post-weaning ADG in crossbreed cattle.

3.4.4.4. Calf temperament and weight gain

Weight gain tended to follow the same directions as WW and pre-weaning ADG. Based on overall measures of temperament WG tends to increase with temperamental calves. Positive correlations were found to most measures of temperament and negative correlations to all positive QBAs (also increased WG to temperamental calves). These correlations, however, were low except for SSD (0.31) which was moderately correlated. Among these measures, CVSSD had negative correlation to WG meaning WG decreased in temperamental calves. Based on literature

Burrow (2001) reported zero (no association) genetic correlation between pre-weaning weight gain to temperament while Prayaga 2003 reported close to zero (insignificant) genetic correlation (-0.01). These studies suggest no genetic association between weight gain and temperament which is different from the result of this study. These studies utilized tropical beef cattle breeds and crosses which are different from our study that utilized temperate breeds of cattle and crosses. Moreover, these studies utilized flight time as method of temperament evaluation which is not utilized in this study.

3.4.4.5. Genetic parameter estimates

Genetic parameter estimates and variances components of productive traits are presented in Appendix Tables A3.14-A3.17. Across all measures of temperament ABW, 205-d WW, pre-weaning ADG, and WG had ranged heritability estimates ($\hat{h}^2$) of 0.791 ± 0.065 to 0.811 ± 0.064, 0.794 ± 0.066 to 0.811 ± 0.065, 0.070 ± 0.008 to 0.073 ± 0.008, and 0.773 ± 0.068 to 0.792 ± 0.067 respectively. Adjusted BW, 205-d WW, and WG had high heritability estimates while pre-weaning ADG had low heritability estimates. Results of these study were high based on ABW, 205-d WW, and WG while low for pre-weaning ADG. Heritability estimates varies from one population to another but for discussion estimates for heritability from literature were included. Heritability estimates using animal models were found to range from 0.25 to 0.59, 0.10 to 0.5, and 0.00 to 0.48 for BW, WW, and ADG respectively (Dadi, et al., 2004) and 0.16 to 0.38 for WG (Caetano et al., 2013).

3.4.5. Effect of beef cattle temperament on reproductive traits

Effect of calf temperament per category on HPG, CS, and WS are presented in Tables 3.12 to 3.16. We found association between calf temperament on HPG, CS, and WS. The effects of primary breed, and year of birth, HPG, CS, WS are presented in Appendix Tables A3.18 and A3.23. Year of birth and primary breed had significant effect on HPG, CS, and WS.

Table 3.12. Least squares means and standard errors for calf docility score (DS) and temperament score (TS) effect on heifer pregnancy (HPG), calving success (CS), and weaning success (WS)[1].

Method	**Dam Reproductive Traits**					
	HPG	**N**	**CS**	**N**	**WS**	**N**
DS[2]	**P-value = 0.284**		**P-value = 0.657**		**P-value = 0.907**	
1	0.86 ± 0.03	233	0.86 ± 0.04	178	1.00 ± 0.12	138
2	0.83 ± 0.04	177	0.87 ± 0.04	147	1.00 ± 0.21	112
3	0.97 ± 0.04	16	0.96 ± 0.05	15	1.00 ± 0.00	14
4	0.76 ± 0.21	5	1.00 ± 0.50	3	1.00 ± 0.00	3
5	-	-	-	-	-	-
6	-	-	-	-	-	-
TS[3]	**P-value = 0.680**		**P-value = 0.952**		**P-value = 0.990**	
1	0.87 ± 0.03	170	0.86 ± 0.04	141	1.00 ± 0.15	112
2	0.84 ± 0.04	206	0.87 ± 0.04	161	1.00 ± 0.14	123
4	0.83 ± 0.05	53	0.89 ± 0.05	40	1.00 ± 0.46	31
5	0.70 ± 0.28	2	1.00 ± 0.50	1	1.00 ± 0.50	1

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed year, random effect of animal with known pedigree, and breeding age as covariate.
[2]Docility score: scale of 1 to 6 with 1 = docile and 6 = very aggressive.
[3]Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence, and tries to attack the observer.
[abc]Superscripts within a column and a given scoring method that are different, differ ($P < 0.05$). "-" indicates no data.

Table 3.13. Least squares means and standard errors for calf positive Qualitative Behavior Assessment (QBA) attributes effect on heifer pregnancy (HPG), calving success (CS), and weaning success (WS)[1].

Positive QBA	Dam Reproductive Traits					
	HPG	N	CS	N	WS	N
Apathetic	**P-value = 0.833**		**P-value = 0.531**		**P-value = 0.940**	
1	0.86 ± 0.03	223	0.87 ± 0.04	163	1.00 ± 0.04	118
2	0.84 ± 0.04	162	0.85 ± 0.04	145	1.00 ± 0.20	117
3	0.85 ± 0.07	37	0.96 ± 0.04	30	1.00 ± 0.50	28
4	0.76 ± 0.13	9	0.91 ± 0.13	5	1.00 ± 0.50	4
Calm	**P-value = 0.973**		**P-value = 0.833**		**P-value = 0.886**	
1	0.84 ± 0.05	80	0.87 ± 0.05	61	1.00 ± 0.37	44
2	0.85 ± 0.04	124	0.85 ± 0.05	97	1.00 ± 0.15	63
3	0.85 ± 0.04	149	0.88 ± 0.04	120	1.00 ± 0.13	105
4	0.84 ± 0.05	78	0.86 ± 0.05	65	1.00 ± 0.08	55
Curious	**P-value = 0.215**		**P-value = 0.521**		**P-value = 0.936**	
1	0.83 ± 0.04	265	0.89 ± 0.04	203	1.00 ± 0.14	146
2	0.89 ± 0.03	148	0.84 ± 0.05	124	1.00 ± 0.21	106
3	0.77 ± 0.16	18	0.92 ± 0.11	16	1.00 ± 0.00	15
4	-	-	-	0	-	-
Happy	**P-value = 0.238**		**P-value = 0.818**		**P-value = 0.809**	
1	0.87 ± 0.03	285	0.85 ± 0.05	223	1.00 ± 0.42	154
2	0.79 ± 0.05	126	0.89 ± 0.05	102	1.00 ± 0.45	96
3	0.82 ± 0.13	20	0.92 ± 0.10	18	1.00 ± 0.48	17
4	-	-	-	-	-	-
Pos. occupied	**P-value = 0.220**		**P-value = 0.188**		**P-value = 0.989**	
1	0.86 ± 0.04	297	0.89 ± 0.04	227	1.00 ± 0.20	161
2	0.88 ± 0.04	125	0.86 ± 0.05	108	1.00 ± 0.21	99
3	0.42 ± 0.29	9	0.39 ± 0.27	8	1.00 ± 0.00	7
4	-	-	-	-	-	-
Relaxed	**P-value = 0.220**		**P-value = 0.790**		**P-value = 0.904**	
1	0.86 ± 0.04	78	0.86 ± 0.05	67	1.00 ± 0.40	45
2	0.82 ± 0.04	141	0.87 ± 0.04	102	1.00 ± 0.10	74
3	0.88 ± 0.03	159	0.85 ± 0.04	133	1.00 ± 0.14	111
4	0.80 ± 0.07	53	0.92 ± 0.05	41	1.00 ± 0.49	37

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed year, random effect of animal with known pedigree, and breeding age as covariate.

[2]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression.

[abc]Superscripts within a column and a given scoring method that are different, differ ($P < 0.05$). "-" indicates no data.

Table 3.14. Least squares means and standard errors calf negative Qualitative Behavior Assessment (QBA) attributes effect on heifer pregnancy (HPG), calving success (CS), and weaning success (WS)[1].

Negative QBA	Dam Reproductive Traits					
	HPG	N	CS	N	WS	N
Active	**P-value = 0.557**		**P-value = 0.535**		**P-value = 0.938**	
1	0.85 ± 0.05	85	0.88 ± 0.03	69	1.00 ± 0.33	55
2	0.86 ± 0.03	211	0.87 ± 0.04	172	1.00 ± 0.14	144
3	0.84 ± 0.04	122	0.67 ± 0.16	94	1.00 ± 0.18	63
4	0.73 ± 0.12	13	1.00 ± 0.50	8	1.00 ± 0.50	5
Agitated	**P-value = 0.189**		**P-value = 0.396**		**P-value = 0.974**	
1	0.85 ± 0.03	312	0.88 ± 0.03	247	1.00 ± 0.13	198
2	0.86 ± 0.04	100	0.87 ± 0.04	84	1.00 ± 0.17	62
3	0.65 ± 0.12	17	0.67 ± 0.16	10	1.00 ± 0.50	5
4	1.00 ± 0.50	2	1.00 ± 0.50	2	1.00 ± 0.50	2
Attentive	**P-value = 0.524**		**P-value = 0.796**		**P-value = 0.966**	
1	0.85 ± 0.04	95	0.94 ± 0.03	69	1.00 ± 0.49	53
2	0.87 ± 0.03	234	0.85 ± 0.04	192	1.00 ± 0.06	140
3	0.80 ± 0.05	101	0.86 ± 0.06	81	1.00 ± 0.05	73
4	1.00 ± 0.50	1	1.00 ± 0.50	1	1.00 ± 0.00	1
Distressed	**P-value = 0.465**		**P-value = 0.796**		**P-value = 0.835**	
1	0.85 ± 0.03	403	0.87 ± 0.03	321	1.00 ± 0.17	249
2	0.80 ± 0.08	28	0.91 ± 0.06	21	1.00 ± 0.00	18
3	-	-	-	-	-	-
4	-	-	-	-	-	-
Fearful	**P-value = 0.629**		**P-value = 0.283**		**P-value = 0.929**	
1	0.85 ± 0.03	328	0.86 ± 0.04	269	1.00 ± 0.13	213
2	0.85 ± 0.04	87	0.87 ± 0.05	64	1.00 ± 0.34	45
3	0.77 ± 0.10	16	0.97 ± 0.03	10	1.00 ± 0.50	9
4			-	-	-	-
Irritated	**P-value = 0.586**		**P-value = 0.513**		**P-value = 0.980**	
1	0.85 ± 0.03	344	0.86 ± 0.04	277	1.00 ± 0.13	211
2	0.87 ± 0.04	71	0.92 ± 0.04	56	1.00 ± 0.34	48
3	0.74 ± 0.11	15	0.87 ± 0.10	9	1.00 ± 0.50	7
4	1.00 ± 0.50	1	1.00 ± 0.50	1	1.00 ± 0.00	1

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed year, random effect of animal with known pedigree, and breeding age as covariate.

[2]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression.

[abc]Superscripts within a column and a given scoring method that are different, differ ($P < 0.05$). "-" indicates no data.

Table 3.15. Least squares means and standard errors calf temperament index effect on heifer pregnancy (HPG), calving success (CS), and weaning success (WS)[1].

Method	**Dam Reproductive Traits**					
	HPG	**N**	**CS**	**N**	**WS**	**N**
TI	**P-value =** 0.925		**P-value =** 0.930		**P-value =** 0.336	
1	0.86 ± 0.04	125	0.87 ± 0.04	97	1.00 ± 0.21	71
2	0.85 ± 0.04	105	0.85 ± 0.05	84	1.00 ± 0.09	62
3	0.84 ± 0.04	103	0.87 ± 0.04	81	1.00 ± 0.05	63
4	0.83 ± 0.05	98	0.89 ± 0.04	81	1.00 ± 0.03	71
TI Positive	**P-value =** 0.760		**P-value =** 0.490		**P-value =** 0.915	
1	0.83 ± 0.04	118	0.88 ± 0.04	89	1.00 ± 0.14	63
2	0.84 ± 0.04	118	0.82 ± 0.06	92	1.00 ± 0.13	64
3	0.88 ± 0.04	97	0.87 ± 0.04	85	1.00 ± 0.09	70
4	0.84 ± 0.05	98	0.90 ± 0.04	77	1.00 ± 0.15	70
TI Negative	**P-value =** 0.603		**P-value =** 0.977		**P-value =** 0.740	
1	0.86 ± 0.04	102	0.87 ± 0.05	80	1.00 ± 0.17	63
2	0.87 ± 0.04	114	0.86 ± 0.05	94	1.00 ± 0.05	73
3	0.81 ± 0.05	104	0.87 ± 0.05	79	1.00 ± 0.09	61
4	0.85 ± 0.04	111	0.88 ± 0.04	90	1.00 ± 0.08	70

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed year, random effect of animal with known pedigree, and breeding age as covariate.

[2]Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

[abc]Superscripts within a column and a given scoring method that are different, differ ($P < 0.05$). "-" indicates no data.

Table 3.16. Least squares means and standard errors for calf four flatform standing scale (SSD) and coefficient of variation of SDD (CVSSD) data effect on heifer pregnancy (HPG), calving success (CS), and weaning success (WS)[1].

Method	Dam Reproductive Traits					
	HPG	N	CS	N	WS	N
SSD	**P-value = 0.885**		**P-value = 0.631**		**P-value = 0.793**	
1	0.85 ± 0.04	122	0.90 ± 0.04	104	1.00 ± 0.10	79
2	0.83 ± 0.04	105	0.87 ± 0.04	81	1.00 ± 0.15	64
3	0.86 ± 0.04	116	0.87 ± 0.04	91	1.00 ± 0.13	69
4	0.85 ± 0.04	88	0.83 ± 0.06	67	1.00 ± 0.21	55
CVSSD	**P-value = 0.606**		**P-value = 0.436**		**P-value = 0.793**	
1	0.86 ± 0.04	129	0.91 ± 0.03	105	1.00 ± 0.09	83
2	0.83 ± 0.04	106	0.88 ± 0.04	83	1.00 ± 0.14	67
3	0.87 ± 0.04	115	0.85 ± 0.05	94	1.00 ± 0.13	67
4	0.83 ± 0.05	81	0.87 ± 0.05	61	1.00 ± 0.18	50

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed year, random effect of animal with known pedigree, and breeding age as covariate.

[2]SSD: standard deviation of total weight over time recorded by four-platform standing scale, CVSSD: coefficient of variation based on the SSD.

[abc]Superscripts within a column and a given scoring method that are different, differ ($P < 0.05$). “-” indicates no data.

3.4.5.1. Heifer pregnancy

None of the measures of temperament had significant effect on HPG. This means that there were no significant association of temperament on HPG based on the results of the study. However, when looking the pattern of least square means (LSMeans) decreased likelihood of heifer pregnancy were found in calves that were temperamental. These were true to TS, negative QBA, TI, negative TI, SSD and CVSSD. Most literature had found significant association of beef cattle temperament on pregnancy. Possible reasons were due to the age during temperament evaluation, method of temperament evaluation and nature of temperament of the calves in the study. In a study by Cooke et al. (2017), Nellore cows were evaluated using chute and exit scores and found that cows that were temperamental had decreased pregnancy rates. The method used in this study was similar to docility score, however, exit score was not used in this study. Also, Nellore breed of cows were used which is a *Bos indicus* breed with more variation in temperament as compared to *Bos taurus* (Angus and Hereford based calves) breed used in this study. Furthermore, temperament evaluation was done at weaning age in this study while in the study of Cooke et al. (2017) lactating and multiparous cows were used for temperament evaluation. Kasimanickam et al. (2014), used Angus beef cattle to determine effect of temperament on pregnancy rate and found significant results. However, exit score was used which in this current study did not utilized. Furthermore, the overall temperament of calves in this study were calm and few had increased temperament scores (Table 3.5). For example, DS is a scale of 1 to 6 with a score of 6 equal to very aggressive temperament. No evaluator had scored 5 and 6 in this study and very few calves had score of 3 (76) and 4 (12) which were 4.93% and 0.78% of the total calves. For TS, very calves also had score of 4 (210) and 5 (7) and these were true also to other measures like negative QBA attributes, TI, SSD, and CVSDD with very few calves had 3 and 4 scores.

3.4.5.2. Calving success

Similar to HPG, none of the measures of temperament had significant effect on CS. This means that there was no significant relationship of temperament on CS based on the results of the study. In a study by Cooke et al. (2012) using *Bos taurus* cows, cow temperament had no effect on pregnancy loss. In this study no significant difference was also found however, there were also factors that may contribute to non-significant result. Similar to HPG, these factors can be the overall temperament of the cattle in this study which is calm. There were very few cattle had aggressive temperament. In fact, using DS, there were no cattle that had score of 5 and 6 which means aggressive and very aggressive temperament and still very few cattle had score of 3 and 4 (Table 3.5). In temperament measures that had even sample size distribution (SSD, CVSSD) there was a decreased likelihood on calving success to temperamental cattle. Increased SSD and CVSSD scores mean increased in temperament and there were also decreasing pattern of calving success. However, there were no significant difference statistically.

3.4.5.3. Weaning success

Temperament had no significant effect on weaning success across all measures of temperament. Similar to HPG and CS, there was an unbalanced sample size distribution based on temperament scores of the calves. For DS, there was no calf that had 5 or 6 score and very few calves had score of 3 and 4. Most of the calved had scores of 1 and 2 across all measures of temperament in this study including positive QBAs except TI, TI+, TI-, SSD, and CVSSD with even distribution of sample size based on temperament scores. These unbalanced distributions may skew the results of statistical analysis. Furthermore, most of the calves had calm temperament with scores of 1 and 2 for DS, TS, Negative QBAs, and 3 and 4 for positive QBAs. These score distributions indicated that the calves used in these were generally calm and do not have much variation to give better resolution of the effect of different temperament on dam reproductive traits.

3.4.5.4. Reproductive success

Effect of temperament using different methods of beef cattle temperament evaluation on RS are presented in Figures 3.3 to 3.21. Data were in percentages wherein increased in percentage means increased success. Result of this study suggested that temperament had no effect on reproductive success. Factor that may contribute to this was similar to other dam reproductive traits which were due to uneven distribution of sample size due to nature of calf temperament in this study.

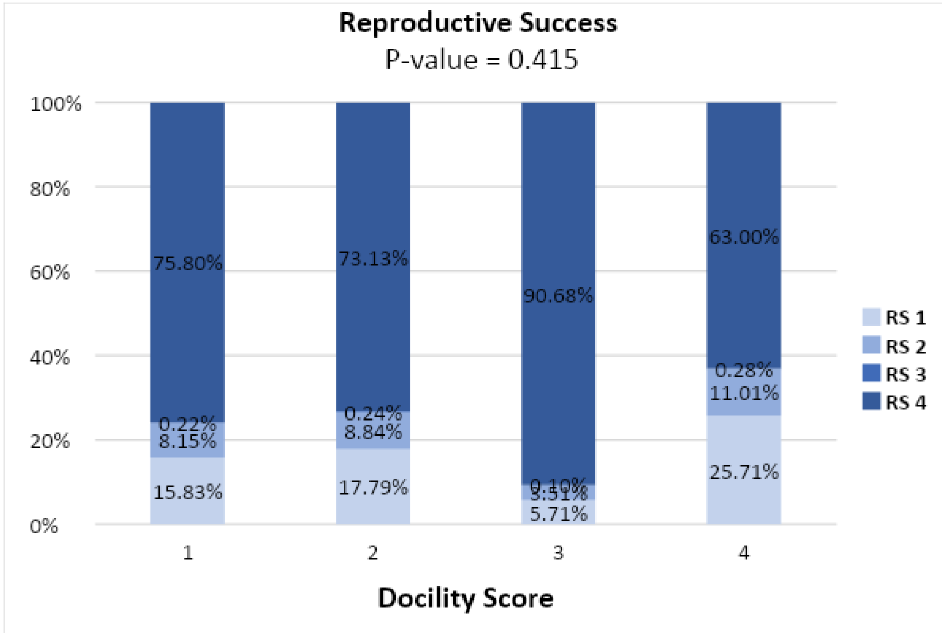


Figure 3.3. Stacked bar graph illustrating relationship of docility score on heifer reproductive success. For each docility score, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* ≤ 0.05 is significant.

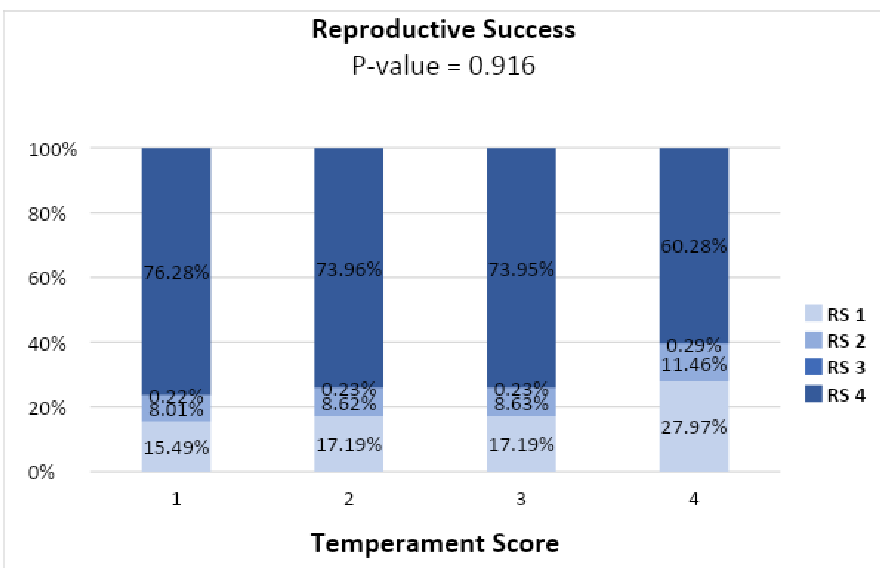


Figure 3.4. Stacked bar graph illustrating relationship of temperament score on heifer reproductive success. For each temperament score, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* ≤ 0.05 is significant.

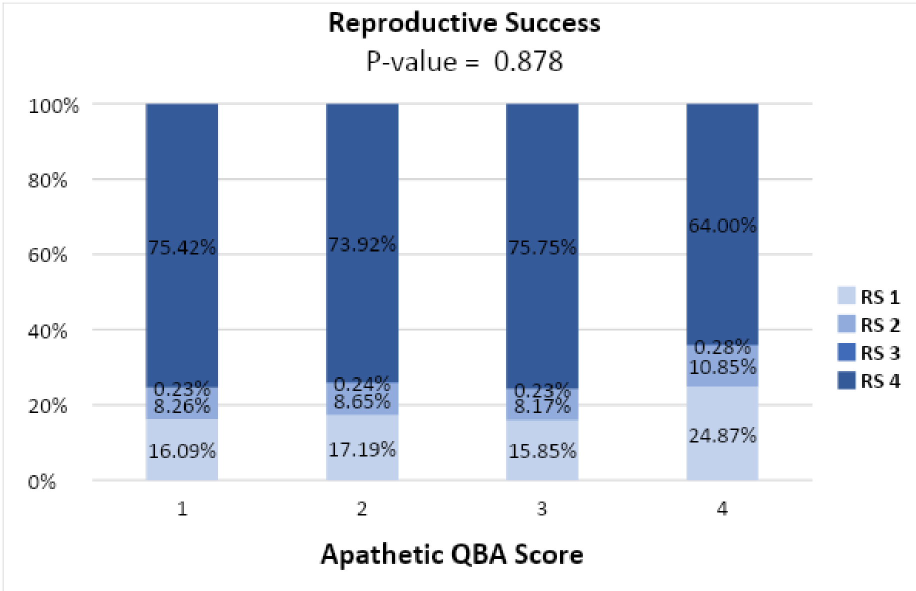


Figure 3.5. Stacked bar graph illustrating relationship of apathetic qualitative behavior score on heifer reproductive success. For each apathetic qualitative behavior score, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* ≤ 0.05 is significant.

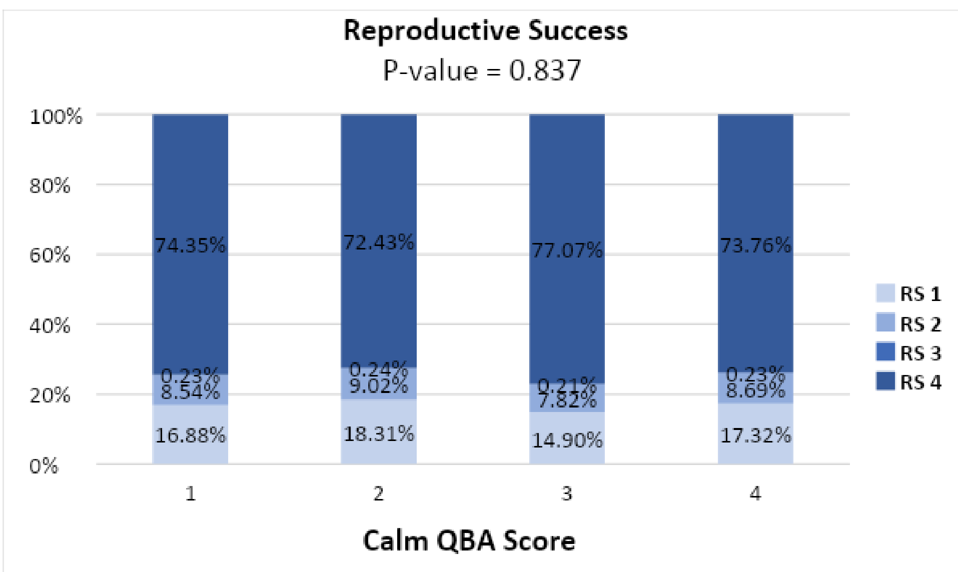


Figure 3.6. Stacked bar graph illustrating relationship of calm qualitative behavior score on heifer reproductive success. For each calm qualitative behavior, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* ≤ 0.05 is significant.

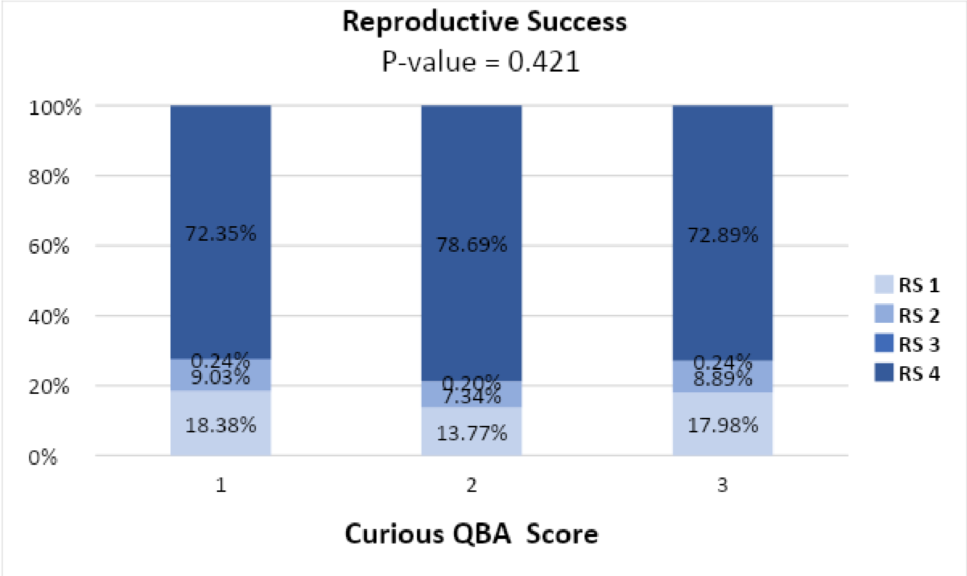


Figure 3.7. Stacked bar graph illustrating relationship of curious qualitative behavior score on heifer reproductive success. For each of curious qualitative behavior, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* ≤ 0.05 is significant.

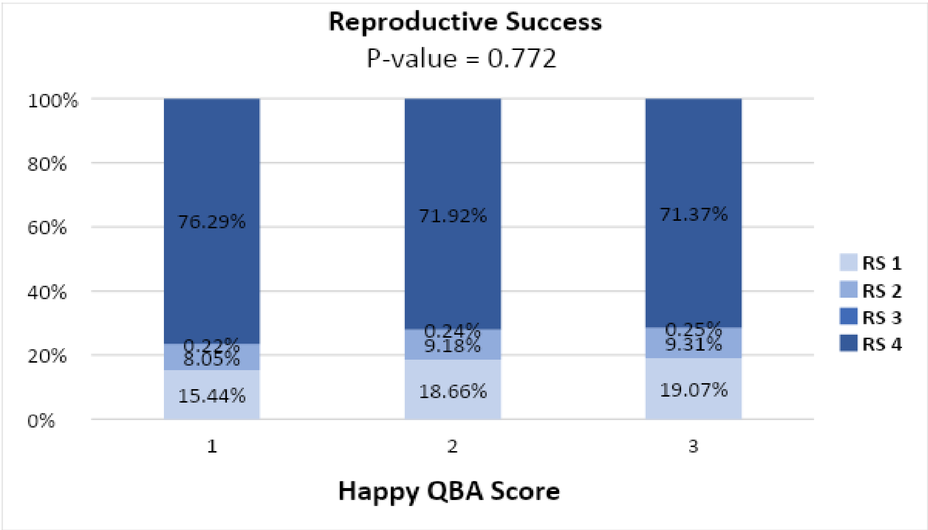


Figure 3.8. Stacked bar graph illustrating relationship of happy qualitative behavior score on heifer reproductive success. For happy qualitative behavior score, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* ≤ 0.05 is significant.

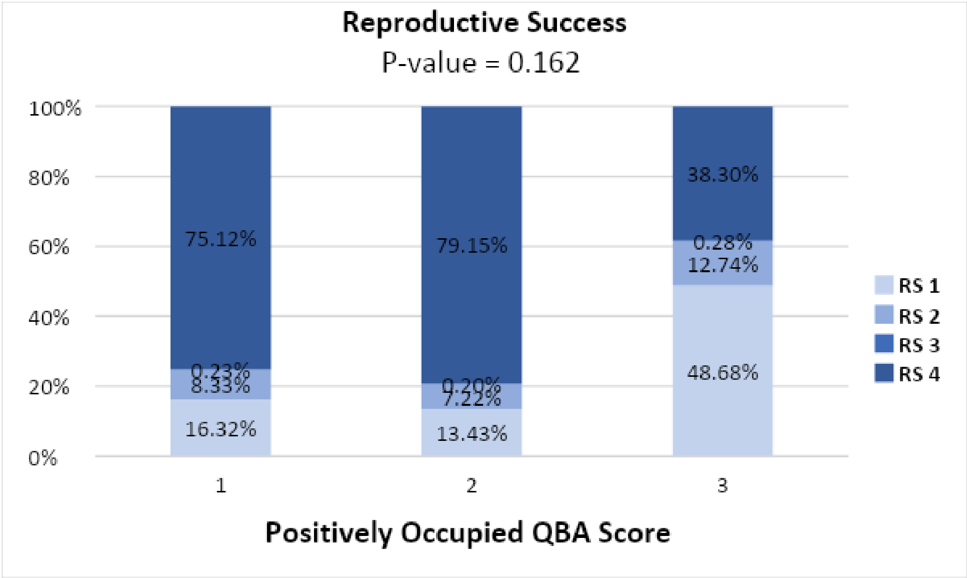


Figure 3.9. Stacked bar graph illustrating relationship of positively qualitative behavior score on heifer reproductive success. For each positively qualitative behavior score, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* ≤ 0.05 is significant.

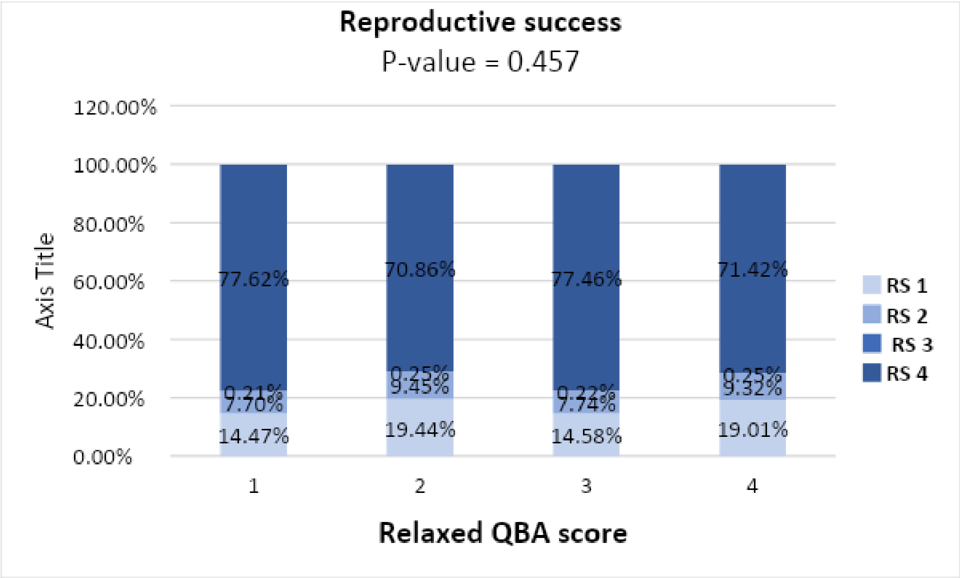


Figure 3.10. Stacked bar graph illustrating relationship of relaxed qualitative behavior score on heifer reproductive success. For each positively qualitative behavior score, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* ≤ 0.05 is significant.

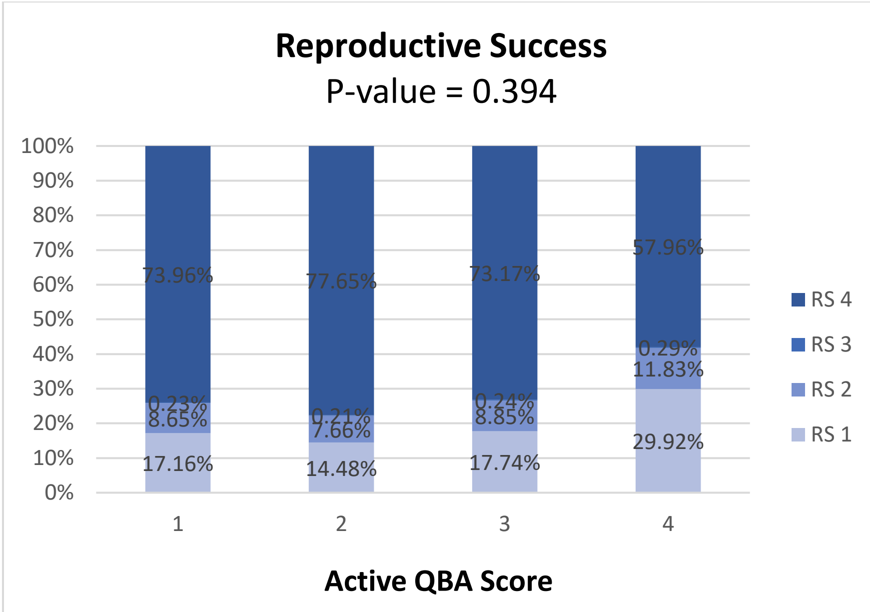


Figure 3.11. Stacked bar graph illustrating relationship of active qualitative behavior score on heifer reproductive success. For each active qualitative behavior score, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* ≤ 0.05 is significant.

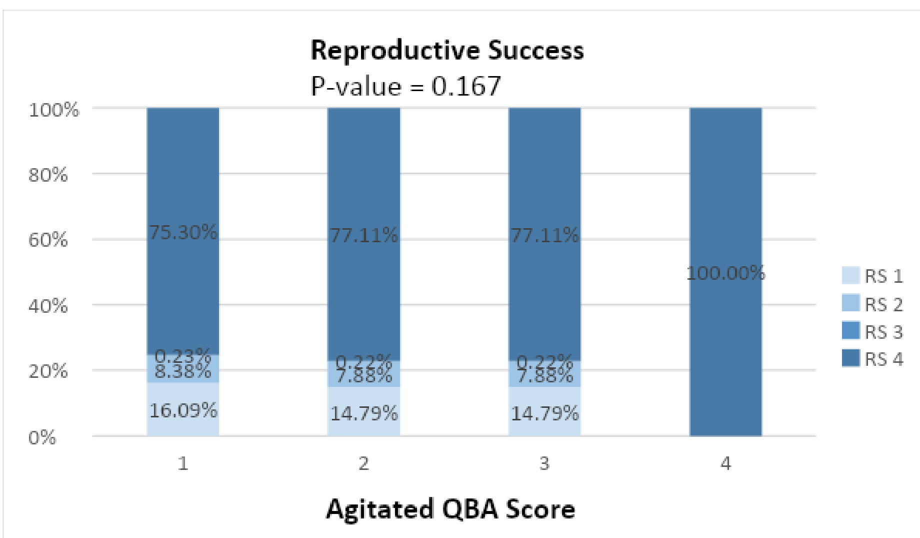


Figure 3.12. Stacked bar graph illustrating relationship to agitated qualitative behavior score on heifer reproductive success. For each agitated qualitative behavior score, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* ≤ 0.05 is significant.

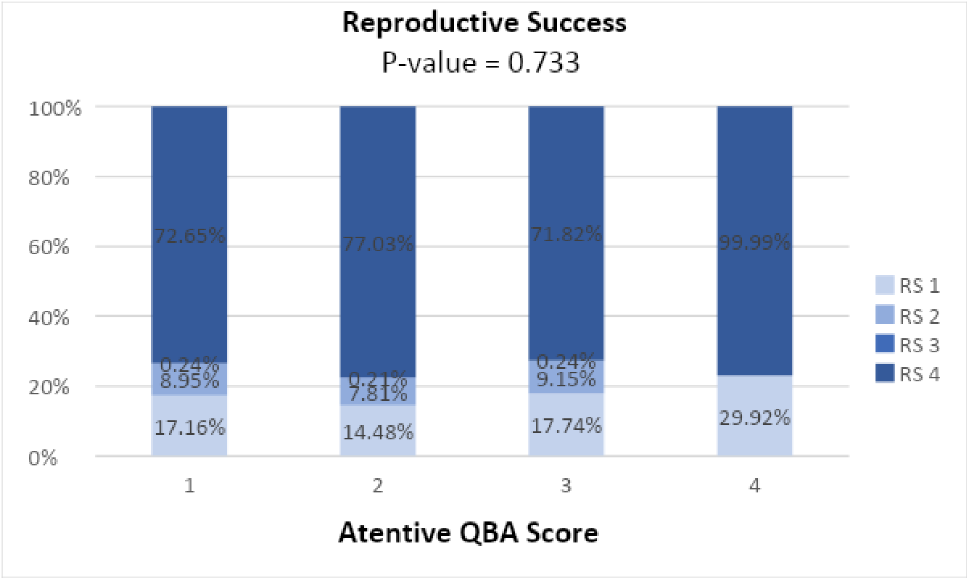


Figure 3.13. Stacked bar graph illustrating relationship of attentive qualitative behavior score on heifer reproductive success. For each attentive qualitative behavior score, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* ≤ 0.05 is significant.

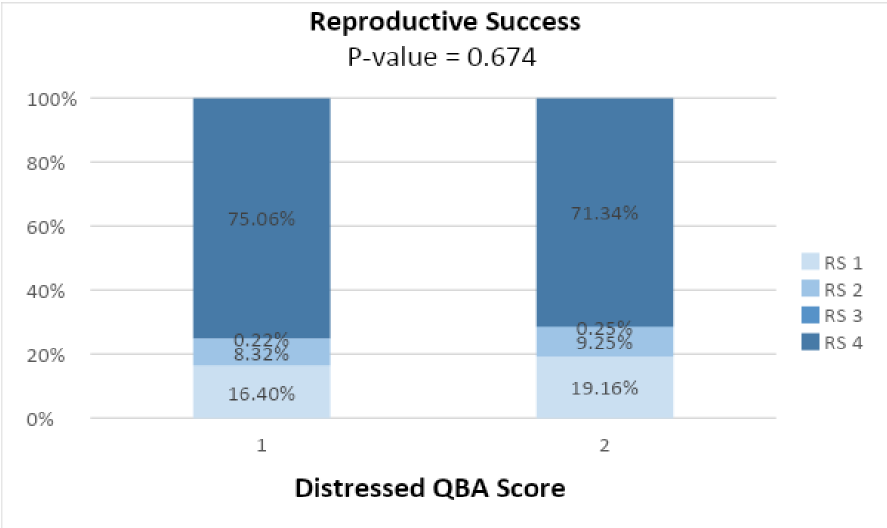


Figure 3.14. Stacked bar graph illustrating relationship of distressed qualitative behavior score on heifer reproductive success. For each distressed qualitative behavior score, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* ≤ 0.05 is significant.

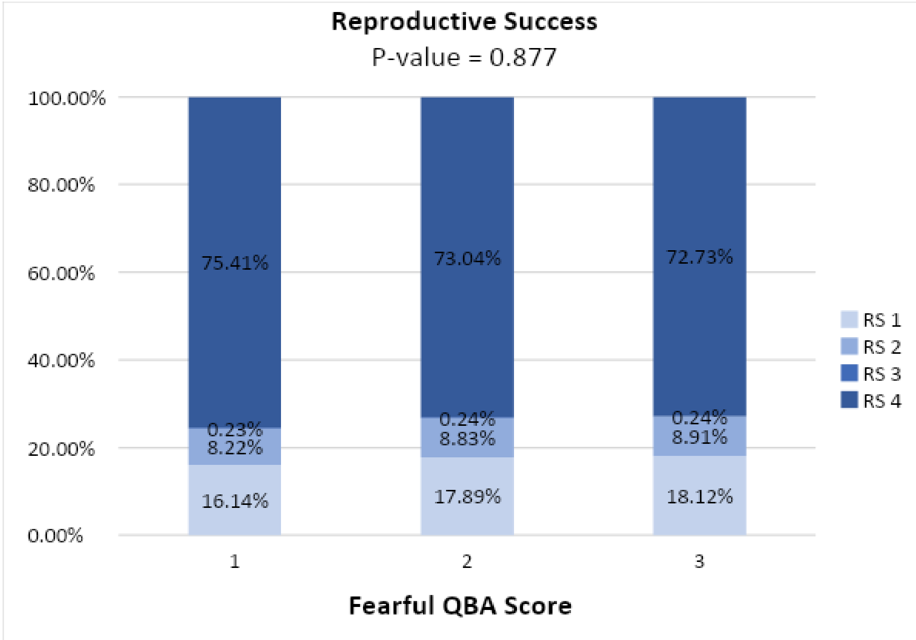


Figure 3.15. Stacked bar graph illustrating relationship of fearful qualitative behavior score on heifer reproductive success. For each fearful qualitative behavior score, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* ≤ 0.05 is significant.

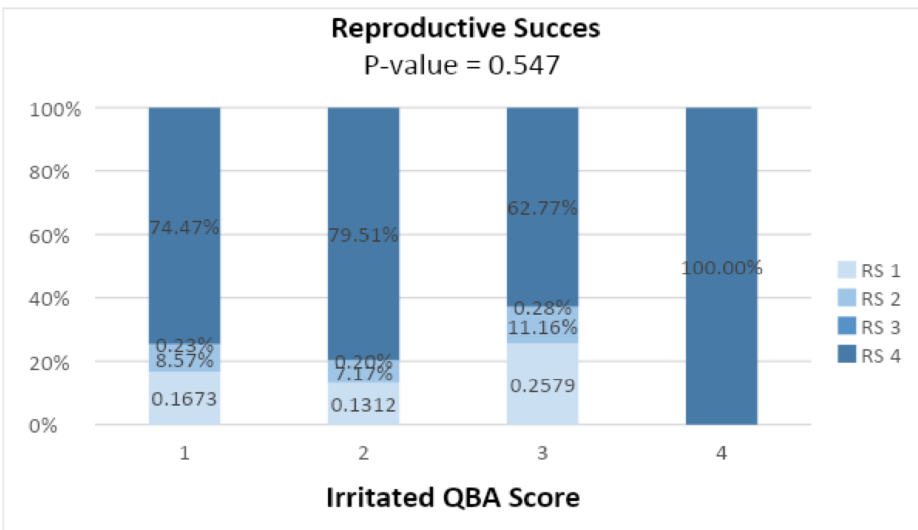


Figure 3.16. Stacked bar graph illustrating relationship of irritated qualitative behavior score on heifer reproductive success. For each irritated qualitative behavior score, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* ≤ 0.05 is significant.

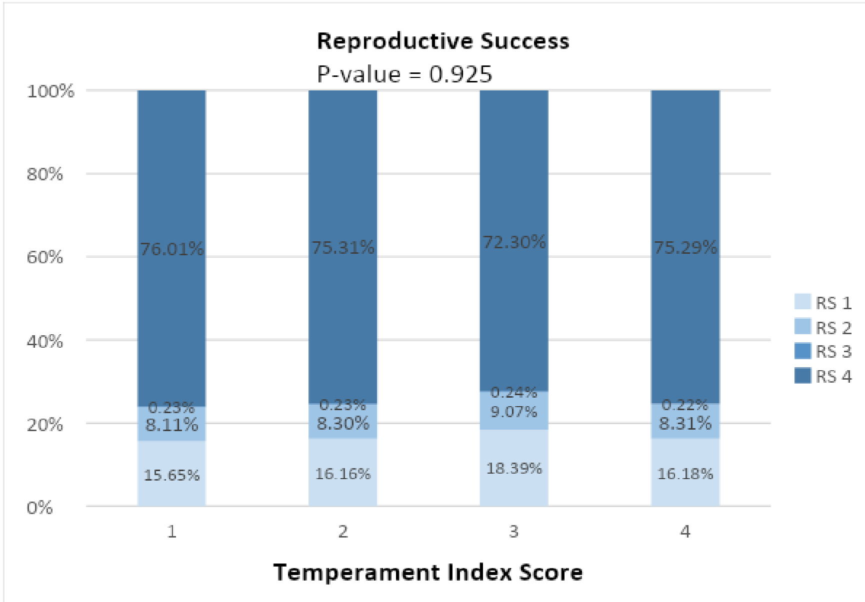


Figure 3.17. Stacked bar graph illustrating relationship of temperament index score on heifer reproductive success. For each temperament index score, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* $\leq$ 0.05 is significant.

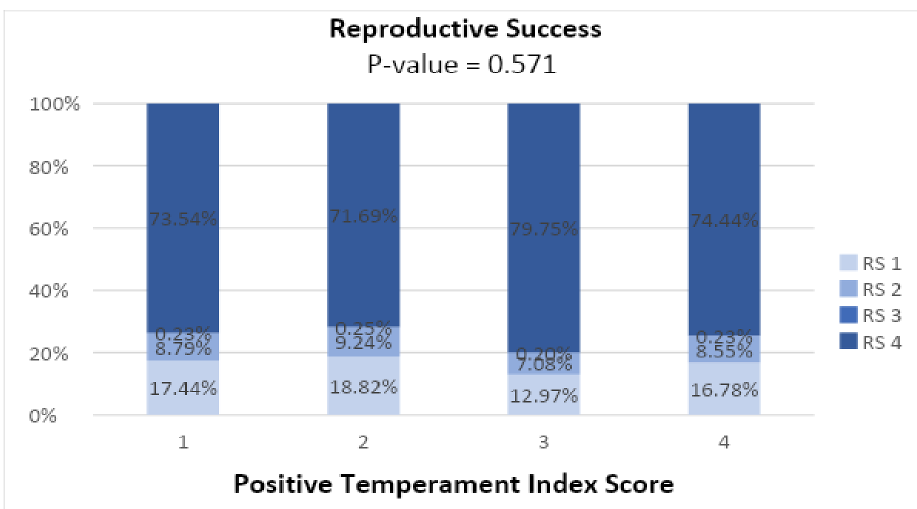


Figure 3.18. Stacked bar graph illustrating relationship of positive temperament index score on heifer reproductive success. For each positive temperament index score, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* $\leq$ 0.05 is significant.

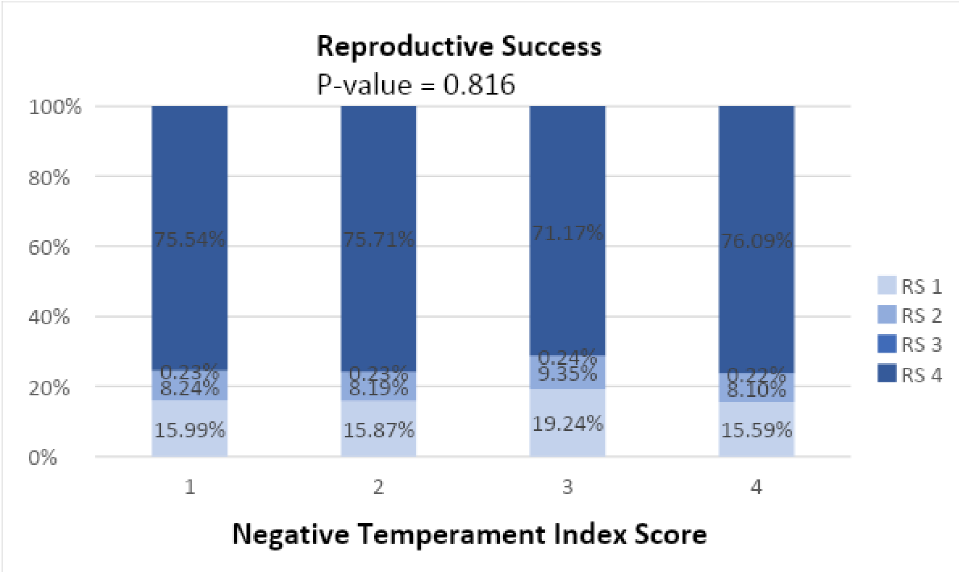


Figure 3.19. Stacked bar graph illustrating relationship of negative temperament index heifer on reproductive success. For each docility score, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* ≤ 0.05 is significant.

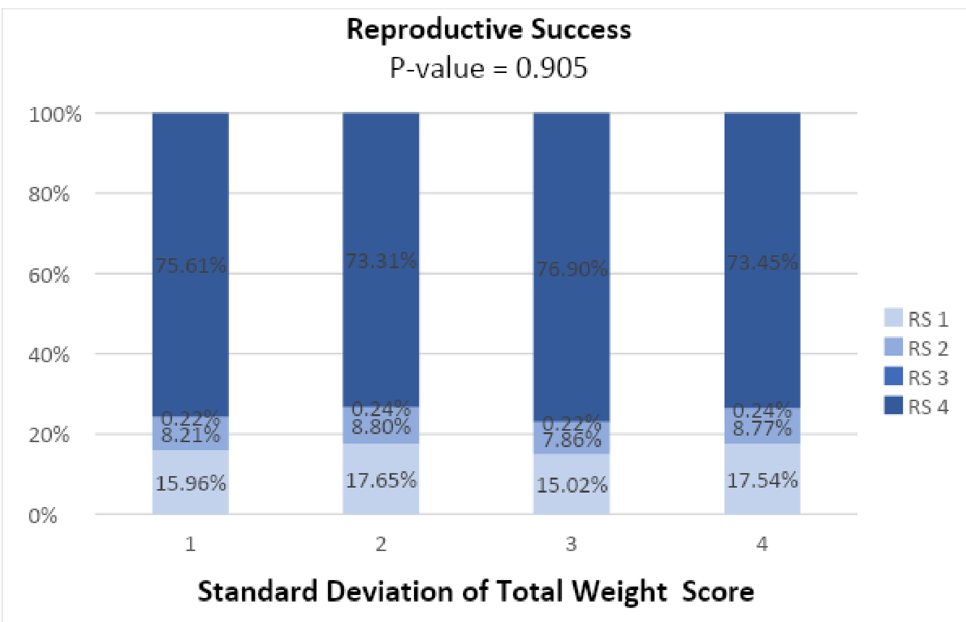


Figure 3.20. Stacked bar graph illustrating relationship of standard deviation of total weight score on heifer reproductive success. For each standard deviation of total weight score, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* ≤ 0.05 is significant.

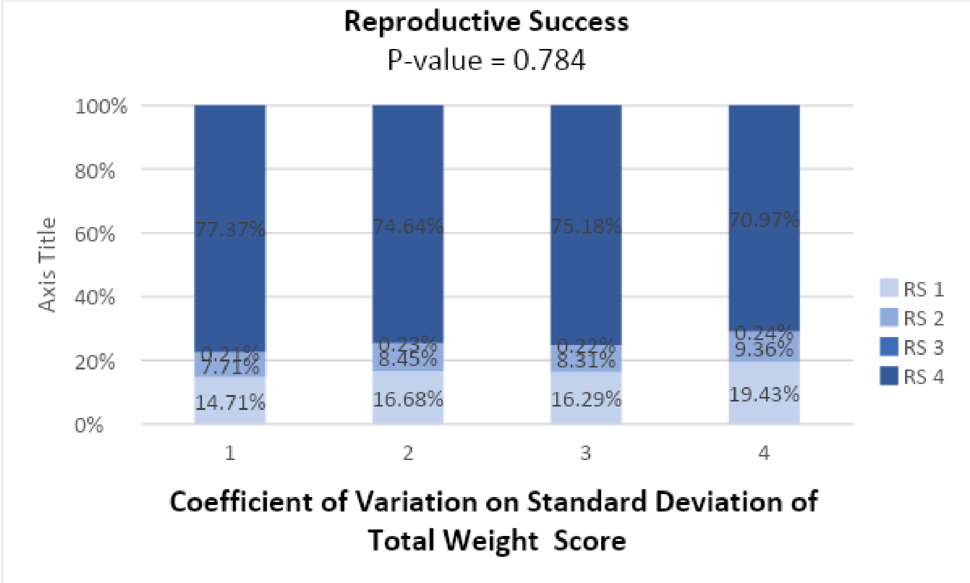


Figure 3.21. Stacked bar graph illustrating relationship of coefficient of variation of standard deviation of total weight (CVSSD) score on heifer reproductive success. For each docility score, the percent of reaching that reproductive success is indicated based on levels of: being open or not pregnant (RS 1), being pregnant but did not calve (2), being pregnant, having the calf, but fails to wean (RS 3), and being pregnant, having the calf, and successfully weaning the calf (RS 4). *P-value* $\leq$ 0.05 is significant.

3.4.5.5. Genetic parameter estimates

Genetic parameter and variance components estimates are presented for dam reproductive traits were presented in Appendix Tables A3.25 to A3.29. Across all measures of temperament HPG, CS, WS, and RS had ranged heritability estimates ($\hat{h}^2$) of 0.003 ± 0.159 to 0.040 ± 0.152, 0.000 to 0.442 ± 0.130, 0.014 ± 1.605 to 0.263 ± 0.673, and 0.000 ± 0.000 to 0.148 ± 0.101 respectively. Based on the literature, heifer pregnancy ranged from 0.00 to 0.20 (Evans et al., 1999) while other authors have higher estimates. Doyle et al. (2000) estimated heritability for heifer pregnancy that ranged from 0.20 to 0.30. Calving success heritability estimates ranged from 0.05 to 0.10 (Mayer et al., 1990) while limited literature were found for WS and RS. Results of these study were comparable to literature regarding heritability estimates of dam reproductive traits.

3.5. Conclusion

In conclusion, temperament had an effect on calf productive traits. Significant effects of temperament on adjusted calf birth weight (ABW), adjusted 205 weaning weight (205-d WW), pre-weaning ADG, and weight gain (WG) is observed in this study. Therefore, selection on calmer temperament cattle has favorable effect on production traits. However, due to low genetic correlations in majority of our models, calf temperament may not have association with ABW, 205-d WW, pre-wean ADG, and WG. This findings is different from literature and possible reasons are: (1) most of these studies evaluated productivity from feedlot to finishing where more handling, and human contact or interaction takes place; (2) before weaning, calf performance mainly is affected my maternal dam effect and response to human handling and interaction were minimal to elicit change in behavioral response that may affect these productive traits; and (3) majority of the calves in this study had calm temperament meaning less variation in temperament. Further studies to confirm our results based on these reasons is recommended.

4. INFLUENCE OF DAM TEMPERAMENT AT WEANING AND SIRE DOCILITY EXPECTED PROGENY DIFFERENCE (EPD) ON CALF PERFORMANCE

4.1. Abstract

The general objective of this study was to the influence of cow temperament at weaning age and sire docility expected progeny difference (EPD) on calf adjusted birth weight (ABW), adjusted 205 weaning weight (205-d WW), weaning average daily gain (ADG), and weight gain (WG). Two hundred ninety (290) Angus or Hereford based cows were scored for multiple temperament measures at weaning. These cows produced 518 calves were available for use in this study. Dam temperament was evaluated at weaning using docility score (DS) Beef Improvement Federation (BIF, 2018), temperament score (TS) (BIF, 2018), qualitative behavioral assessment (QBA) (Sant'Anna and Paranhos da Costa, 2013), temperament indexes (TI, TI positive, TI negative), Four Flatform Standing Scale (FFSS) data to produce standard deviation of weight over time (SSD), and coefficient of variation of SSD (CVSSD). Sire temperament was based off docility expected progeny difference (EPD) quartile ranking from breed associations where the sire was registered. Calf performance traits included calf adjusted birth weight (ABW), adjusted 205 weaning weights (205-d WW), pre-weaning average daily gain (ADG), and weight gain (WG). Calf ABW were based on adjusted factors based on age of dam and sex of calf while WW 205-d WW is based on adjusted 205 weaning weight following BIF (2018) equation. The final models for calf performance traits were determined using SAS software (SAS Institute, Cary, NC, USA). For each trait (ABW, 205-d WW, ADG, and WG) dam temperament, sire docility EPD, systematic environmental fixed effects of primary breed, year, sex, and interactions were tested. The final model included dam temperament, sire docility EPD, year, sex, random effect of calf and maternal

effect of dam for ABW, 205-d WW, Pre-weaning ADG, and WG. Result of the analysis showed significant effect of dam on calf 205-d WW, ADG, and WG. However, Sire docility EPD also had no significant effect on calf performance. Therefore, selection of dam with calm temperament at weaning will improve calf productive traits.

4.2. Introduction

Beef cattle temperament is considered economically relevant trait in cattle because of its effects on human safety, animal welfare, longevity of farm facilities, and most importantly its influence on productivity, reproductive performance, health, meat quality, and profitability (Golden et al., 2000; Weary et al., 2009; and Norris et al., 2014). Cattle that are calm during handling have higher average daily gain (Burrow and Dillon, 1997; Voisinet et al., 1997, and Sant'Anna et al., 2014), improved feed efficiency (Nkrumah et al., 2007), increased reproductive performance (Cooke et al., 2012; and Kasimanickam, R. 2014), and increased immune function (Fell et al., 1999; and Oliphint, 2003) compared to cattle with poor temperament. Excitable cattle produced tougher meat, higher incidences of borderline dark cutters (Voisinet et al., 1997), lower marbling scores and hot carcass weights than cattle with calm temperament (Gardner et al., 1999). Furthermore, our previous study showed that productive traits (ABW, 205-d WW, ADG, WG) are associated with negatively with temperament. Lastly, cattle with aggressive temperament are more likely to injure animal handlers during routine management practices (Grandin, 1989) and in terms of profitability, Busby et al. (2005) reported that docile calves returned $62.19 per head more than aggressive calves.

Given that beef cattle temperament has a favorable effect, there is a growing interest in selection for temperament in beef cattle. In the United States, some breed associations like the American Angus Association, Northern American Limousin Foundation, and American

Simmental Association have incorporated docility expected progeny differences (EPD) in their selection programs. Heritability estimates for beef cattle temperament has been found to be low to moderately heritable (Haskell et al., 2014) therefore can be improved through selection. Phenotypic and genetic correlations of temperament to feedlot performance, meat quality, ease of transport, and some reproductive traits were established (Nkrumah et al., 2007; Norris et al., 2014) and therefore selection to improve beef cattle temperament will also lead to genetic improvements in these traits (Norris et al., 2014).

Most studies on beef cattle temperament focused on association or effect on its own performance and limited studies have been conducted on maternal and paternal genetic influence of beef cattle temperament on progeny performance. Maternal and paternal genetic effects account for genes in the dam and sire that influence phenotype of the offspring (Beckman et al., 2007). Non-genetic influence by the dam are the uterine environment and nourishment, for example, that affects offspring phenotype. In livestock species, it is established that dam has an influence on birth weight and weaning weight (Burfening and Kress, 1993; Eler et al., 1995; Franke et al., 2001). Likewise, dam and sire temperament may influence offspring productive traits and temperament. In this study, we hypothesized that sire and dam temperament influence offspring performance and temperament through the genes and non-genetic influence of the dam to offspring. Therefore, the objective of this study was to determine the influence of cow temperament at weaning and sire docility EPD rank on calf birth weight (BW), weaning weight (WW), weaning average daily gain (ADG), and weight gain to weaning (WG).

4.3. Materials and methods

4.3.1. Animals

All cattle were managed according to the Federation of Animal Science Societies Guide for the Care and Use of Agricultural Animals in Agriculture Research and Teaching (FASS, 2010). All procedures were reviewed and approved by the Institutional Animal Care and Use Committee of North Dakota State University.

Two hundred eighty-nine (289) cows were used in this study. Cow temperament was evaluated at weaning over a four-year period (2014 to 2017; Year 1: n = 58, Year 2: n = 77, Year 3: n = 61 and Year 4: n = 93). Cows were produced at the North Dakota State University Central Grasslands Research Extension Center (CGREC), located approximately 14 km NW of Streeter, ND. The cow herd in which these cows were produced consisted of approximately 425 Angus and Hereford based females (mature cows and heifers) that are bred to either Angus, Hereford or Sim-Angus bulls and were raised in pasture.

4.3.2. Dam temperament evaluation

Temperament evaluation on cows was conducted using objective and subjective methods of beef cattle temperament evaluation. The objective method utilized Four Flatform Standing Scale (FFSS) data to produce standard deviation of weight over time (SSD) and coefficient of variation of SSD (CVSSD) as measure of temperament. Subjective methods used were docility score (DS) (BIF, 2018), temperament score (TS) (Sant'Anna and Paranhos da Costa, 2013), qualitative behavioral assessment (QBA) (Sant'Anna and Paranhos da Costa, 2013), and temperament indexes (TI, TI positive, TI negative). Details of these procedures and how temperament scores were grouped into categories were described in the materials and methods section of Chapter 2 and 3, respectively, of this dissertation. Using the average score per animal, each animal was assigned into a discrete category based on the original scale (DS, TS, and QBA) or quartile placement (TI, TI positive, TI negative), which is provided in Table 4.1.

Table 4.1. Description of criteria for assigning new categories for DS and TS[1].

Categorical Scores	DS	TS	QBA	TI, TI+, TI-, SSD, CVSSD
1	≤ 1.5	≤ 1.67	≤ 34	≤ Q1
2	> 1.5 to ≤ 2.5	> 1.67 to ≤ 2.67	> 34 to ≤ 68	> Q1 to ≤ Q2
3	> 2.5 to ≤ 3.5	-	> 68 to ≤ 102	> Q2 to ≤ Q3
4	> 3.5 to ≤ 4.5	> 2.67 to ≤ 3.67	>102	> Q3 to ≤ Q4
5	> 4.5 to ≤ 5.5	> 3.67	-	-
6	> 5.5	-	-	-

[1]DS: docility score, TS: temperament score, QBA: qualitative behavior attributes, TI: temperament index using 12 QBA attributes, TI+: TI using 6 positive QBA attributes, TI-: TI using 6 negative QBA attributes, SSD: standard deviation of the Four Flatform Standing Scale (FPSS) data (SSD), CVSSD: coefficient of variation of the SSD (CVSSD) "-" indicates not available.

4.3.3. Sire docility EPD

Sire docility EPD were obtained from American Angus and Simmental Associations, and ranked based on percentile ranking (accessed last November 10, 2020). Sires with percentile ranking of less than or equal to 25% were given a score of 1, while sires with percentile ranking of greater than 25% to less than or equal to 50%, greater than 50% to less than or equal to 75%, and greater than 75% to less than or equal to 100% were given a score of 2, 3, and 4, respectively. The American Hereford Association does not report sire docility EPD at the time of this study, therefore they were not included.

4.3.4. Calf performance

Data on calf performance over 4-year period (2016 to 2019) from the cows used in this study were obtained. Birth weights (BW) were recorded immediately after birth and assigned into management groups and raised with dams on pasture. At weaning, weaning weight (WW) were recorded using the built-in electronic scale of a Silencer Chute (Moly Manufacturing Inc., Lorraine, KS). Weaning ADG was calculated using the difference of adjusted birth weight and adjusted weaning weight divided by number of days at weaning. Weight gain at weaning (WG) was calculated using the difference of adjusted birth weight and adjusted weaning weight. Birth weights used in this study were adjusted based on age of dam using adjustment factors set by BIF (2018) (ABW) (Table 4.2). Weaning weights were adjusted using adjusted 205-day weaning weight (205-d WW) on the basis of average daily gain from birth to weaning similar to weaning weight adjustments in Chapter 3 of this dissertation.

Table 4.2. Adjustment factors for birth weight and weaning weight when calculating 205 adjusted weaning weights[1].

Age of Dam (yr)	**BW (lb)**	**WW (lb)**	
	All	Male	Female
2	8	60.00	54.00
3	5	40.00	36.00
4	2	20.00	18.00
5 to 10	0.00	0.00	0.00
>=11	3.00	20.00	18.00

[1]Beef Improvement Federation (2018), Guidelines for uniform beef improvement programs, BW: Birth weight, WW: Weaning weight.

4.3.5. Statistical analysis

The final models for calf performance traits were determined using SAS software (SAS Institute, Cary, NC, USA). For each trait (BW, WW, pre-weaning ADG, and WG) dam temperament and sire docility EPD, including interactions, were fitted. Dam temperament measurements included DS, TS, QBA attributes (QBA1 to QBA12), TI, TI+, TI-, SSD, and CVSSD) were fitted in the model independently of each other (n=19/trait/model). For each model, influences of systematic environmental fixed effects of primary breed (n = 2), year (n = 4), sex (n = 2), two-way interactions of fixed effects and random effect of calf were included to determine the final model for each trait (BW, WW, Pre-wean ADG, and WG) using MIXED procedure of SAS (SAS Institute, Cary, NC, USA).

The final statistical model determined by SAS software (SAS Institute, Cary, NC, USA) for each trait were used to calculate least squares means, additive genetic variances, maternal permanent environmental variances, residual variances, and heritability estimates using ASReml 4.2 (Gilmour et al., 2015) to allow for an animal model based on current pedigree, appropriate distribution of data, and model effects. Random maternal effects were fitted in the model to account for calves that were born from the same dams (229 out of 518 calves, 44.21%).

Least square means and standard errors were generated for fixed effects with relevant t-statistics provided through ASReml 4.2 (Gilmour et al., 2015). Pairwise comparisons were controlled for Type I Error using Tukey-Kramer method by 1) converting the t-statistic to a q-statistics as $q = \sqrt{2} * t$ and 2) by finding the related p-value using the Real Statistics Resource Pack software (Release 7.6) Excel add-in QDIST function with *k* as the fixed effect degrees of freedom and the *df* as the residual degrees of freedom (Zaiontz, 2021).

4.4. Results and discussion

4.4.1. Record summary

Production records and summary statistics of calves used in the study over the 4-year period (2016 to 2019) are presented in Tables 4.3 and 4.4. These calves were from 289 dams born from 2014 to 2017 that produced 518 calves in total. Of these 518 calves, only 492 to 495 had production records available (Table 4.3).

Table 4.3. Record summary of calf production traits with records and dam with temperament scores used across 4-year period.

Production Traits[1]	**Year (no. dams)**				**Overall**
	2016 (80)	**2017 (158)**	**2018**[2] **(216)**	**2019 (289)**	
Birth weight	58	121	88	228	495
Weaning weight	58	121	88	225	492
Pre-weaning ADG	58	121	88	225	492
Weight gain	58	121	88	225	492

[1]ADG = average daily gain.
[2]Less number of dams used due to embryo transfer work.
"-" = no data

Table 4.4. Mean and standard deviation of production traits measured across 4-year period.

Year	Traits[1]			
	Birth weight (lb)	Weaning weight (lb)	Weaning ADG (lb)	Weight gain (lb)
	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD
2016	73.67 ± 10.32	620.99 ± 57.85	2.90 ± 0.34	547.32 ± 53.24
2017	83.63 ± 9.71	704.88 ± 66.48	3.63 ± 0.54	621.05 ± 62.08
2018	84.03 ± 11.30	564.16 ± 62.53	2.58 ± 0.48	480.13 ± 56.76
2019	83.88 ± 11.61	581.38 ± 72.97	2.47 ± 0.38	497.40 ± 67.66
Overall	82.70 ± 11.42	613.34 ± 86.97	2.83 ± 0.65	530.60 ± 83.31

[1]Production traits were adjusted based on Beef Improvement Federation Guidelines (BIF, 2018), Mean and standard deviation (SD) are reported.
"-" = no data

4.4.2. Dam temperament evaluation

Record summary distribution of the number of calves with records that had sire and/or dam temperament score available over the 4-year period are presented in Table 4.5. Using docility (DS) and temperament score (TS), majority of the calves had dam with temperament scores of 1 and 2 (DS; n = 443, 92.87%; and TS; n = 425, 89.10%). Similarly, majority of the calves had a dam with scores of 1 and 2 using positive qualitative behavior attributes (QBAs) of apathetic (n = 414, 86.79%), curious (n = 449, 94.33%), happy (n = 440, 92.24%), and positively occupied (n = 466, 97.69%). However, positive QBA attributes using calm and relaxed had majority scores of 3 and 4 (n = 293, 62.43%; and n = 276, 57.86% respectively), which aligned with calm temperament trends seen in other methods. Majority of the calves had their dams scores of 1 and 2 also for negative QBA attributes using active (n = 354, 74.21%), agitated (n = 465, 97.48%), attentive (n = 327, 68.55%), distressed (n = 477, 100%), fearful (n = 460, 96.44%), and irritated (n = 464, 97.27%). For temperament index (TI), TI positive, TI negative, standard deviation of total weight over time (SSD) and coefficient of variation based on the SSD (CVSSD), dam temperament scores approximately had even score distribution since they were based on quartile ranks among the dams

Table 4.5. Record summary distribution of the number of calves with records that had sire and/or dam temperament scores available over the 4-year period.

Method	Score[8]					Total
	1	2	3	4	5*	
DS[1]	230	213	29	5	-	477
TS[2]	199	226	*	50	2	477
QBA[3]						
Positive QBA						
Apathetic	199	215	59	4	-	477
Calm	72	112	187	106	-	477
Curious	235	214	27	-	-	476
Happy	252	188	37	-	-	477
Pos. occupied	255	211	11	-	-	477
Relaxed	75	126	204	72	-	477
Negative QBA					-	
Active	104	250	117	6	-	477
Agitated	353	112	9	3	-	477
Attentive	81	246	146	4	-	477
Distressed	440	37	-	-	-	477
Fearful	381	79	17	-	-	477
Irritated	374	90	12	1	-	477
TI[4]	114	114	109	140	-	477
TI positive	101	113	124	139	-	477
TI negative	98	141	110	128	-	477
SSD[5]	146	112	118	101	-	477
CVSSD[6]	146	103	129	99	-	477
Sire EPD[7]	115	141	51	21	-	328

[1]DS = Docility score.
[2]TS = Temperament score. *Score of 5 is only relevant to TS and score of 3 is excluded.
[3]QBA = QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.
[4]TI = Temperament index: the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).
[5]SSD: standard deviation of total weight over time recorded by four-platform standing scale,
[6]CVSSD: coefficient of variation based on the SSD.
[7]Sire EPD = sire docility expected progeny difference.

used. Lastly, majority of calves had their sire docility EPD scores of 1 and 2 (256 out of 328, 78.05%) while 72 out of 328 or 21.95% had sire docility EPD scores of 3 and 4 combined. In literature, variation of distribution for temperament score was observed using different methods of temperament evaluation but is dependent on the populations available for research. Sant'Anna et al. (2014), using temperament score (TS) similar to the method used in this study, had majority cattle had scores of 2 while using chute score (CS), the majority of the cattle had 3 scores. In the same study of Sant'Anna et al. (2014), using movement score (method adapted from Grandin, 1993), majority of the cattle had 1 and 2 score. Overall, majority of temperament evaluation method used in this study suggest that majority of dam and sire used in this study have calm temperament. The cattle used in the study were primarily crosses of Angus and Hereford breeds of cattle, which are generally calm in temperament.

4.4.3. Statistical modelling

It must be noted that the available calf records used in this study were well below the typical threshold of 1,000 records used with animal modeling with pedigree. Therefore, outcomes from this study are influenced by this discrepancy in sample size. Even so, much of the work provide a preliminary investigation of whether dam or sire temperament may be influential on calf performance.

The final model for calf performance traits (ABW, 205-d WW, ADG, and WG) included fixed effect of dam temperament, sire EPD, primary breed, sex, and year, random effect of calf, and dam maternal effect. Initially, significant interactions were included in the final model if it contributed to more than 33% of the models. However, fitting a significant interaction for each trait often resulted to non-estimable least square means including fitting these interactions as nested effects. This was driven by small sample size and lack of all interaction levels being present, thereby causing prediction failure using ASReml 4.2 (Gilmour et al., 2015). The interactions were therefore dropped in the final model. Details of statistical modelling for main effects per trait are discussed in the succeeding sections below.

4.4.3.1. Adjusted birth weight

The model terms that contributed to the model (P-value ≤ 0.25) when including dam temperament (n = 19 models evaluated) were: the fixed effect of dam temperament (3, 15.79%), sire EPD (16, 84.21%), primary breed (19, 100%), sex (19, 100%), and year (18, 94.74%); interactions of dam temperament with: Sire EPD (8, 42.11%), primary breed (5, 26.32%), year (8, 42.11%), and sex (2, 10.53%); and interactions of sire EPD with year (16, 84.21%), and sex (7, 36.84%).

4.4.3.2. Adjusted weaning weight

The model terms that had significant effect (*P-value* ≤ 0.25) from 19 models of dam temperament were the fixed effect of dam temperament (2, 10.53%), sire EPD (16, 84.21%), primary breed (1, 5.26%), sex (16, 84.21%), and year (19, 100%). The reduced model tested included fixed effects of dam temperament, Sire EPD, primary breed, sex, and year. Primary breed was included to serve as a blocking factor in the model.

4.4.3.3. Weaning average daily gain (ADG)

The model terms that had significant effect (*P-value* ≤ 0.25) from 19 models of dam temperament were the fixed effect of dam temperament (3, 15.79%), Sire EPD (6, 31.58%), primary breed (1, 5.26%), sex (14, 73.68%), and year (19, 100%); interactions of dam temperament with Sire EPD (7, 36.84%), primary breed (2, 10.53%), year (3, 15.79%), and sex (2, 10.53%); interactions of sire EPD with year (14, 73.68%), and sex (5, 26.32%); and interaction of year and sex (9, 47.37%).

4.4.3.4. Weight Gain

The model terms that had significant effect (*P-value* ≤ 0.25) from 19 models of dam temperament were the fixed effect of dam temperament (2, 10.53%), Sire EPD (1, 5.26%), sex

(14, 73.68%), and year (19, 100%); interactions of dam temperament with sire EPD (6, 31.58%), year (5, 26.32%), and primary breed (1, 5.26%); interactions of sire EPD with year (1, 5.26%), and sex (11, 57.89%); and interaction of year and sex (3, 15.79%).

4.4.4. Effect of Sire and dam temperament on calf productive traits

4.4.4.1. Sire and dam temperament effect on calf adjusted birth weight

The effect of sire and dam temperament using different methods of beef cattle temperament evaluations on ABW are presented in Tables 4.6 to 4.11. None of the measures of temperament had significant effect on ABW. This means that there were no significant association of dam and sire temperament on calf birth weight based on the results of the study. However, TS tended (*P-value* = 0.077) to be significant. When looking at calf AWB using TS, there was decrease in birth weight as beef cattle temperament increases. This observation was true when comparing temperament scores of 1 and 2 to scores of 3 and 4. There was an increase in calf ABW from dam temperament score of 1 to 2 but calf ABW decreased when dam temperament scores increased to 3 and 4. Vann et al. (2017) found out that dam temperament had an influence on calf performance specifically calf BW and ADG at weaning. In another study, Koch (1972) found that maternal temperament effects accounted to 15 to 20% variation in birth weight. Furthermore, Turner et al. (2013), observed that fearful cows produce calves with decreased BW. However, Burrow and Corbet (2000) found no association of sire temperament using flight speed scores on calf birth weight wherein birth weights of calves of bulls with low flight speed and high flight speed scores are statistically similar. Results of this study was not in agreement as compared to other similar studies but may be due to limited number of animals and general temperament or distribution of temperament scores of the dams in the study. Temperament scores of dams were mostly 1 and 2 and few had scores of 3 and 4. These scores indicated that the majority of the dams in the study

Table 4.6. Least squares means and standard errors for dam docility score (DS) and temperament score (TS) effect on calf adjusted birth weight (ABW), adjusted 205 weaning weight (205-d WW), weaning average daily gain (ADG), and weight gain (WG)[1].

Method	Calf Productive Traits							
	ABW	**N**	**205-d WW**	**N**	**ADG**	**N**	**WG**	**N**
DS[2]	**P-value = 0.766**		**P-value = 0.052**		**P-value = 0.016**		**P-value = 0.040**	
1	93.213 ± 4.948	224	627.259 ± 26.795[b]	222	3.005 ± 0.160[b]	222	534.884 ± 24.820[b]	222
2	93.383 ± 4.814	200	637.870 ± 26.138[a,b]	199	3.061 ± 0.156[b]	199	545.611 ± 24.206[a,b]	199
3	94.420 ± 5.415	27	669.954 ± 30.215[a]	27	3.286 ± 0.176[a]	27	576.372 ± 28.016[a]	27
4	98.374 ± 7.024	5	661.496 ± 40.907[a,b]	5	3.124 ± 0.229[a,b]	5	563.939 ± 38.004[a,b]	5
5	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-
TS[3]	**P-value = 0.077**		**P-value = 0.015**		**P-value = 0.023**		**P-value = 0.030**	
1	92.707 ± 4.812	188	633.101 ± 27.287[a,b]	187	3.026 ± 0.162[a,b]	187	540.457 ± 25.218[a,b]	187
2	94.3642 ± 4.752	218	608.436 ± 29.127[a]	216	2.893 ± 0.170[a]	216	519.080 ± 26.980[a]	216
4	89.434 ± 5.085	49	647.866 ± 26.932[b]	49	3.100 ± 0.159[b]	49	553.361 ± 24.909[b]	49
5	83.193 ± 10.975	1	602.712 ± 65.341[a,b]	1	2.921 ± 0.365[a,b]	1	520.167 ± 61.225[a,b]	1

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of dam temperament measurement (DS, TS), sire docility expected progeny difference (EPD), primary breed, sex, year, random effect of animal with known pedigree, and maternal effect.
[2]Docility score: scale of 1 to 6 with 1 = docile and 6 = very aggressive.
[3]Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer.
[abc]Superscripts within a column and a given scoring method that are different, differ ($P < 0.05$). "-" indicates no data.

Table 4.7. Least squares means and standard errors for dam positive Qualitative Behavior Assessment (QBA) attributes effect on calf adjusted birth weight (ABW), adjusted 205 weaning weight (205-d WW), weaning average daily gain (ADG), and weight gain (WG)[1].

Positive QBA[2]	Calf Productive Traits							
	ABW	**N**	**205-d WW**	**N**	**ADG**	**N**	**WG**	**N**
Apathetic	**P-value = 0.155**		**P-value = 0.162**		**P-value = 0.178**		**P-value = 0.125**	
1	93.158 ± 4.797	191	641.991 ± 26.374	190	3.078 ± 0.159	190	549.583 ± 24.400	190
2	92.935 ± 4.668	205	640.130 ± 28.352	204	3.101 ± 0.168	204	544.992 ± 26.264	204
3	95.136 ± 4.938	56	622.798 ± 27.067	55	2.980 ± 0.164	55	529.767 ± 25.058	55
4	79.196 ± 8.521	4	605.558 ± 50.950	4	2.913 ± 0.285	4	527.940 ± 47.499	4
Calm	**P-value = 0.749**		**P-value = 0.394**		**P-value = 0.389**		**P-value = 0.363**	
1	92.123 ± 5.084	69	640.391 ± 28.047	69	3.084 ± 0.166	69	547.997 ± 25.983	69
2	94.183 ± 4.911	109	645.691 ± 27.423	109	3.096 ± 0.162	109	552.794 ± 25.395	109
3	92.815 ± 4.955	180	636.272 ± 27.811	178	3.036 ± 0.164	178	542.251 ± 25.791	178
4	93.223 ± 4.845	98	623.213 ± 28.941	97	2.982 ± 0.170	97	531.498 ± 26.837	97
Curious	**P-value = 0.927**		**P-value = 0.003**		**P-value = 0.006**		**P-value = 0.002**	
1	93.287 ± 4.863	228	649.085 ± 26.099[b]	226	3.129 ± 0.158[b]	226	555.562 ± 24.061[b]	226
2	93.696 ± 4.840	202	619.598 ± 26.300[a]	201	2.977 ± 0.159[a]	201	526.549 ± 24.271[a]	201
3	92.789 ± 5.440	26	649.641 ± 30.113[a,b]	26	3.131 ± 0.178[a,b]	26	557.521 ± 27.830[a,b]	26
4	-	-	-	-	-	-	-	-
Happy	**P-value = 0.684**		**P-value = <0.001**		**P-value = <0.001**		**P-value = <0.001**	
1	93.716 ± 4.829	241	655.737 ± 26.913	239	3.163 ± 0.160[b]	239	563.309 ± 24.766[b]	239
2	92.650 ± 4.894	181	674.818 ± 29.058	180	3.230 ± 0.171[a]	180	580.969 ± 26.765[a]	180
3	94.354 ± 5.219	34	625.743 ± 26.426	34	2.981 ± 0.158[a]	34	532.404 ± 24.308[a]	34
4	-	-	-	-	-	-	-	-
Pos. occupied	**P-value = 0.217**		**P-value = 0.011**		**P-value = 0.011**		**P-value = 0.003**	
1	94.075 ± 4.802	244	650.134 ± 26.293	243	3.136 ± 0.159	243	557.507 ± 24.122[b]	243
2	93.174 ± 4.844	201	678.607 ± 35.770	199	3.333 ± 0.207	199	592.609 ± 32.953[a]	199
3	86.404 ± 6.276	11	624.856 ± 25.910	11	3.003 ± 0.158	11	531.298 ± 23.759[a]	11
4	-	-	-	-	-	-	-	-
Relaxed	**P-value = 0.601**		**P-value = 0.655**		**P-value = 0.784**		**P-value = 0.634**	
1	93.440 ± 5.088	73	640.422 ± 27.555	73	3.072 ± 0.164	73	549.277 ± 25.531	73
2	94.890 ± 4.936	121	637.093 ± 27.824	120	3.065 ± 0.165	120	543.576 ± 25.811	120
3	94.153 ± 4.963	195	642.342 ± 27.717	193	3.072 ± 0.164	193	548.118 ± 25.745	193
4	92.272 ± 4.914	67	627.401 ± 28.686	67	3.010 ± 0.169	67	534.877 ± 26.624	67

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of dam temperament measurement (positive QBA), sire docility expected progeny difference (EPD), primary breed, sex, year, random effect of animal with known pedigree, and maternal effect.

[2]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression.

[abc]Superscripts within a column and a given scoring method that are different, differ ($P < 0.05$). “-” indicates no data.

Table 4.8. Least squares means and standard errors for dam negative Qualitative Behavior Assessment (QBA) attributes effect on calf adjusted birth weight (ABW), adjusted 205 weaning weight (205-d WW), weaning average daily gain (ADG), and weight gain (WG)[1].

Negative QBA[2]	Calf Productive Traits							
	ABW	N	204-d WW	N	ADG	N	WG	N
Active	**P-value = 0.799**		**P-value = 0.757**		**P-value = 0.784**		**P-value = 0.778**	
1	93.426 ± 4.989	98	642.643 ± 27.063	98	3.080 ± 0.162	98	549.600 ± 25.076	98
2	93.574 ± 4.842	241	636.749 ± 28.060	239	3.068 ± 0.167	239	544.242 ± 26.007	239
3	93.646 ± 4.912	112	634.482 ± 27.549	111	3.044 ± 0.164	111	541.526 ± 25.519	111
4	83.472 ± 11.103	5	604.933 ± 66.399	5	2.946 ± 0.371	5	522.734 ± 62.043	5
Agitated	**P-value = 0.720**		**P-value = 0.580**		**P-value = 0.650**		**P-value = 0.624**	
1	93.681 ± 4.796	336	640.872 ± 26.998	333	3.067 ± 0.160	333	547.642 ± 25.015	333
2	93.170 ± 4.937	110	637.870 ± 27.974	110	3.074 ± 0.165	110	545.227 ± 25.934	110
3	91.082 ± 6.997	8	600.847 ± 41.600	8	2.860 ± 0.234	8	510.618 ± 38.729	8
4	83.447 ± 11.087	2	603.477 ± 66.290	2	2.935 ± 0.370	2	521.432 ± 61.962	2
Attentive	**P-value = 0.682**		**P-value = 0.096**		**P-value = 0.284**		**P-value = 0.046**	
1	94.075 ± 4.802	77	649.476 ± 26.410	77	3.120 ± 0.162	77	557.243 ± 24.303[a,b]	77
2	93.174 ± 4.844	236	626.413 ± 26.188	233	3.028 ± 0.161	233	532.180 ± 24.105[b]	233
3	86.404 ± 6.276	139	635.346 ± 50.820	139	3.223 ± 0.273	139	544.003 ± 47.285[a]	139
4	-	-	621.839 ± 27.327	4	3.016 ± 0.166	4	529.990 ± 25.174[a,b]	4
Distressed	**P-value = 0.493**		**P-value = 0.577**		**P-value = 0.382**		**P-value = 0.450**	
1	93.578 ± 4.787	421	639.341 ± 26.878	418	3.163 ± 0.160	418	546.511 ± 24.906	418
2	92.033 ± 5.214	35	647.070 ± 29.752	35	3.230 ± 0.171	35	556.201 ± 27.561	35
3	-	-	-	-	2.981 ± 0.158	-	-	-
4	-	-	-	-	-	-	-	-
Fearful	**P-value = 0.834**		**P-value = 0.094**		**P-value = 0.181**		**P-value = 0.080**	
1	93.281 ± 4.798	354	639.933 ± 26.902	361	3.060 ± 0.160	361	547.163 ± 24.903	361
2	94.081 ± 4.988	77	640.077 ± 28.199	77	3.066 ± 0.166	77	546.616 ± 26.118	77
3	91.970 ± 6.149	15	589.701 ± 35.450	15	2.828 ± 0.204	15	498.373 ± 32.952	15
4	-	-	-	-	-	-	-	-
Irritated	**P-value = 0.627**		**P-value = 0.386**		**P-value = 0.399**		**P-value = 0.439**	
1	93.667 ± 4.786	356	641.913 ± 27.048	353	3.075 ± 0.160	353	548.681 ± 25.076	353
2	92.959 ± 4.897	89	636.507 ± 27.896	89	3.045 ± 0.164	89	544.060 ± 25.878	89
3	89.928 ± 6.344	10	608.206 ± 37.114	3	2.897 ± 0.212	3	519.357 ± 34.531	3
4	-	-	-	-	-	-	-	-

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of dam temperament measurement (negative QBA), sire docility expected progeny difference (EPD), primary breed, sex, year, random effect of animal with known pedigree, and maternal effect.

[2]QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression.

($P < 0.05$) is significant. "-" indicates no data.

Table 4.9. Least squares means and standard errors for dam temperament index effect on calf adjusted birth weight (ABW), adjusted 205 weaning weight (205-d WW), weaning average daily gain (ADG), and weight gain (WG)[1].

Method	Calf Productive Traits							
	ABW	N	205-d WW	N	ADG	N	WG	N
TI	**P-value = 0.576**		**P-value = 0.368**		**P-value = 0.688**		**P-value = 0.264**	
1	92.980 ± 4.966	108	642.330 ± 27.447	108	3.067 ± 0.164	108	549.540 ± 25.387	108
2	94.027 ± 4.832	112	646.862 ± 27.949	112	3.099 ± 0.166	112	555.494 ± 25.849	112
3	91.550 ± 4.962	102	636.916 ± 27.122	100	3.065 ± 0.162	100	543.452 ± 25.094	100
4	93.296 ± 4.877	134	627.311 ± 27.945	133	3.023 ± 0.167	133	534.839 ± 25.860	133
TI Positive	**P-value = 0.805**		**P-value = 0.823**		**P-value = 0.819**		**P-value = 0.809**	
1	93.298 ± 4.918	98	643.575 ± 27.420	98	3.083 ± 0.163	98	551.042 ± 25.426	98
2	94.654 ± 4.951	109	636.346 ± 28.377	108	3.082 ± 0.168	108	543.836 ± 26.334	108
3	93.125 ± 4.998	117	640.370 ± 28.130	116	3.074 ± 0.166	116	546.110 ± 26.151	116
4	93.085 ± 4.847	132	634.140 ± 27.935	131	3.029 ± 0.165	131	541.723 ± 25.928	131
TI Negative	**P-value = 0.163**		**P-value = 0.123**		**P-value = 0.232**		**P-value = 0.174**	
1	92.370 ± 4.864	93	647.308 ± 27.406	92	3.135 ± 0.165	92	553.461 ± 25.395	92
2	94.658 ± 4.921	131	624.838 ± 27.045	130	3.018 ± 0.163	130	533.174 ± 25.050	130
3	95.411 ± 4.846	108	648.842 ± 26.991	107	3.107 ± 0.163	107	554.181 ± 25.043	107
4	92.202 ± 4.851	124	635.388 ± 27.032	124	3.061 ± 0.163	124	543.969 ± 25.051	124

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of dam temperament measurement (TI, TI positive, TI negative), sire docility expected progeny difference (EPD), primary breed, sex, year, random effect of animal with known pedigree, and maternal effect.
[2]Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).
($P < 0.05$) is significant.

Table 4.10. Least squares means and standard errors for dam four flatform standing scale (SSD) and coefficient of variation of SDD (CVSSD) data effect on calf adjusted birth weight (ABW), adjusted 205 weaning weight (205-d WW), weaning average daily gain (ADG), and weight gain (WG)[1].

Method[2]	Calf Productive Traits							
	Birth Weight	N	WW	N	ADG	N	WG	N
SSD	**P-value = 0.607**		**P-value = 0.333**		**P-value = 0.223**		**P-value = 0.299**	
1	92.098 ± 4.969	136	643.939 ± 28.081	135	3.103 ± 0.164	135	551.779 ± 26.042	135
2	94.386 ± 4.878	107	641.366 ± 27.817	106	3.061 ± 0.163	106	548.316 ± 25.772	106
3	93.122 ± 4.917	115	627.161 ± 28.320	114	2.985 ± 0.165	114	534.820 ± 26.257	114
4	92.587 ± 4.985	98	646.208 ± 27.608	98	3.087 ± 0.161	98	552.572 ± 25.565	98
CVSSD	**P-value = 0.177**		**P-value = 0.101**		**P-value = 0.259**		**P-value = 0.161**	
1	93.644 ± 4.931	137	646.058 ± 27.833	136	3.101 ± 0.165	136	552.706 ± 25.870	136
2	92.612 ± 4.888	99	651.016 ± 27.420	98	3.071 ± 0.162	98	556.012 ± 25.455	98
3	95.293 ± 4.857	123	625.832 ± 27.928	122	2.991 ± 0.164	122	534.817 ± 25.942	122
4	91.515 ± 4.926	97	636.014 ± 27.593	97	3.097 ± 0.163	97	544.276 ± 25.594	97

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of dam temperament measurement (SSD, CVSSD), sire docility expected progeny difference (EPD), primary breed, sex, year, random effect of animal with known pedigree, and maternal effect.
[2]SSD: standard deviation of total weight over time recorded by four-platform standing scale, CVSSD: coefficient of variation based on the SSD.
($P < 0.05$) is significant.

Table 4.11. Least squares means and standard errors for sire docility expected progeny difference (EPD) on calf adjusted birth weight (ABW) using dam docility score (DS), temperament score (TS), Qualitative Behavior Assessment (QBA) attributes and temperament index (TI) temperament evaluations[1].

Method[2]	**Sire Docility EPD**								
	1	**N**	**2**	**N**	**3**	**N**	**4**	**N**	**P-value[3]**
DS	96.925 ± 5.540	105	94.985 ± 5.665	130	89.9776 ± 5.179	42	97.5014 ± 5.885	17	0.371
TS	92.438 ± 5.781	105	92.634 ± 6.116	130	90.0188 ± 5.919	42	84.6075 ± 5.453	17	0.277
QBA									
Positive QBA									
Apathetic	92.265 ± 5.554	105	92.859 ± 5.784	130	90.156 ± 5.605	42	85.146 ± 5.070	17	0.304
Calm	95.342 ± 5.370	105	95.644 ± 5.712	130	93.233 ± 5.459	42	88.125 ± 4.937	17	0.352
Curious	95.490 ± 5.389	105	95.919 ± 5.724	130	93.369 ± 5.498	42	88.251 ± 4.999	17	0.342
Happy	95.705 ± 5.376	105	96.330 ± 5.698	130	93.508 ± 5.478	42	88.750 ± 4.973	17	0.349
Pos. occupied	93.600 ± 5.443	105	94.071 ± 5.764	130	91.075 ± 5.593	42	86.125 ± 5.062	17	0.291
Relaxed	95.873 ± 5.388	105	96.431 ± 5.747	130	93.848 ± 5.495	42	88.603 ± 4.975	17	0.336
Negative QBA									
Active	93.426 ± 4.989	105	93.574 ± 4.842	130	93.646 ± 4.912	42	83.472 ± 11.103	17	0.345
Agitated	92.628 ± 5.972	105	92.944 ± 6.318	130	90.432 ± 6.113	42	85.376 ± 5.644	17	0.346
Attentive	95.172 ± 5.592	105	95.893 ± 5.966	130	92.766 ± 5.716	42	88.004 ± 5.250	17	0.321
Distressed	94.976 ± 5.438	105	95.500 ± 5.749	130	92.880 ± 5.534	42	87.865 ± 5.005	17	0.345
Fearful	95.277 ± 5.521	105	95.760 ± 5.845	130	93.127 ± 5.608	42	88.279 ± 5.130	17	0.360
Irritated	Not estimable	105	Not estimable	130	Not estimable	42	Not estimable	17	0.334
TI	95.139 ± 5.348	105	95.656 ± 5.671	130	92.997 ± 5.440	42	88.061 ± 4.906	17	0.344
TI positive	95.804 ± 5.366	105	96.065 ± 5.693	130	93.772 ± 5.474	42	88.519 ± 4.911	17	0.352
TI negative	95.956 ± 5.317	105	96.311 ± 5.628	130	93.855 ± 5.403	42	88.519 ± 4.860	17	0.317
SSD	95.113 ± 5.388	105	95.616 ± 5.719	130	93.151 ± 5.483	42	88.313 ± 4.945	17	0.393
CVSSD	95.506 ± 5.345	105	95.996 ± 5.665	130	93.084 ± 5.441	42	88.478 ± 4.903	17	0.341

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of dam temperament, sire docility EPD, primary breed, sex, year, random effect of animal with known pedigree, and maternal effect.

[2]Docility score: scale of 1 to 6 with 1 = docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index: the first principal component score generated from QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[3]P-value ≤ 0.05 is significant.

Table 4.12. Least squares means and standard errors for sire docility expected progeny difference (EPD) effect on calf adjusted 205 weaning weight (205-d WW) using dam docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI)) temperament evaluations[1].

Method[2]	**Sire Docility EPD**								
	1	**N**	**2**	**N**	**3**	**N**	**4**	**N**	**P-value**[3]
DS	659.293 ± 30.237	105	661.300 ± 31.679	129	637.115 ± 30.679	42	638.871 ± 27.455	17	0.375
TS	634.285 ± 33.053	105	637.955 ± 34.720	129	609.734 ± 33.710	42	610.141 ± 30.786	17	0.305
Positive QBA									
Apathetic	636.835 ± 31.585	105	639.448 ± 32.561	129	615.969 ± 31.731	42	618.225 ± 28.417	17	0.429
Calm	646.021 ± 30.291	105	649.569 ± 31.914	129	625.250 ± 30.604	42	624.726 ± 27.234	17	0.433
Curious	648.960 ± 29.071	105	651.536 ± 30.428	129	627.413 ± 29.393	42	629.856 ± 26.153	17	0.382
Happy	660.940 ± 29.448	105	662.673 ± 30.853	129	640.707 ± 29.799	42	644.078 ± 26.575	17	0.496
Pos. occupied	0.000 ± 660.645	105	660.222 ± 30.774	129	641.082 ± 30.130	42	642.848 ± 26.695	17	0.512
Relaxed	647.136 ± 30.081	105	649.424 ± 31.707	129	625.036 ± 30.432	42	625.662 ± 26.998	17	0.408
Negative QBA									
Active	640.019 ± 33.154	105	642.999 ± 34.725	129	617.726 ± 33.790	42	618.064 ± 30.671	17	0.380
Agitated	630.895 ± 34.181	105	634.410 ± 35.843	129	607.786 ± 34.839	42	609.975 ± 31.856	17	0.367
Attentive	643.356 ± 30.469	105	641.742 ± 32.033	129	622.352 ± 30.830	42	625.625 ± 27.848	17	0.491
Distressed	652.919 ± 30.626	105	656.836 ± 32.004	129	630.615 ± 30.975	42	632.451 ± 27.498	17	0.376
Fearful	633.162 ± 31.039	105	637.209 ± 32.579	129	610.370 ± 31.374	42	612.208 ± 28.290	17	0.361
Irritated	Not estimable	105	Not estimable	129	Not estimable	42	Not estimable	17	0.362
TI	647.815 ± 29.911	105	650.653 ± 31.383	129	627.174 ± 30.224	42	627.777 ± 26.769	17	0.447
TI positive	648.308 ± 30.305	105	651.833 ± 31.824	129	626.462 ± 30.725	42	627.828 ± 27.098	17	0.409
TI negative	649.691 ± 29.394	105	651.974 ± 30.738	129	626.214 ± 29.643	42	628.497 ± 26.127	17	0.337
SSD	649.638 ± 30.405	105	653.425 ± 31.932	129	626.521 ± 30.747	42	629.090 ± 27.195	17	0.373
CVSSD	650.054 ± 30.081	105	654.232 ± 31.541	129	625.429 ± 30.430	42	629.204 ± 26.895	17	0.310

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of dam temperament, sire docility EPD, primary breed, sex, year, random effect of animal with known pedigree, and maternal effect.

[2]Docility score: scale of 1 to 6 with 1 = docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index: the first principal component score generated from QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[3]P-value ≤ 0.05 is significant.

Table 4.13. Least squares means and standard errors for sire docility expected progeny difference (EPD) effect on weaning average daily gain (ADG) using dam docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI)) temperament evaluations[1].

Method[2]	Sire Docility EPD								
	1	**N**	**2**	**N**	**3**	**N**	**4**	**N**	**P-value[3]**
DS	3.100 ± 0.180	105	3.254 ± 0.190	129	3.002 ± 0.183	42	3.120 ± 0.167	17	0.155
TS	2.971 ± 0.194	105	3.129 ± 0.205	129	2.866 ± 0.198	42	2.974 ± 0.183	17	0.151
Positive QBA									
Apathetic	2.991 ± 0.189	105	3.153 ± 0.198	129	2.903 ± 0.191	42	3.024 ± 0.174	17	0.182
Calm	3.026 ± 0.180	105	3.187 ± 0.191	129	2.940 ± 0.183	42	3.045 ± 0.166	17	0.200
Curious	3.057 ± 0.176	105	3.216 ± 0.187	129	2.962 ± 0.180	42	3.081 ± 0.163	17	0.157
Happy	3.097 ± 0.176	105	3.243 ± 0.187	129	3.017 ± 0.179	42	3.140 ± 0.163	17	0.254
Pos. occupied	3.129 ± 0.179	105	3.279 ± 0.190	129	3.055 ± 0.184	42	3.167 ± 0.166	17	0.245
Relaxed	3.010 ± 0.169	105	3.072 ± 0.164	129	3.065 ± 0.165	42	3.072 ± 0.164	17	0.191
Negative QBA									
Active	3.013 ± 0.196	105	3.174 ± 0.207	129	2.920 ± 0.201	42	3.031 ± 0.184	17	0.177
Agitated	2.963 ± 0.200	105	3.125 ± 0.211	129	2.863 ± 0.204	42	2.985 ± 0.189	17	0.158
Attentive	3.071 ± 0.184	105	3.223 ± 0.196	129	2.984 ± 0.188	42	3.108 ± 0.172	17	0.219
Distressed	3.070 ± 0.181	105	3.232 ± 0.191	129	2.975 ± 0.184	42	3.096 ± 0.167	17	0.162
Fearful	2.960 ± 0.184	105	3.125 ± 0.195	129	3.125 ± 0.195	42	2.988 ± 0.171	17	0.160
Irritated	Not estimable	105	Not estimable	129	Not estimable	42	Not estimable	17	0.162
TI	3.039 ± 0.179	105	3.200 ± 0.190	129	2.950 ± 0.183	42	3.064 ± 0.165	17	0.186
TI positive	3.044 ± 0.180	105	3.205 ± 0.191	129	2.956 ± 0.184	42	3.064 ± 0.165	17	0.197
TI negative	3.018 ± 0.163	105	3.135 ± 0.165	129	3.107 ± 0.163	42	3.061 ± 0.163	17	0.155
SSD	3.041 ± 0.178	105	3.194 ± 0.189	129	2.937 ± 0.181	42	3.065 ± 0.163	17	0.166
CVSSD	3.101 ± 0.165	105	3.097 ± 0.163	129	3.071 ± 0.162	42	2.991 ± 0.164	17	0.148

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of dam temperament, sire docility EPD, primary breed, sex, year, random effect of animal with known pedigree, and maternal effect.
[2]Docility score: scale of 1 to 6 with 1 = docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index: the first principal component score generated from QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.
[3]P-value ≤ 0.05 is significant.

Table 4.14. Least squares means and standard errors for sire docility expected progeny difference (EPD) effect on calf weight gain (WG) using dam docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI)) temperament evaluations[1].

	Sire Docility EPD								
Method[2]	**1**	**N**	**2**	**N**	**3**	**N**	**4**	**N**	**P-value[3]**
DS	563.642 ± 28.021	105	564.194 ± 29.293	128	543.670 ± 28.405	42	549.300 ± 25.345	17	0.446
TS	542.446 ± 30.643	105	544.615 ± 32.104	128	520.370 ± 31.223	42	525.633 ± 28.424	17	0.374
Positive QBA									
Apathetic	545.440 ± 29.267	105	546.394 ± 30.104	128	527.089 ± 29.369	42	533.359 ± 26.245	17	0.526
Calm	551.335 ± 28.065	105	553.697 ± 29.507	128	532.830 ± 28.321	42	536.679 ± 25.121	17	0.517
Curious	554.052 ± 26.814	105	555.269 ± 27.994	128	534.964 ± 27.075	42	541.890 ± 24.018	17	0.462
Happy	565.932 ± 27.092	105	566.163 ± 28.307	128	547.899 ± 27.379	42	555.583 ± 24.324	17	0.568
Pos. occupied	567.985 ± 27.111	105	565.745 ± 28.135	128	551.067 ± 27.612	42	557.090 ± 24.369	17	0.612
Relaxed	552.471 ± 27.908	105	553.383 ± 29.353	128	532.475 ± 28.205	42	537.520 ± 24.933	17	
Negative QBA									
Active	547.913 ± 30.777	105	549.603 ± 32.168	128	528.037 ± 31.347	42	532.549 ± 28.383	17	0.461
Agitated	539.447 ± 31.749	105	541.702 ± 33.230	128	518.657 ± 32.343	42	525.113 ± 29.505	17	0.435
Attentive	549.111 ± 28.076	105	545.457 ± 29.456	128	530.919 ± 28.377	42	537.928 ± 25.581	17	0.589
Distressed	559.273 ± 28.386	105	561.822 ± 29.592	128	539.186 ± 28.684	42	545.143 ± 25.368	17	0.445
Fearful	538.901 ± 28.750	105	541.513 ± 30.116	128	518.267 ± 29.038	42	524.190 ± 26.105	17	0.426
Irritated	Not estimable	105	Not estimable	128	Not estimable	42	Not estimable	17	0.430
TI	553.459 ± 27.664	105	554.857 ± 28.958	128	535.136 ± 27.924	42	539.871 ± 24.644	17	0.534
TI positive	553.434 ± 28.130	105	555.964 ± 29.477	128	533.691 ± 28.497	42	539.622 ± 25.042	17	0.476
TI negative	554.890 ± 27.229	105	555.717 ± 28.403	128	533.746 ± 27.429	42	540.433 ± 24.087	17	0.405
SSD	551.779 ± 26.042	105	552.572 ± 25.565	128	548.316 ± 25.772	42	534.820 ± 26.257	17	0.425
CVSSD	555.410 ± 27.933	105	558.227 ± 29.219	128	533.206 ± 28.225	42	540.968 ± 24.849	17	0.370

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of dam temperament, sire docility EPD, primary breed, sex, year, random effect of animal with known pedigree, and maternal effect.

[2]Docility score: scale of 1 to 6 with 1 = docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index: the first principal component score generated from QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[3]P-value ≤ 0.05 is significant.[3]P-value ≤ 0.05 is significant.

were docile in temperament and there was not enough variation in terms of temperament. Dams in this study were *Bos taurus* crossbreeds mostly Angus and few Hereford and Simmental influenced breeds. *Bos taurus* breeds are generally docile than *Bos indicus* (Burrow, 2001) and in the study of Vann et al. (2017), *Bos indicus* breed were included in the study.

4.4.4.2. Sire and Dam temperament effect on calf adjusted 205 weaning weight

Least squares means and standard errors for sire and dam temperament effect on 205-d WW using various methods of temperament evaluation are presented 4.6 to 4.10 and 4.12. Significant results were observed on dam temperament evaluation using DS (*P-value* = 0.052), TS (*P-value* = 0.015), and positive QBA attributes that included curious (*P-value* = 0.003), happy (*P-value* = 0.001), and positively occupied (*P-value* = 0.011). Moreover, pairwise comparisons using Tukey-Kramer to control type I error showed significant effect except happy and positively occupied QBA attributes. However, based on our study sire had no significant effect on calf 205-d WW. Limited literature that investigated the effect of sire and dam on calf WW was published to compare the result of our study. However, Brown et al. (2015) found that ewes with good temperament had increased number of lambs weaned and had lambs with increased yearling weights.

4.4.4.3. Sire and Dam temperament effect on weaning average daily gain

Significant effect of pre-weaning ADG were observed using different methods of temperament evaluation. Significant effects were observed using DS (*P-value* = 0.016), TS (*P-value* = 0.023), and positive QBA attributes that included curious (*P-value* = 0.006), happy (*P-value* = 0.001), and positively occupied (*P-value* = 0.011) (Tables 4.5 to 4.9 and 4.12). Pairwise comparisons using Tukey-Kramer to control type I error showed significant effect except positively occupied QBA attribute. Similar to weaning weight, sire docility EPD had no significant effect on calf 205-d WW. Result of our study is similar to Vann et al. (2017), wherein dam temperament influence on ADG at weaning. In addition, Koch (1972) found that maternal temperament effects accounted to 35 to 45% pre-weaning daily gain.

4.4.4.4. Sire and Dam temperament effect on calf weight gain

Dam temperament had an effect on WG based on DS, (*P-value* = 0.040), TS (*P-value* = <0.030), positive QBA attributes that included curious (*P-value* = 0.002), happy (*P-value* = 0.001), and positively occupied (*P-value* = 0.003), and attentive negative QBA attribute (*P-value* = 0.046) (4.6 to 4.10 and 4.14). Moreover, pairwise comparisons using Tukey-Kramer to control type I error showed significant effect. Similar to other calf productive traits, sire docility EPD had no effect on calf WG. Limited literature that investigated the effect of sire and dam temperament effect on calf weight gain was published. Thereby comparison on the results of this study particularly WG is also limited. However, studies have shown that sire temperament had an effect on offspring temperament. Kasimacnickan et al. (2018) found significant effect of sire docility EPD scores (P-value < 0.024) on calf temperament. In addition, calves sired by *Bos taurus* breeds have calmer temperament compared to *Bos taurus* sired calves (Hearnshaw and Moris, 1984; and Parandos da Costa et al., 2002).

4.4.5. Genetic parameter estimations

Genetic parameter and variance components estimates for calf productive traits when sire and dam temperament are included in the model are presented in Appendix Tables A4.1 to A4.4. Across all measures of dam temperament, ABW, 205-d WW, weaning ADG, and WG, had ranged heritability estimates ($\hat{h}^2$) of 0.498 ± 0.208 to 0.636 ± 0.212, 0.240 ± 0.190 to 0.390 ± 0.213, 0.560 ± 0.174 to 0.640 ± 0.175, and 0.204 ± 0.173 to 0.335 ± 0.196, respectively. BW and pre-weaning ADG were highly heritable while WW and WG were moderately heritable. It should be noted that the standard errors are quite large from these estimates because of the sample size, therefore it is likely the values will change if more calf records are added. Even so, no studies have been found fitting sire and dam temperament to estimate genetic parameters for calf productive traits. Heritability estimates of similar production traits have been published. For BW, our study are higher than the studies of El-Saied et al. (2006) that reported 0.36 using Charolais cattle and Eriksson et al. (2004) that reported 0.44 and 0.48 using Charolais and Hereford cattle. Heritability estimates for WW ranged from 0.19 to 0.47 according to Groeneveld et al. (1998) while Montaldo and Kinghorn (2003) estimated 0.38 heritability which are similar to the ranged heritability estimates in our study. Result of our study showed that heritability estimations are improved when sire and dam temperament are included in the model. However, the BW and WW used from the previous studies are unadjusted.

4.5. Conclusion

In conclusion, dam temperament is associated with calf performance based on the results of this study. We found significant effects of dam temperament on calf adjusted 205 weaning weight (205-d WW), weaning ADG, and weight gain (WG). Therefore, selection of dam with calm temperament will improve productivity. However, no significant association of sire temperament on calf productive traits. Limitations of our study are: (1) small sample size (less than 1,000); (2) Hereford sires do not have docility EPD; and (3) the general temperament of the dams and sires in our study. Recommendations for future studies should be based on these limitations.

5. GENERAL CONCLUSION AND FUTURE DIRECTION

Evaluators scored differently using subjective methods however, in prediction of genetic merit (breeding value predictions), evaluators have lesser impact on methods already implemented by breed association provided that evaluator is included in the model. The novel movement-based objective methods (four-platform standing scale, FPSS) using standard deviation of FPSS data (SSD) and coefficient of variation of SSD (CVSSD) has moderate genetic correlation to methods used by breed associations suggesting that selection using these methods yield similar outcomes. Calf temperament has a positive effect on productive traits. Selection of dam with favorable temperament produce calf with improved productive traits.

It is recommended in the future studies to utilize cattle population with greater variability in terms of temperament for example *Bos indicus* cattle and crosses. Less variation in temperament in this study could also be due to the methods used for temperament evaluation in study. The methods used in this study were mostly subjective methods and may not have captured variability to discriminate calves based on their temperament. It is also recommended to utilize other objective method for example flight speed or exit velocity and possibly may capture more variation. Lastly, increasing the number of animals use in genetic correlation is recommended to increase accuracy and confirm results of our study.

REFERENCES

Adamczyk, K., J. Pokorska, J. Makulska, B. Earley, and M. Mazurek. Genetic analysis and evaluation of behavioral traits in cattle. Genetic analysis and evaluation of behavioral traits in cattle. Liv. Sci. 154:1-12. doi.org/10.1016/j.livsci.2013.01.016.

Anon. 1988. Genetic and environmental methods of improving the temperament of Bos indicus and crossbred cattle. Australian Meat Research Committee Final Report UNQ7. James Cook University of North Queensland.

Beckman, D. W., R. M. Enns, S. E. Speidel, B. W. Brigham, and D. J. Garrick. 2007. Maternal effects on docility in Limousin cattle. J. Anim. Sci. 85:650–657. doi: 10.2527/jas.2006-450.

Beef Improvement Federation. 2018. Guidelines for uniform beef improvement programs. 9th ed. Revised March, 2018. Available from https://beefimprovement.org/wp-content/uploads/2018/03/BIFGuidelinesFinal_updated0318.pdf (accessed March 9, 2021). Updated on March 2018.

Brehrends, S. M., R. K Miller, F.M. Rouquette Jr., R.D. Randel, B.G. Warrington, T.D.A. Forbes, T.H. Welsh, H. Lippke, J.M. Behrends, G.E. Carstens, and J.W. Holloway. 2009. Relationship of temperament, growth, carcass characteristics and tenderness in beef steers. Meat Sci. 81:433–438. doi:10.1016/j.meatsci.2008.09.003

Benhajali, H., X. Boivin, J. Sapa, P. Pellegrini, P. Boulesteix, P. Lajudie, and F. Phocas. Assessment of different on-farm measures of beef cattle temperament for use in genetic evaluation. J. Anim. Sci. 88:3529–3537. doi:10.2527/jas.2010-3132.

Brown, D.J., N. M. Fogarty, C. L. Iker, D. M. Ferguson, D. Blanche, and G. M. Gaunt. 2015. Genetic evaluation of maternal behaviour and temperament in Australian sheep. Animal Production Sci 56(4):767-774. doi:10.1071/AN14945

Burdick, N. C. J. A.Carroll, R. D. Randel, S. T. Willard, R. C. Vanne, C. C. Chase Jr. S. D. Lawhon, L. E. Hulbert, and T. H. Welsh Jr. 2011. Influence of temperament and transportation on physiological and endocrinological parameters in bulls. Liv. Sci. 139(3): 213-221. doi.org/10.1016/j.livsci.2011.01.013

Burfening, P. J., and D. D. Kress. 1993. Direct and maternal effects on birth and weaning weight in sheep. Small Ruminant Res. 10:153-163. doi.org/10.1016/0921-4488(93)90058-P.

Burrow, H. M., G. W. Seifert, and N. J. Corbet. 1988. A new technique for measuring temperament in cattle. Proc. Aust. Soc. Anim. Prod. 17:154-157.

Burrow, H. M. and Dillon, R. D. 1997. Relationships between temperament and growth in a feedlot and commercial carcass traits of Bos indicus crossbreds. Aust. J. Exp. Agric. 37: 407-411.

Burrow, H. M., and N. J. Corbet. 2000. Genetic and environmental factors affecting temperament of zebu and zebu-derived beef cattle grazed at pasture in the tropics. Aust. J. Exp. Agr. 51: 155–162. doi: 10.1071/AR99053.

Burrow, H. M. 2001. Variances and covariances between productive and adaptive traits and temperament in a composite breed of tropical beef cattle. Livestock Production Sci. 70:213–233. doi.org/10.1016/S0301-6226(01)00178-6.

Busby, W. D., P. Beedle, D. Strohbehn, L. R. Corah, and J. F. Stika. 2005. Effects of disposition on feedlot gain and quality grade. J. Anim. Sci. 83(2):63.

Caetano, S. L., R. P. Savegnago, A. A. Boligon, S. B. Ramos, T. C. S. Chud, R. B. Lôbo, and D. P. Munari. 2013. Estimates of genetic parameters for carcass, growth and reproductive traits in Nellore cattle. Liv. Sci. 155:1-7. doi.org/10.1016/j.livsci.2013.04.004

Café, L. M., B. L. McIntyre, D. L. Robinson, G. H. Geesink, W. Barendse, and P. L. Greenwood. 2010. Production and processing studies on calpain-system gene markers for tenderness in Brahman cattle: 1. Growth, efficiency, temperament, and carcass characteristics. J. of Ani. Sci. 88(9):3047–3058. doi:10.2527/jas.2009-2678

Café, L. M., D. L. Robinson, D. M. Ferguson, B. L. McIntyre, G. H. Geesink, and P. L. Greenwood. 2011. Cattle temperament: Persistence of assessments and associations with productivity, efficiency, carcass and meat quality traits. J. of Ani. Sci. 89(5):1452–1465. doi.org/10.2527/jas.2010-3304.

Canellas, L. C., J. O. J. Barcellos, L. N. Nunes, T. E. Oliveira, E. R. Prates, and D. C. Darde. 2012. Post-weaning weight gain and pregnancy rate of beef heifers bred at 18 months of age: a meta-analysis approach. Revista Brasileira de Zootecnia. 41:1632-1637. doi.org/10.1590/S1516-35982012000700011.

Cooke, R. F., J. D. Arthington, D. B. Araujo, and G. C. Lamb. 2009. Effects of acclimation to human interaction on performance, temperament, physiological responses, and pregnancy rates of Brahman-crossbred cows. J. of Ani. Sci. 87(12): 4125–4132. doi:10.2527/jas.2009-2021.

Cooke, R.F., 2011. Effects of temperament and animal handling on fertility. Proceedings: Applied Reproductive Strategies in Beef Cattle . Boise, Idaho, USA.

Cooke, R. F, D. W. Bohnert, B. I. Cappellozza, C. J. Mueller, and T. DelCurto. 2012. Effects of temperament and acclimation to handling on reproductive performance of Bos taurus beef females. J. Anim. Sci. 90:3547–3555. doi:10.2527/jas2011-4768.

Cooke, R. F., K. M. Schubach, R. S. Marques, R. F. G. Peres, L. G. T. Silva, R. S. Carvalho, R. S. Cipriano, D. W. Bohnert, A. V. Pires, and J. L. M. Vasconcelos. 2017. Effects of temperament on physiological, productive, and reproductive responses in *Bos indicus* beef cows. J. of Anim. Sci. 95(1):1–8. doi.org/10.2527/jas.2016.1098.

Core, S., T. Widowski, G. Mason, and S. Miller. 2009. Eye white percentage as a predictor of temperament in beef cattle. J. Anim. Sci. 87:2168–2174. doi:10.2527/jas.2008-1554.

Crookshank, H. R., Elissalde, M. H., White, R. G., Clanton, D. C., and H. E. Smalley. 1979. Effect of transportation and handling of calves upon blood serum composition. J. of Anim. Sci. 48:430.

Curley Jr. K. O., J. C. Paschal, T. H. Welsh Jr., and R. D. Randel. 2006. Technical note: Exit velocity as a measure of cattle temperament is repeatable and associated with serum concentration of cortisol in Brahman bulls. J. Anim. Sci. 84:3100–3103. doi:10.2527/jas.2006-055

Da Silva Coutinho, M. A., P. M. Ramos, S. da L. e Silva, L. S. Martello, A. S. C. Pereira, and E. F. Delgado. 2017. Divergent temperaments are associated with beef tenderness and the inhibitory activity of calpastatin. Meat Sci. 134:61-67. doi:10.1016/j.meatsci.2017.06.017.

Dadi, H., S. J. Schoeman, and G. F. Jordaan. 2004. Estimation of (Co)variance of Growth Components and Genetic Parameters Traits in Beef Cattle. J. Appl. Anim. Res. 26:77-82. doi: 10.1080/09712119.2004.9706512.

Doyle, S. P., B. L. Golden, R. D. Green, and J. S. Brinks. 2000. Additive genetic parameter estimates for heifer pregnancy and subsequent reproduction in Angus females. J. Anim. Sci. 78:2091–2098. doi.org/10.2527/2000.7882091x.

El-Saied U. M. , L. F. de la Fuente, R. Rodríguez, and F. San Primitivo. 2006. Genetic parameter estimates for birth and weaning weights, pre-weaning daily weight gain and three type traits for Charolais beef cattle in Spain. Spanish Journal of Agricultural Research 4(2):146-155.

Eler, J. P., L. D. Van Vleck, J. B. Ferraz, and R. B. Lôbo. 1995. Estimation of variances due to direct and maternal effects for growth traits of Nelore cattle. 73(11):3253-3258.doi.org/10.2527/1995.73113253x.

Eriksson S., A. Nasholm, K. Johansson, J. Philipson. 2004. Genetic parameters for calving difficulty, stillbirth, and birth weight for Hereford and Charolais at first and later parities. J Anim Sci 82:375-383. doi.org/10.2527/2004.822375x.

Evans, J. L., B. L. Golden, R. M. Bourdon, and K. L. Long. 1999. Additive genetic relationships between heifer pregnancy and scrotal circumference in Hereford cattle. J. Anim. Sci. 77:2621–2628. doi.org/10.2527/1999.77102621x.

Fell, L. R., I. G. Colditz, K. H. Walker and D. L. Watson. 1999. Associations between temperament, performance and immune function in cattle entering commercial feedlot. Aust. J. of Exp. Ag. 39 (7):795–802. doi.org/10.1071/EA99027.

Fordyce, G., M. E. Goddard and G. W. Seifert. 1982. The measurement of temperament in cattle and the effect of experience and genotype. Proc. Aust. Soc. Anim. Prod. 14:329–332.

Fordyce, G., J. R. Wythes, W. R. Shorthose, D. W. Underwood, and R. K. Shepherd. 1988. Cattle temperaments in extensive beef herds in northern Queensland. 2. Effect of temperament on carcass and meat quality. Australian Journal of Experimental Ag. 28(6):689 – 693. doi.org/10.1071/EA9880689.

Francisco, C. L., F. D. Resende, J. M. B. Benatti, A. M. Castilhos, R. F. Cooke, and A. M. Jorge. 2015. Impacts of temperament on Nellore cattle: physiological responses, feedlot performance, and carcass characteristics. J. Anim. Sci. 93:5419–5429. doi:10.2527/jas.2015-9411.

Francisco, C. L., R. F. Cooke, R. S. Marques, R. R. Mills, and D. W. Bohnert. 2012. Effects of temperament and acclimation to handling on feedlot performance of *Bos taurus* feeder cattle originated from a rangeland-based cow–calf system. J. Anim. Sci. 90:5067–5077. doi:10.2527/jas2012-5447.

Franke, D. E., O. Habet , L. C. Tawah, A. R. Williams, and S. M. DeRouen. 2001. Direct and maternal genetic effects on birth and weaning traits in multibreed cattle data and predicted performance of breed crosses. J. Anim. Sci. 2001. 79:1713–1722. doi.org/10.2527/2001.7971713x.

Friedrich, J., B. Brand, and M. Schwerin. 2015. Genetics of cattle temperament and its impact on livestock production and breeding – a review. Arch. Anim. Breed. 58:13–21 doi:10.5194/aab-58-13-2015.

Gardner, B. A., H. G. Dolezal, L. K. Bryant, F. N. Owens, and R. A. Smith. 1999. Health of finishing steers: Effects on performance, carcass traits, and meat tenderness. J. of Anim. Sci., 77:3168–3175.doi.org/10.2527/1999.77123168x.

Garza-Brenner, E., A. M. Sifuentes-Rincon, F. A. Rodriguez-Almaeida, R. D. Randel, G. M. Parra-Bracamonte, and W. Arellano-Vera. 2020. Influence of temperament-related genes on live weight traits of Charolais cows. R. Bras. 49. doi.org/10.37496/rbz4920180121.

Gauly, M., H. Mathiak, K. Hoffman, M. Kraus, and G. Erhardt. Estimating genetic variability in temperamental traits in German Angus and Simmental cattle. 2001. App. Anim. Behav. Sci. 74:109-119. doi.org/10.1016/S0168-1591(01)00151-4.

Grandin, T. 1989. Behavioral principles of livestock handling. The Professional Animal Scientist. 5(2):1-11. doi.org/10.15232/S1080-7446(15)32304-4.

Grandin, T. 1993. Behavioral agitation during handling of cattle is persistent over time. Appl. Anim. Behav. Sci. 36:1-9. doi:10.1016/0168-1591(93)90094-6.

Grandin, T., M. J. Deesing, J. J. Struthers, and A. M. Swinker. 1995. Cattle with hair whorl patterns above the eyes are more behaviorally agitated during restraint. Appp. Ani. Bev. Sci. 46:1-2. doi:10.1016/0168-1591(95)00638-9.

Grandin, T. 2018. Assessment of Temperament in Cattle and Its Effect on Weight Gain and Meat Quality and Other Research on Hairwhorls, Coat Color, Bone Thickness, and Fertility. http://grandin.com/behaviour/principles/assessment.temperament.html.

Groeneveld E., B. E. Mostert, T. Rust. 1998. The covariance structure of growth traits in the Afrikaner beef population. Liv. Prod Sci. 55:99-107. doi.org/10.1016/S0301-6226(98)00132-8.

Glenske, K., Brandt, H., Prinzenberg, E.-M., Gauly, M., and Erhardt, G. (2011). Verification of a QTL on BTA1 for temperament in German Simmental and German Angus calves. Archiv. Anim. Breed. 53:388-392. doi.org/10.5194/aab-53-388-2010.

Golden, B. L., D. J. Garrick, S. Newman, and R. M. Enns. 2000. Economically relevant traits a framework for the next generation of EPDS. Pages 2–13 in 32nd Annual Research Symposium. Beef Improv. Fed., Raleigh, NC.

Haskell, J. H., G. Simm, and S. P. Turner. 2014. Genetic selection for temperament traits in dairy and beef cattle. Front. Genet. 5:368. doi:10.3389/fgene.2014.00368.

Hearnshaw, H., R. Barlow, and G. Want. 1979. Development of a “temperament” or “handling difficulty” score for cattle. Proc. Assoc. Advmt. Anim. Breed. Genet 1:164-166. http://www.aaabg.org/livestocklibrary/1979/ab79049.pdf. (assessed 10 January 2021).

Hearnshaw, H., C. A. Morris. 1984. Genetic and environmental effects on temperament score in beef cattle. Aus. J. of Ag. Res. 35(5) 723-733. doi.org/10.1071/AR9840723.

Herd, R. M., V. H. Oddy and E. C. Richardson. 2004. Biological basis for variation in residual feed intake in beef cattle. 1. Review of potential mechanisms. Aust. J. of Exp. Ag. 44(5):423-430. doi.org/10.1071/EA02220.

Hieber, J. K. 2016. Temperament evaluation in beef cattle: understanding evaluator bias within subjective measurements of docility score, temperament score, and qualitative behavior assessment. M. S. Thesis. Department of Animal Sciences, North Dakota State University.

Hine, B. C., A. M Bell, D. D. O. Niemeyer, C. J. Duff, N. M. Butcher, S. Dominik, A. B. Ingham, and I. G. Colditz. 2019. Immune competence traits assessed during the stress of weaning are heritable and favorably genetically correlated with temperament traits in Angus cattle. J. of Anim. Sci. 97(10):4053–4065. doi.org/10.1093/jas/skz260.

Holland, M. D., and K. G. Odde. 1992. Factors affecting calf birth weight: A review. Theriogenology 38:769-798. doi.org/10.1016/0093-691X(92)90155-K.

Hoppe, S., H. R. Brandt, S. Konig, G. Erhardt, and M. Gauly. 2010. Temperament traits of beef calves measured under field conditions and their relationships to performance. J. Anim. Sci. 88:1982-1989. doi:10.2527/jas.2008-1557.

Hulsman, L. L., D. J. Garrick, C. A. Gill, J. O. Sanders, and D. G. Riley. 2013. Investigation of genomic estimated breeding values and association of methodologies using Bayesian inference in a Nellore-Angus crossbred population for two traits. Ph.D. Dissertation. Texas A&M University, College Station.

Hulsman Hanna, L. L., D. J. Garrick, C. A. Gill, A. D. Herring, J. O. Sanders, and D. G. Riley. 2014. Comparison of breeding value prediction for two traits in a Nellore-Angus crossbred population using different Bayesian modeling methodologies. Genet. Mol. Biol. 37:631-637. doi:10.1590/s1415-47572014005000021.

Hulsman Hanna, L. L., Garrick, D. J., Gill, C. A., Herring, A. D., Riggs, P. K., Miller, R. K., et al. 2014. Genome-wide association study of temperament and tenderness using Bayesian approaches in a Nellore-Angus crossbred population. *Livest. Sci*. 161:17–27. doi: 10.1016/j.livsci.2013.12.012.

Hulsman Hanna, L. L., J. K. Hieber, H. Yu, E. F. Celestino Jr., C. R. Dahlen, S. A. Wagner, and D. G. Riley. 2019. Blood collection has negligible impact on scoring temperament in Angus based weaned calves. Liv. Sci. 230:103835. doi:10.1016/j.livsci.2019.103835.

Kadel, M. J., D. J. Johnston, H. M. Burrow, H. Graser, and D. M. Ferguson. 2006. Genetics of flight time and other measures of temperament and their value as selection criteria for improving meat quality traits in tropically adapted breeds of beef cattle. Australian Journal of Agricultural Research 57(9):1029-1035. doi.org/10.1071/AR05082.

Kaiser, H. F. 1960. The application of electronic computers to factor analysis. Educ. Psychol. Meas. 20:141-151.

Kasimanickam, R. 2014. Influence of temperament score and handling facility on stress, reproductive hormone concentrations, and fixed time AI pregnancy rates in beef heifers. Reprod. Domest. Anim. 49:775–782. doi.org/10.1111/rda.12368.

Kasimanickam, R., S. Schroeder, M. Assay, V. Kasimanickam, D. A. Moore, J. M. Gay, and W. D. Whittier. 2014. Influence of temperament score and handling facility on stress, reproductive hormone concentrations, and fixed time AI pregnancy rates in beef heifers. Reprod. Dom. Anim. 49:775–782. doi: 10.1111/rda.12368.

Kasimanickam, V. R., R. L. Abdel Aziz, H. M. Williams, R. K. Kasimanickam. 2018. Predictors of beef cattle temperament at weaning and its impact on temperament at breeding and reproductive performance. Reprod. Dom. Anim. 53:484-494. doi: 10.1111/rda.13135.

Kasimanickam, R., M Asay, S. Schroeder, V. Kasimanickam, J. M. Gay, J. P. Kastelic, J. B. Hall and W. D. Whittier. 2014. Calm Temperament Improves Reproductive Performance of Beef Cows. Reprod. Dom. Anim. 49:1063–1067. doi: 10.1111/rda.12436.

Kertz, A. F., L. F. Reutzel, B. A. Barton, and R. L. Ely. 1997. Body weight, body condition score, and wither height of prepartum Holstein cows and birth weight and sex of calves by parity: A database and summary. J. Dairy Sci. 80:525–529. doi.org/10.3168/jds.S0022-0302(97)75966-6.

Kilgour, R., 1975. Open-field test as an assessment of temperament in dairy cows. Anim. Behav. 23:615-624. https://doi.org/10.1016/0003-3472(75)90139-6.

Kim, N. Y., J. K. Son, I. C. Cho, S. M. Shin, S. H. Park, P. N Seong, J. H. Woo, N. G. Park, and H. B. Park. 2018. Estimation of genetic parameters for temperament in Jeju crossbred horses. Asian-Australas J Anim Sci. 31(8):1098–1102. doi: 10.5713/ajas.17.0252.

King, D. A., C. E. Schuehle Pfeiffer, R. D. Randel, T. H. Welsh Jr., R. A. Oliphint, B. E. Baird, K. O Curley Jr., R. C. Vann, D. S. Hale, and J. W. Savell. 2006. Influence of animal temperament and stress responsiveness on the carcass quality and beef tenderness of feedlot cattle. Meat Science, 74:546–556. doi: 10.1016/j.meatsci.2006.05.004.

Koch, R. M., 1972. The role of maternal effect in animal breeding: VI. Maternal effects in beef cattle. J. of Anim. Sci. 35(6):1316-1323. doi: 10.2527/jas1972.3561316x.

Lanier, J. L., T. Grandin, R. D. Green, D. Avery, and K. McGee. 2000. The relationship between reaction to sudden, intermittent movements and sounds and temperament. J. of Ani. Sci., Vol. 78(6):1467–1474. doi.org/10.2527/2000.7861467x.

Lanier, J.L., and T. Grandin. 2002. The relationship between Bos Taurus feedlot cattle temperament and foreleg bone measurements. Western Section, American Society of Ani. Sci. 53:97-98. http://hdl.handle.net/10217/4349 (accessed 12 November 2020).

Le Neindre, P., X. Boivin, and A. Boissy. 1996. Handling of extensively kept animals. App. Ani. Behav. Sci. 49:73-81. doi:10.1016/0168-1591(95)00669-9.

Ledesma R. D., and P. Valero-Mora. 2007. Determining the number of factors to retain in EFA: an easy to use computer program for carrying out parallel analysis. Pract. Assess. & Eval. 12(2):1-11. doi.org/10.7275/wjnc-nm63.

Llonch P., M. Somarriba, C. A. Duthie, M. J. Haskell, J. A. Rooke, S. Troy, R. Roehe, and S. P. Turner. 2016. Association of Temperament and Acute Stress Responsiveness with Productivity, Feed Efficiency, and Methane Emissions in Beef Cattle: An Observational Study. Front. Vet. Sci. 13. doi.org/10.3389/fvets.2016.00043.

Meyer, K., K. Hammond, P. F. Parnell, M. J. MacKinnon, and S. Sivarajasingam. 1990. Estimates of heritability and repeatability for reproductive traits in Australian beef cattle. Liv. Prod. Sci. 25:15-30. doi.org/10.1016/0301-6226(90)90038-8.

Montaldo, H. H., And B. P. Kinghorn. 2003. Additive and non-additive, direct and maternal genetic effects for growth traits in a multibreed population of beef cattle. Arch Med Vet 35(2):243-248.

Nkrumah, J. D., D. H. Crews, Jr, J. A. Basarab, M. A. Price, E. K. Okine, Z. Wang, C. Li, and S. S. Moore. 2007. Genetic and phenotypic relationships of feeding behavior and temperament with performance, feed efficiency, ultrasound, and carcass merit of beef cattle. J. of Anim. Sci. 85(10):2382–2390. doi.org/10.2527/jas.2006-657.

Norris, D., J.W. Ngambi, M. Mabelebele, O.J. Alabi and K. Benyi. 2014. Genetic Selection for Docility: A Review. The J. of Anim. & Plant Sci., 24(2): 374-379.

Oliphint, R. A. 2006. Evaluation of the inter-relationships of temperament, stress responsiveness and immune function in beef calves. Master's thesis, Texas A&M University. Texas A&M University.

Olmos, G., and S. P. Turner. 2008. The relationships between temperament during routine handling tasks, weight gain and facial hair whorl position in frequently handled beef cattle. App. Anim. Beh. Sci. 115:25-36. doi.org/10.1016/j.applanim.2008.05.001.

Paranhos da Costa M. J. R., U. Piovezan, , J. N. S. G. Cyrillo, and A.G. Razook. 2002. Genetic factors affecting cattle temperament in four beef breeds. 7th World Congress on Genetics Applied to Livestock Production, August 19-23, 2002, Montpellier, France.

Parham J. T., A. E. Tanner, M. L. Wahlberg, T. Grandin, and R. M. Lewis. 2019. Subjective methods to quantify temperament in beef cattle are insensitive to the number and biases of observers. J. Appl. Anim. 212:30-35. doi.org/10.1016/j.applanim.2019.01.005.

Parham J. T., A. E. Tanner. K. Barkley, L. Pullen, M. L. Wahlberg, W. S. Swecker Jr., and R. M. Lewis. 2019. Temperamental cattle acclimate more substantially to repeated handling. J. Appl. Anim. 222:36-43. doi.org/10.1016/j.applanim.2019.01.001.

Petherick, J.C., Holroyd, R.G., Doogan, V.J., and Venus, B.K., 2002. Productivity, carcass and meat quality of lot-fed *Bos indicus* cross steers grouped according to temperament. Aust. J. Exp. Agr. 42:389-398. doi.org/10.1071/EA01084.

Petherick, J. C., V. J. Doogan, R. G. Holroyd, P. Plsson, and B. K. Venus. 2009. Quality of handling and holding yard environment, and beef cattle temperament: 1. Relationships with flight speed and fear of humans. App. Ani. Beh. Sci. 120:18-27. doi:10.1016/j.applanim.2009.05.008.

Phocas, F., X. Boivin, J. Sapa, G. Trillat, A. Boissy, and P. Le Neindre. 2006. Genetic correlations between temperament and breeding traits in Limousin heifers. Anim. Sci. 82:805-811. doi:10.1017/asc200696.

Prayaga, K. C. 2003. Evaluation of beef cattle genotypes and estimation of direct and maternal genetic effects in a tropical environment. 2. Adaptive and temperament traits. Australian Journal of Agricultural Research. 54(10):1027 – 1038. doi:10.1071/AR03072.

Prayaga, K. C., and J. M. Henshall. 2005. Adaptability in tropical beef cattle: Genetic parameters of growth, adaptive and temperament traits in a crossbred population. Aust. J. Exp. Agric. 45:971–983. doi:10.1071/EA05045.

Randal, J. T., A. E. Tanner, M. L. Wahlberg, T. Grandin, R. M. Lewis. 2019. Subjective methods to quantify temperament in beef cattle are insensitive to the number and biases of observers. Appl. Anim. Behav. Sci. 212:30-35. doi:10.1016/j.applanim.2019.01.005.

Randel, R. D., R. C. Vann, and T. H. Welsch, Jr. 2012. Selection tools for temperament. Proceedings paper. Beef Improvement Federation Research Symposium and Annual Meeting. April 18-21, 2012. Houston, Texas.

Réale, D., S. M. Reader, D. Sol, P. T. McDougall, and N. J. Dinge-manse, 2007. Integrating animal temperament within ecology and evolution, Biol. Rev. 8:291–318. doi: 10.1111/j.1469-185X.2007.00010.x

Riley, D. G., C. A. Gill, A. D., Herring, P. K. Riggs, J. E. Sawyer, D. K. Lunt, J. O. Sanders. 2014. Genetic evaluation of aspects of temperament in Nellore-Angus calves. J Anim Sci. 92(8):3223-30. doi: 10.2527/jas.2014-7797.

Rose, S., Grandin, T., and Wailes, W.R. 2002. The relationship between Holstein head coloration and temperament. Animal Sciences Research Report. Colorado State University. pp. 147-148.

Sant'Anna, A. C., and M. J. R. Paranhos da Costa, F. Baldi, P. M. Rueda, and L. G. Albuquerque. 2012. Genetic associations between flight speed and growth traits in Nellore cattle. J. Anim. Sci. 90:3427–3432. doi:10.2527/jas2011-5044.

Sant'Anna, A. C., and M. J. R. Paranhos da Costa. 2013. Validity and feasibility of qualitative behavior assessment for the evaluation of Nellore cattle temperament. Livest. Sci. 157:254-262. doi:10.1016/j.livsci.2013.08.004.

Sant’Anna, A. C., F. Baldi, T. S. Valente, L. G. Albuquerque, L. M. Menezes, A. A. Boligon, M. J. R. Paranhos da Costa. 2014. Genetic associations between temperament and performance traits in Nellore beef cattle. J. of Anim. Breed. Genet. 132(1):42-50. doi:10.1111/jbg.12117.

Schmidt S. E., D. A. Neuendorff, D. G. Riley, R. C. Vann, S. T. Willard, T. H. Welsh, Jr., and R. D. Randel**.** Genetic parameters of three methods of temperament evaluation of Brahman calves. *J. of Anim. Sci*. 92(7):3082–3087. doi:10.2527/jas.2013-7494.

Schrooten, C., H. Bovenhuis, W. Coppieters, and J. A. M. Van Arendonk. 2000. Whole Genome Scan to Detect Quantitative Trait Loci for Conformation and Functional Traits in Dairy Cattle, J. Dairy Sci. 83:795–806. https://doi.org/10.3168/jds.S0022-0302(00)74942-3.

Schwartzkopf-Genswein, K. S., J. M. Stookey, and R. Welford. 1997. Behavior of Cattle During Hot-Iron and Freeze Branding and the Effects on Subsequent Handling Ease. J. Anim. Sci. 75:2064–2072. doi.org/10.2527/1997.7582064x.

Schwartzkopf-Genswein, K. S., J. M. Stookey, T. G. Crowe, and B. M. A. Genswein. 1998. Comparison of image analysis, exertion force, and behavior measurements for use in the assessment of beef cattle responses to hot-iron and freeze branding. J. of Ani. Sci. 76(4):972–979. doi:10.2527/1998.764972x.

Schmutz, S. M., J. M. Stookey, D. C. Winkelman-Sim, C. S. Waltz, Y. Plante, and F. C. Buchanan. 2001. A QTL Study of Cattle Behavioral Traits in Embryo Transfer Families. J. of Heredity. 92(3):290–292. doi:10.1093/jhered/92.3.290.

Sebastian T., J. M. Watts, J. M. Stookey, F. Buchanan, and C. Waldner. 2011. Temperament in beef cattle: Methods of measurement and their relationship to production. Can. J. Anim. Sci. 91:557-565. doi:10.4141/cjas2010-041.

Stookey, J. M., T. Nickel, J. Hanson, and S. Vandenbosch. 1994. A movement-measuring device for objectively measuring temperament in beef cattle and for use in determining factors that influence handling. J. Anim. Sci. 72(1):207.

Stephansen, R. S., A. Fogh, and E.Norberg. 2018. Genetic parameters for handling and milking temperament in Danish first-parity Holstein cows. J. of Dairy Sci. 101(12):11033-11039. doi:10.3168/jds.2018-14804.

Torres-Vázquez, J. A., and M. L. Spangler. 2016. Genetic parameters for docility, weaning weight, yearling weight, and intramuscular fat percentage in Hereford cattle. J. Anim. Sci. 94:21–27. doi:10.2527/jas2015-9566.

Tulloh, N. H. 1961. Behaviour of cattle in yards. II. Astudy of temperament. Anim. Behavior. 9:1–2. doi.org/10.1016/0003-3472(61)90046-X.

Turner, S. P., E. A. Navajas, J. J. Hyslop, D. W. Ross, R. I. Richardson, N. Prieto, M. Bell, M. C. Jack, and R. Roehe. 2011. Associations between response to handling and growth and meat quality in frequently handled *Bos taurus* beef cattle. J. of Ani. Sci. 89(12):4239–4248. doi.org/10.2527/jas.2010-3790.

Turner, S. P., M. C. Jack, and A. B. Lawrence. Precalving temperament and maternal defensiveness are independent traits but precalving fear may impact calf growth. J. of Ani. Sci. 91(9):4417-4425. doi:10.2527/jas.2012-5707.

Valente, T. S., O. D. Albito, A. C. Sant'Anna , R. Carvalheiroa, F. Baldia , L. G. Albuquerquea, and M. J. R. Paranhos da Costa. 2017. Genetic parameter estimates for temperament, heifer rebreeding, and stayability in Nellore cattle. Liv. Sci. 206:45-50. doi.org/10.1016/j.livsci.2017.10.010.

Vann, R. C., B. P. Littlejohn, D. G. Riley, T. H. Welsh, Jr., R. D. Randel, and S. T. Willard. 2017. The influence of cow temperament on temperament and performance of offspring. J. of Anim. Sci. 95(4):242. doi:10.2527/asasann.2017.496.

Vetters, M. D. D., T. E. Engle, J. K. Ahola, and T. Grandin. 2013. Comparison of flight speed and exit score as measurements of temperament in beef cattle. J. of Ani. Sci. 91(1):374–381. doi:10.2527/jas.2012-5122.

Voisinet, B. D., T. Grandin, J. D. Tatum, S. F. O'Connor, and J. J. Struthers. 1997. Feedlot cattle with calm temperaments have higher average daily gains than cattle with excitable temperaments. J. Anim. Sci. 75:892-896. doi:10.2527/1997.754892.

Weary, D. M., J. M. Huzzey, and M. A. G. von Keyserlingk. 2009. Using behavior to predict and identify ill health in animals. J. of Anim. Sci., 87:770–777. doi.org/10.2527/jas.2008-1297.

Waynert, D.F., J.M. Stookey, K.S. Schwartzkopf-Genswein, J.M. Watts, C.S. Waltz. 1999. The response of beef cattle to noise during handling. Applied Animal Behaviour Science 62(1):27–42. https://doi.org/10.1016/S0168-1591(98)00211-1.

Yu, H. 2016. The exploration of a four-platform standing scale in the application of measuring temperament in beef cattle. M. S. Thesis. Department of Animal Sciences, North Dakota State University.

Yu, H., G. Morota, E. F. Celestino, Jr., C. R. Dahlen, S. A. Wagner, D. G. Riley and L. L. Hulsman Hanna. 2020. Deciphering cattle temperament measures derived from a four-platform standing scale using genetic factor analytic modeling. Frontiers in Genetics: Livestock Genomics. doi: 10.3389/fgene.2020.00599.

Zaiontz, C. 2020. Real Statistics Using Excel. Available from www.real-statistics.com. https://www.real-statistics.com/free-download/real-statistics-resource-pack/.(Accessed March 2, 2021).

Zwick, W.R. and Velicer, W.F. 1986. Comparison of five rules for determining the number of components to retain. Psychological Bulletin, 99:432-442.

APPENDIX

Table A1. Least squares means and standard errors for primary breed effect on calf docility score (DS), temperament score (TS), Qualitative Behavior Assessment (QBA) attributes and temperament index (TI) on calf adjusted birth weight (ABW)[1].

Method[2]	Primary Breed				
	Angus	**N**	**Hereford**	**N**	**P-value[3]**
DS	86.36 ± 0.92	1348	87.50 ± 2.40	182	0.614
TS	86.67 ± 1.02	1348	87.77 ± 2.37	182	0.627
QBA					
Positive QBA					
Apathetic	87.49 ± 0.74	1348	88.75 ± 2.33	182	0.576
Calm	86.49 ± 0.50	1153	87.64 ± 2.24	150	0.608
Curious	85.21 ± 2.45	1347	86.39 ± 3.30	183	0.602
Happy	87.21 ± 0.63	1348	88.38 ± 2.28	182	0.603
Pos. occupied	85.41 ± 0.77	1348	86.60 ± 2.33	182	0.596
Relaxed	86.73 ± 0.51	1348	87.90 ± 2.24	182	0.603
Negative QBA					
Active	86.01 ± 0.60	1348	87.30 ± 2.25	182	0.565
Agitated	85.57 ± 1.29	1348	86.75 ± 2.50	182	0.597
Attentive	86.26 ± 1.08	1343	87.58 ± 2.46	186	0.562
Distressed	84.38 ± 1.78	1348	85.56 ± 2.84	182	0.602
Fearful	89.36 ± 2.45	1348	90.54 ± 3.27	182	0.600
Irritated	86.02 ± 1.76	1346	87.20 ± 2.80	184	0.600
TI	86.48 ± 0.50	1348	87.61 ± 2.25	182	0.617
TI positive	86.66 ± 0.49	1348	87.78 ± 2.23	182	0.614
TI negative	86.64 ± 0.49	1348	87.78 ± 2.23	182	0.609
SSD	86.52 ± 0.50	1348	87.64 ± 2.27	182	0.623
CVSSD	86.52 ± 0.50	1348	87.70 ± 2.26	182	0.602

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, sex, year, and random effect of animal with known pedigree. Docility score: scale of 1 to 6 with 1 = docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence, and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index: the first principal component score generated from QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[3]$P < 0.05$ within row is significant.

Table A2. Least squares means and standard errors for sex effect on calf docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) on calf adjusted birth weight (ABW)[1].

Method[2]	**Sex**				
	Steer	**N**	**Heifer**	**N**	**P-value**[3]
DS	90.02 ± 1.45	775	83.84 ± 1.43	748	<0.001
TS	90.26 ± 1.47	775	84.17 ± 1.46	748	<0.001
QBA					
Positive QBA					
Apathetic	91.16 ± 1.34	775	85.08 ± 1.32	748	<0.001
Calm	90.08 ± 1.20	775	84.06 ± 1.19	748	<0.001
Curious	88.87 ± 2.69	775	82.72 ± 2.68	748	<0.001
Happy	90.86 ± 1.27	775	84.72 ± 1.26	748	<0.001
Pos. occupied	89.08 ± 0.34	775	82.93 ± 1.34	748	<0.001
Relaxed	90.31 ± 1.21	775	84.32 ± 1.20	748	<0.001
Negative QBA					
Active	89.70 ± 1.24	775	83.62 ± 1.23	748	<0.001
Agitated	89.20 ± 1.67	775	83.11 ± 1.65	748	<0.001
Attentive	90.00 ± 1.56	775	83.84 ± 1.54	748	<0.001
Distressed	81.90 ± 2.09	775	88.04 ± 2.10	748	<0.001
Fearful	93.00 ± 2.68	775	86.90 ± 2.67	748	<0.001
Irritated	89.67 ± 2.07	775	83.56 ± 2.07	748	<0.001
TI	90.12 ± 1.21	775	83.96 ± 1.20	748	<0.001
TI positive	90.25 ± 1.20	775	84.19 ± 1.19	748	<0.001
TI negative	90.23 ± 1.20	775	84.19 ± 1.19	748	<0.001
SSD	90.14 ± 1.22	775	84.02 ± 1.21	748	<0.001
CVSSD	90.19 ± 1.21	775	84.03 ± 1.21	748	<0.001

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, sex, year, and random effect of animal with known pedigree. Docility score: scale of 1 to 6 with 1 = docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence, and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index: the first principal component score generated from QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[3]$P < 0.05$ within row is significant.

Table A3. Least squares means and standard errors for year effect on calf docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) on calf adjusted birth weight (ABW)[1].

Method[2]	**Year**								
	2014	**N**	**2015**	**N**	**2016**	**N**	**2017**	**N**	**P-value**
DS	87.99 ± 0.53	420	86.30 ± 1.50	372	84.44 ± 1.56	335	88.99 ± 1.52	393	<0.001
TS	88.06 ± 1.55	420	86.66 ± 1.53	382	85.02 ± 1.57	337	89.13 ± 1.52	403	<0.001
QBA									
Positive QBA									
Apathetic	88.33 ± 1.45	420	87.77 ± 1.42	379	86.45 ± 1.51	335	89.93 ± 1.36	396	0.003
Calm	87.03 ± 1.33	420	86.91 ± 1.27	379	85.34 ± 1.33	335	88.99 ± 1.28	396	<.001
Curious	86.80 ± 2.71	420	85.16 ± 2.75	379	83.35 ± 2.74	335	87.89 ± 2.74	396	<.001
Happy	87.81 ± 1.35	420	87.66 ± 1.42	379	85.88 ± 1.48	335	89.83 ± 1.34	396	<.001
Pos. occupied	86.91 ± 1.38	420	85.49 ± 1.48	379	83.54 ± 1.50	335	88.07 ± 1.45	396	<.001
Relaxed	87.51 ± 1.33	420	87.13 ± 1.28	379	85.41 ± 1.34	335	89.23 ± 1.28	396	<.001
Negative QBA									
Active	87.14 ± 1.36	420	86.11 ± 1.30	379	85.03 ± 1.36	335	88.36 ± 1.31	396	0.002
Agitated	86.87 ± 1.76	420	85.76 ± 1.70	379	83.83 ± 1.75	335	88.17 ± 1.73	396	<.001
Attentive	88.20 ± 1.64	420	85.94 ± 1.61	379	84.72 ± 1.67	335	88.82 ± 1.62	396	<.001
Distressed	85.99 ± 2.14	420	84.36 ± 2.12	379	82.50 ± 2.18	335	87.03 ± 2.16	396	<.001
Fearful	90.46 ± 2.74	420	89.30 ± 2.72	379	88.06 ± 2.72	335	91.97 ± 2.72	396	<.001
Irritated	87.56 ± 2.15	420	86.02 ± 2.09	379	84.23 ± 2.14	335	88.64 ± 2.12	396	<.001
TI	88.41 ± 1.32	420	86.23 ± 1.28	379	84.44 ± 1.33	335	89.08 ± 1.28	396	<.001
TI positive	87.22 ± 1.32	420	87.05 ± 1.28	379	85.28 ± 1.33	335	89.33 ± 1.28	396	<.001
TI negative	88.27 ± 1.30	420	86.55 ± 1.27	379	84.96 ± 1.32	335	89.05 ± 1.27	396	<.001
SSD	88.04 ± 1.32	420	86.54 ± 1.29	379	84.47 ± 1.35	335	89.26 ± 1.29	396	<.001
CVSSD	88.12 ± 1.32	420	86.44 ± 1.29	379	84.68 ± 1.34	335	89.21 ± 1.30	396	<.001

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, sex, year, and random effect of animal with known pedigree. Docility score: scale of 1 to 6 with 1 = docile and 6 = very aggressive. [3]Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index: the first principal component score generated from QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[3]$P < 0.05$ within row is significant.

Table A4. Least squares means and standard errors for primary breed effect on calf docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) on calf adjusted 205 weaning weight (205-d WW)[1].

Method[2]	**Primary Breed**				
	Angus	**N**	**Hereford**	**N**	**P-value[3]**
DS	634.44 ± 5.61	1341	639.70 ± 13.37	182	0.682
TS	630.69 ± 6.19	1341	636.64 ± 13.35	182	0.645
QBA					
Positive QBA					
Apathetic	629.56 ± 4.64	1341	635.07 ± 12.95	182	0.667
Calm	632.59 ± 3.47	1341	638.01 ± 12.57	182	0.673
Curious	626.16 ± 13.96	1341	631.63 ± 18.54	182	0.672
Happy	634.11 ± 4.03	1341	639.80 ± 12.81	182	0.659
Pos. occupied	640.18 ± 4.74	1341	646.05 ± 13.04	182	0.649
Relaxed	632.37 ± 3.51	1341	637.91 ± 12.59	182	0.667
Negative QBA					
Active	633.21 ± 3.94	1341	638.42 ± 12.64	182	0.685
Agitated	636.76 ± 7.64	1341	642.11 ± 14.11	182	0.678
Attentive	636.34 ± 6.49	1341	642.23 ± 13.73	182	0.647
Distressed	617.67 ± 10.25	1341	623.24 ± 15.87	182	
Fearful	646.43 ± 14.01	1341	652.30 ± 18.52	182	0.649
Irritated	638.08 ± 10.26	1341	643.70 ± 15.79	182	0.662
TI	632.73 ± 3.45	1341	638.22 ± 12.50	182	0.667
TI positive	632.46 ± 3.47	1341	637.95 ± 12.60	182	0.670
TI negative	632.47 ± 3.47	1341	637.83 ± 12.63	182	0.678
SSD	632.19 ± 3.44	1341	636.73 ± 12.50	182	0.722
CVSSD	632.38 ± 3.47	1341	638.01 ± 12.62	182	0.663

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, sex, year, and random effect of animal with known pedigree. Docility score: scale of 1 to 6 with 1 = docile and 6 = very aggressive. [3]Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index: the first principal component score generated from QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[3]$P < 0.05$ within row is significant.

Table A5. Least squares means and standard errors for sex effect on calf docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) on calf adjusted 205 weaning weight (205-d WW)[1].

Method[2]	**Sex**				
	Steer	**N**	**Heifer**	**N**	**P-value**[3]
DS	649.21 ± 8.22	775	624.93 ± 8.05	748	<0.001
TS	645.77 ± 8.37	775	621.55 ± 8.24	748	<0.001
QBA					
Positive QBA					
Apathetic	644.49 ± 7.57	775	620.14 ± 7.40	748	<0.001
Calm	647.42 ± 6.84	775	623.17 ± 6.74	748	<0.001
Curious	640.96 ± 15.20	775	616.82 ± 15.14	748	<0.001
Happy	649.00 ± 7.17	775	624.92 ± 7.09	748	<0.001
Pos. occupied	655.11 ± 7.59	775	631.12 ± 7.52	748	<0.001
Relaxed	647.26 ± 6.86	775	623.02 ± 6.77	748	<0.001
Negative QBA					
Active	647.93 ± 7.03	775	623.71 ± 6.93	748	<0.001
Agitated	651.56 ± 9.54	775	627.31 ± 9.38	748	<0.001
Attentive	651.52 ± 8.80	775	627.05 ± 8.67	748	<0.001
Distressed	632.49 ± 11.87	775	608.42 ± 11.74	748	<0.001
Fearful	661.51 ± 5.25	775	637.23 ± 15.12	748	<0.001
Irritated	653.00 ± 11.79	775	628.78 ± 11.72	748	<0.001
TI	647.51 ± 6.80	775	623.44 ± 6.70	748	<0.001
TI positive	647.30 ± 6.85	775	623.11 ± 6.75	748	<0.001
TI negative	647.18 ± 6.87	775	623.12 ± 6.77	748	<0.001
SSD	646.17 ± 6.80	775	622.74 ± 6.70	748	<0.001
CVSSD	647.23 ± 6.86	775	623.16 ± 6.76	748	<0.001

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, sex, year, and random effect of animal with known pedigree. Docility score: scale of 1 to 6 with 1 = docile and 6 = very aggressive. [3]Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index: the first principal component score generated from QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.
[3]$P < 0.05$ within row is significant.

Table A6. Least squares means and standard errors for year effect on calf docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) on calf adjusted 205 weaning weight (205-d WW)[1].

Method[2]	Year 2014	N	2015	N	2016	N	2017	N	P-value[3]
DS	582.65 ± 8.67[a]	420	612.57 ± 8.47[b]	382	647.42 ± 8.76[c]	337	705.65 ± 8.55[d]	403	<0.001
TS	580.05 ± 8.87[c]	420	609.86 ± 8.69[b]	382	643.21 ± 8.86[b]	337	701.53 ± 8.62[a]	403	<0.001
QBA									
Positive QBA									
Apathetic	582.95 ± 8.21[c]	420	607.60 ± 8.01[b,c]	382	638.08 ± 8.47[b]	337	700.64 ± 7.62[a]	403	<0.001
Calm	582.25 ± 7.59[c]	420	611.06 ± 7.23[b,c]	382	644.93 ± 7.51[b]	337	702.96 ± 7.19[a]	403	<.001
Curious	574.99 ± 15.34[c]	420	604.93 ± 15.56[b,c]	382	639.08 ± 15.50[b]	337	696.57 ± 15.47[a]	403	<0.001
Happy	581.03 ± 7.66[c]	420	614.07 ± 8.01[b,c]	382	648.12 ± 8.29[b]	337	704.61 ± 7.53[a]	403	<0.001
Pos. occupied	581.13 ± 7.86[c]	420	622.93 ± 8.37[b]	382	655.62 ± 8.45[b]	337	712.78 ± 8.16[a]	403	<0.001
Relaxed	582.06 ± 7.58[c]	420	610.89 ± 7.26[c]	382	644.76 ± 7.53[b]	337	702.84 ± 7.21[a]	403	<0.001
Negative QBA									
Active	582.28 ± 7.74[c]	420	611.95 ± 7.37[b,c]	382	644.97 ± 7.69[b]	337	704.06 ± 7.40[a]	403	<0.001
Agitated	585.76 ± 0.04[c]	420	615.40 ± 9.70[b]	382	649.46 ± 9.93[b]	337	707.11 ± 9.78[a]	403	<0.001
Attentive	585.74 ± 9.32[c]	420	614.12 ± 9.11[c]	382	650.80 ± 9.39[b]	337	706.49 ± 9.09[a]	403	<0.001
Distressed	566.66 12.11[c]	420	596.78 ± 11.98[b]	382	630.43 ± 12.28[b]	337	687.96 ± 12.13[a]	403	<0.001
Fearful	594.88 ± 5.55[c]	420	625.46 ± 5.41[b]	382	660.25 ± 5.39[b]	337	716.87 ± 15.45[a]	403	<0.001
Irritated	587.03 ± 12.26[c]	420	617.02 ± 1.88[b]	382	650.87 ± 12.14[b]	337	708.63 ± 12.03[a]	403	<0.001
TI	582.38 ± 7.46[c]	420	611.09 ± 7.20[c]	382	646.02 ± 7.45[b]	337	702.40 ± 7.16[a]	403	<0.001
TI positive	582.34 ± 7.55[c]	420	610.82 ± 7.27[b,c]	382	645.00 ± 7.52[b]	337	702.66 ± 7.22[a]	403	<0.001
TI negative	581.47 ± 7.48[c]	420	611.21 ± 7.24[b]	382	645.44 ± 7.50[b]	337	702.47 ± 7.23[a]	403	<0.001
SSD	579.79 ± 7.41[c]	420	612.86 7.19[b]	382	641.19 7.46[b]	337	703.99 ± 7.16[a]	403	<0.001
CVSSD	581.17 ± 7.49[c]	420	611.51 ± 7.25[b]	382	645.36 ± 7.52[b]	337	702.75 ± 7.25[a]	403	<0.001

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, sex, year, and random effect of animal with known pedigree.

[2]Docility score: scale of 1 to 6 with 1 = docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD. [abc]Superscripts within a row and a given scoring method that are different, differ ($P < 0.05$).

Table A7. Least squares means and standard errors for primary breed effect on calf docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) on weaning average daily gain (ADG)[1].

Method[2]	**Primary Breed**				
	Angus	**N**	**Hereford**	**N**	**P-value[3]**
DS	2.60 ± 0.03	1360	2.66 ± 0.07	182	0.348
TS	2.60 ± 0.03	1360	2.66 ± 0.07	182	0.332
QBA					
Positive QBA					
Apathetic	2.59 ± 0.02	1360	2.65 ± 0.07	182	0.325
Calm	2.60 ± 0.01	1360	2.66 ± 0.06	182	0.334
Curious	2.55 ± 0.07	1360	2.61 ± 0.10	182	0.330
Happy	2.60 ± 0.02	1360	2.67 ± 0.07	182	0.332
Pos. occupied	2.60 ± 0.02	1360	2.66 ± 0.07	182	0.330
Relaxed	2.60 ± 0.01	1360	2.66 ± 0.06	182	0.337
Negative QBA					
Active	2.60 ± 0.02	1360	2.66 ± 0.06	182	0.333
Agitated	2.63 ± 0.04	1360	2.69 ± 0.07	182	0.349
Attentive	2.61 ± 0.03	1360	2.68 ± 0.07	182	0.306
Distressed	2.50 ± 0.05	1360	2.56 ± 0.08	182	0.334
Fearful	2.70 ± 0.07	1360	2.76 ± 0.10	182	0.328
Irritated	2.63 ± 0.05	1360	2.69 ± 0.08	182	0.328
TI	2.59 ± 0.01	1360	2.66 ± 0.06	182	0.328
TI positive	2.60 ± 0.01	1360	2.66 ± 0.06	182	0.333
TI negative	2.60 ± 0.01	1360	2.66 ± 0.06	182	0.345
SSD	2.59 ± 0.01	1360	2.65 ± 0.06	182	0.390
CVSSD	2.59 ± 0.01	1360	2.66 ± 0.06	182	0.329

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, sex, year, and random effect of animal with known pedigree.

[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[3]$P < 0.05$ within row is significant.

Table A8. Least squares means and standard errors for sex effect on calf docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) on weaning average daily gain (ADG)[1].

Method[2]	**Sex**				
	Steer	**N**	**Heifer**	**N**	**P-value[3]**
DS	2.69 ± 0.04	775	2.56 ± 0.04	748	<0.001
TS	2.69 ± 0.04	775	2.57 ± 0.04	748	<0.001
QBA					
Positive QBA					
Apathetic	2.69 ± 0.04	775	2.56 ± 0.04	748	<0.001
Calm	2.69 ± 0.03	775	2.56 ± 0.03	748	<0.001
Curious	2.64 ± 0.08	775	2.52 ± 0.08	748	<0.001
Happy	2.70 ± 0.04	775	2.57 ± 0.04	748	<0.001
Pos. occupied	2.70 ± 0.04	775	2.57 ± 0.04	748	<0.001
Relaxed	2.69 ± 0.03	775	2.57 ± 0.03	748	<0.001
Negative QBA					
Active	2.69 ± 0.04	775	2.56 ± 0.04	748	<0.001
Agitated	2.72 ± 0.05	775	2.60 ± 0.05	748	<0.001
Attentive	2.71 ± 0.04	775	2.58 ± 0.04	748	<0.001
Distressed	2.59 ± 0.06	775	2.47 ± 0.06	748	<0.001
Fearful	2.79 ± 0.08	775	2.67 ± 0.08	748	<0.001
Irritated	2.73 ± 0.06	775	2.60 ± 0.06	748	<0.001
TI	2.69 ± 0.03	775	2.56 ± 0.03	748	<0.001
TI positive	2.69 ± 0.03	775	2.56 ± 0.03	748	<0.001
TI negative	2.69 ± 0.03	775	2.56 ± 0.03	748	<0.001
SSD	2.68 ± 0.03	775	2.56 ± 0.03	748	<0.001
CVSSD	2.69 ± 0.03	775	2.56 ± 0.03	748	<0.001

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, sex, year, and random effect of animal with known pedigree.

[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[3]$P < 0.05$ within row is significant.

Table A9. Least squares means and standard errors for year effect on calf docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) on weaning average daily gain (ADG)[1].

Method[2]	Year								
	2014	N	2015	N	2016	N	2017	N	P-value[3]
DS	2.35 ± 0.04^{c}	420	2.50 ± 0.04^{b}	379	2.67 ± 0.04^{b}	335	2.98 ± 0.04^{a}	396	<0.001
TS	2.36 ± 0.05^{c}	420	2.51 ± 0.04^{b}	379	2.67 ± 0.05^{b}	335	2.98 ± 0.04^{a}	396	<0.001
QBA									
Positive QBA									
Apathetic	2.37 ± 0.04^{c}	420	2.50 ± 0.04^{b,c}	379	2.65 ± 0.04^{b}	335	2.97 ± 0.04^{a}	396	<0.001
Calm	2.35 ± 0.04^{c}	420	2.51 ± 0.04^{b}	379	2.68 ± 0.04^{b}	335	2.97 ± 0.04^{a}	396	<0.001
Curious	2.31 ± 0.08^{c}	420	2.46 ± 0.08^{b,c}	379	2.63 ± 0.08^{b}	335	2.93 ± 0.08^{a}	396	<0.001
Happy	2.35 ± 0.04^{c}	420	2.52 ± 0.04^{b,c}	379	2.69 ± 0.04^{b}	335	2.98 ± 0.04^{a}	396	<0.001
Pos. occupied	2.34 ± 0.04^{c}	420	2.52 ± 0.04^{b,c}	379	2.68 ± 0.04^{b}	335	2.99 ± 0.04^{a}	396	<0.001
Relaxed	2.35 ± 0.04^{c}	420	2.51 ± 0.04^{b,c}	379	2.68 ± 0.04^{b}	335	2.97 ± 0.04^{a}	396	<0.001
Negative QBA									
Active	2.36 ± 0.04^{c}	420	2.51 ± 0.04^{b,c}	379	2.67 ± 0.04^{b}	335	2.97 ± 0.04^{a}	396	<0.001
Agitated	2.39 ± 0.05^{d}	420	2.54 ± 0.05^{b}	379	2.71 ± 0.05^{b}	335	3.01 ± 0.05^{a}	396	<0.001
Attentive	2.38 ± 0.05^{c}	420	2.51 ± 0.05^{b}	379	2.70 ± 0.05^{b}	335	2.99 ± 0.05^{a}	396	<0.001
Distressed	2.26 ± 0.06^{c}	420	2.41 ± 0.06^{b}	379	2.58 ± 0.06^{b}	335	2.88 ± 0.06^{a}	396	<0.001
Fearful	2.46 ± 0.08^{c}	420	2.61 ± 0.08^{b}	379	2.78 ± 0.08^{b}	335	3.08 ± 0.08^{a}	396	<0.001
Irritated	2.39 ± 0.06^{c}	420	2.54 ± 0.06^{b}	379	2.71 ± 0.06^{b}	335	3.01 ± 0.0 ^{a}	396	<0.001
TI	2.37 ± 0.04^{c}	420	2.50 ± 0.04^{b}	379	2.67 ± 0.04^{b}	335	2.97 ± 0.04^{a}	396	<0.001
TI positive	2.35 ± 0.04^{c}	420	2.51 ± 0.04^{b,c}	379	2.67 ± 0.04^{b}	335	2.97 ± 0.04^{a}	396	<0.001
TI negative	2.36 ± 0.04^{c}	420	2.50 ± 0.04^{b}	379	2.67 ± 0.04^{b}	335	2.97 ± 0.04^{a}	396	<0.001
SSD	2.35 ± 0.04^{c}	420	2.51 ± 0.04^{b}	379	2.65 ± 0.04^{b}	335	2.98 ± 0.04^{a}	396	<0.001
CVSSD	2.35 ± 0.04^{c}	420	2.51 ± 0.04^{b}	379	2.67 ± 0.04^{b}	335	2.97 ± 0.04^{a}	396	<0.001

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, sex, year, and random effect of animal with known pedigree.

[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD. ^{abc}Superscripts within a row and a given scoring method that are different, differ ($P < 0.05$).

Table A10. Least squares means and standard errors for primary breed effect on calf docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) on calf adjusted 205 weight gain (205-d WW)[1].

Method[2]	Primary Breed				
	Angus	N	Hereford	N	P-value[3]
DS	544.43 ± 5.27	1341	558.53 ± 13.61	182	0.272
TS	541.26 ± 5.89	1341	556.05 ± 13.58	182	0.251
QBA					
Positive QBA					
Apathetic	540.81 ± 4.24	1341	555.48 ± 13.20	182	0.253
Calm	542.71 ± 2.85	1341	557.18 ± 12.83	182	0.261
Curious	535.33 ± 14.05	1341	549.80 ± 18.83	182	0.261
Happy	545.35 ± 3.58	1341	559.83 ± 13.02	182	0.261
Pos. occupied	549.57 ± 4.38	1341	564.18 ± 13.26	182	0.256
Relaxed	542.77 ± 2.91	1341	557.30 ± 12.85	182	0.259
Negative QBA					
Active	542.97 ± 3.44	1341	557.43 ± 12.89	182	0.260
Agitated	546.41 ± 7.42	1341	560.70 ± 14.35	182	0.268
Attentive	545.96 ± 6.22	1341	560.98 ± 13.98	182	0.244
Distressed	525.89 ± 10.19	1341	540.35 ± 16.15	182	0.261
Fearful	559.34 ± 14.08	1341	574.00 ± 18.79	182	0.254
Irritated	546.96 ± 10.11	1341	561.80 ± 16.06	182	0.249
TI	542.55 ± 2.82	1341	557.33 ± 12.74	182	0.248
TI positive	542.74 ± 2.84	1341	557.25 ± 12.84	182	0.260
TI negative	542.74 ± 2.84	1341	556.96 ± 12.85	182	0.270
SSD	542.60 ± 2.81	1341	555.64 ± 12.72	182	0.307
CVSSD	542.60 ± 2.84	1341	557.13 ± 12.84	182	0.307

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, sex, year, and random effect of animal with known pedigree.

[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[3]$P < 0.05$ within a row is significant.

Table A11. Least squares means and standard errors for sex effect on calf docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) on calf weight gain (WG)[1].

Method[2]	**Sex**				
	Steer	**N**	**Heifer**	**N**	**P-value**[3]
DS	566.07 ± 8.28	776	536.89 ± 8.15	748	<0.001
TS	563.20 ± 8.43	776	534.11 ± 8.34	748	<0.001
QBA					
Positive QBA					
Apathetic	562.80 ± 7.62	776	533.49 ± 7.52	748	<0.001
Calm	564.45 ± 6.89	776	535.43 ± 6.85	748	<0.001
Curious	557.04 ± 15.42	776	528.08 ± 15.36	748	<0.001
Happy	567.04 ± 7.21	776	538.14 ± 7.20	748	<0.001
Pos. occupied	571.33 ± 7.66	776	542.43 ± 7.62	748	<0.001
Relaxed	564.51 ± 6.91	776	535.55 ± 6.88	748	<0.001
Negative QBA					
Active	564.75 ± 7.10	776	535.65 ± 7.04	748	<0.001
Agitated	568.10 ± 9.62	776	539.01 ± 9.48	748	<0.001
Attentive	568.09 ± 8.87	776	538.85 ± 8.78	748	<0.001
Distressed	547.56 ± 12.02	776	518.68 ± 11.91	748	<0.001
Fearful	581.16 ± 15.42	776	552.17 ± 15.35	748	<0.001
Irritated	568.91 ± 11.89	776	539.85 ± 11.86	748	<0.001
TI	564.39 ± 6.84	776	535.49 ± 6.80	748	<0.001
TI positive	564.49 ± 6.89	776	535.50 ± 6.85	748	<0.001
TI negative	564.22 ± 6.90	776	535.49 ± 6.86	748	<0.001
SSD	563.19 ± 6.83	776	535.05 ± 6.79	748	<0.001
CVSSD	564.35 ± 6.89	776	535.38 ± 6.85	748	<0.001

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, sex, year, and random effect of animal with known pedigree.

[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[3]$P < 0.05$ within row is significant.

Table A12. Least squares means and standard errors for year effect on calf docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) on calf weight gain (WG)[1].

Method[2]	**Year**								
	2014	**N**	**2015**	**N**	**2016**	**N**	**2017**	**N**	**P-value**
DS	496.72 ± 8.70^{c}	420	525.74 ± 8.54^{b,c}	372	559.65 ± 8.88^{b}	335	623.82 ± 8.68^{a}	396	<0.001
TS	494.57 ± 8.91^{c}	420	523.74 ± 8.76^{b}	372	556.23 ± 8.99^{b}	335	620.09 ± 8.74^{a}	396	<0.001
QBA									
Positive QBA									
Apathetic	497.68 ± 8.27^{c}	420	522.47 ± 8.10^{b,c}	372	552.46 ± 8.6^{b}	335	619.97 ± 7.74^{a}	396	<0.001
Calm	495.40 ± 7.63^{c}	420	525.02 ± 7.30^{b,c}	372	558.17 ± 7.64^{b}	335	621.17 ± 7.32^{a}	396	<0.001
Curious	488.36 ± 15.54^{c}	420	517.37 ± 15.79^{b,c}	372	550.58 ± 15.73^{b}	335	613.93 ± 15.7^{a}	396	<0.001
Happy	495.10 ± 7.68^{c}	420	529.14 ± 8.09^{b,c}	372	562.24 ± 8.43^{b}	335	623.87 ± 7.63^{a}	396	<0.001
Pos. occupied	494.75 ± 7.90^{c}	420	535.54 ± 8.47^{b}	372	567.07 ± 8.57^{b}	335	630.15 ± 8.30^{a}	396	<0.001
Relaxed	495.71 ± 7.62^{c}	420	525.08 ± 7.34^{b,c}	372	558.06 ± 7.67^{b}	335	621.28 ± 7.33^{a}	396	<0.001
Negative QBA									
Active	495.92 ± 7.79^{c}	420	525.20 ± 7.45^{b,c}	372	557.87 ± 7.82^{b}	335	621.81 ± 7.53^{a}	396	<0.001
Agitated	499.31 ± 0.09^{c}	420	528.53 ± 9.78^{b,c}	372	561.50 ± 10.06^{b}	335	624.88 ± 9.92^{a}	396	<0.001
Attentive	499.68 ± 9.37^{c}	420	526.91 ± 9.21^{b,c}	372	563.01 ± 9.52^{b}	335	624.27 ± 9.23^{a}	396	<0.001
Distressed	479.00 ± 12.25^{c}	420	508.27 ± 12.14^{b}	372	540.91 ± 12.46^{b}	335	604.31 ± 12.32^{a}	396	<0.001
Fearful	511.34 ± 15.73^{c}	420	541.57 ± 15.61^{b}	372	576.00 ± 15.6^{b}	335	637.75 ± 15.66^{a}	396	<0.001
Irritated	500.13 ± 12.35^{c}	420	529.34 ± 11.99^{b}	372	562.21 ± 12.28^{b}	335	625.83 ± 12.19^{a}	396	<0.001
TI	496.90 ± 7.49^{c}	420	524.14 ± 7.27^{b,c}	372	558.07 ± 7.57^{b}	335	620.66 ± 7.28^{a}	396	<0.001
TI positive	495.72 ± 7.58^{c}	420	524.95 ± 7.34^{b,c}	372	558.10 ± 7.64^{b}	335	621.20 ± 7.33^{a}	396	<0.001
TI negative	495.87 ± 7.50^{c}	420	524.72 ± 7.30^{b}	372	558.17 ± 7.61^{b}	335	620.65 ± 7.34^{a}	396	<0.001
SSD	494.09 ± 7.42^{c}	420	526.49 ± 7.24^{b}	372	553.52 ± 7.57^{b}	335	622.38 ± 7.27^{a}	396	<0.001
CVSSD	495.56 ± 7.51^{c}	420	524.92 ± 7.31^{b,c}	372	557.92 ± 7.63^{b}	335	621.05 ± 7.36^{a}	396	<0.001

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, sex, year, and random effect of animal with known pedigree.

[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[abc]Superscripts within a row and a given scoring method that are different, differ ($P < 0.05$).

Table A13. Genetic parameters estimation ($\hat{\sigma}_a^2$, $\hat{\sigma}_e^2$, $\hat{\sigma}_p^2$, and $\hat{h}^2$) for adjusted birth weight (ABW) when including temperament in the model[1].

Method	$\hat{\sigma}_a^2$	$\hat{\sigma}_e^2$	$\hat{\sigma}_p^2$	$\hat{h}^2$
DS[1]	102.630 ± 11.130	23.732 ± 7.631	127.360 ± 5.442	0.806 ± 0.064
TS[2]	100.612 ± 11.020	24.704 ± 7.578	126.320 ± 5.386	0.797 ± 0.064
QBA[3]				
Positive QBA				
Apathetic	101.932 ± 11.092	23.805 ± 7.605	126.740 ± 5.418	0.804 ± 0.064
Calm	99.873 ± 10.939	24.435 ± 7.518	125.310 ± 5.344	0.797 ± 0.064
Curious	103.022 ± 11.162	23.521 ± 7.637	127.540 ± 5.454	0.808 ± 0.064
Happy	102.132 ± 11.077	23.944 ± 7.601	127.080 ± 5.422	0.804 ± 0.064
Pos. occupied	101.447 ± 11.027	24.195 ± 7.561	126.640 ± 5.400	0.801 ± 0.064
Relaxed	100.459 ± 10.979	24.097 ± 7.530	125.560 ± 5.361	0.800 ± 0.064
Negative QBA				
Active	99.618 ± 10.959	24.914 ± 7.550	125.530 ± 5.350	0.794 ± 0.064
Agitated	99.790 ± 10.990	25.244 ± 7.581	126.030 ± 5.368	0.792 ± 0.064
Attentive	103.149 ± 11.139	23.237 ± 7.619	127.390 ± 5.448	0.810 ± 0.064
Distressed	103.440 ± 11.135	23.137 ± 7.611	127.580 ± 5.453	0.811 ± 0.064
Fearful	100.006 ± 10.978	24.908 ± 7.548	125.910 ± 5.365	0.794 ± 0.064
Irritated	100.451 ± 11.051	25.023 ± 7.606	126.470 ± 5.392	0.794 ± 0.064
TI[4]	101.194 ± 11.060	24.444 ± 7.591	126.640 ± 5.404	0.799 ± 0.064
TI positive	99.536 ± 10.962	24.905 ± 7.547	125.440 ± 5.349	0.794 ± 0.064
TI negative	99.139 ± 10.955	25.155 ± 7.554	125.290 ± 5.342	0.791 ± 0.065
SSD[5]	103.487 ± 11.152	23.153 ± 7.616	127.640 ± 5.457	0.811 ± 0.064
CVSSD[6]	103.110 ± 11.171	23.526 ± 7.638	127.640 ± 5.457	0.808 ± 0.064

[1]Variance components and genetic parameter were estimated ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, sex, year, and random effect of animal with known pedigree.

$\hat{\sigma}_a^2$ is estimated additive genetic variance, $\hat{\sigma}_e^2$= estimated residual variance, $\hat{\sigma}_p^2$ is estimated phenotypic variance, $\hat{h}^2$ is the estimated heritability.

[1]DS = Docility score.

[2]TS = Temperament score.

[3]QBA = QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.

[4]TI = Temperament index: the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

[5]SSD: standard deviation of total weight over time recorded by four-platform standing scale,

[6]CVSSD: coefficient of variation based on the SSD.

Table A14. Genetic parameters estimation ($\hat{\sigma}_a^2$, $\hat{\sigma}_e^2$, $\hat{\sigma}_p^2$, and $\hat{h}^2$) for adjusted 205 weaning weight (205-d WW) when including temperament in the model[1].

Method	$\hat{\sigma}_a^2$	$\hat{\sigma}_e^2$	$\hat{\sigma}_p^2$	$\hat{h}^2$
DS[1]	3,221.200 ± 360.717	805.345 ± 248.563	4,027.500 ± 174.050	0.800 ± 0.066
TS[2]	3,244.810 ± 361.740	788.226 ± 249.439	4,034.000 ± 174.520	0.804 ± 0.066
QBA[3]				
Positive QBA				
Apathetic	3,187.750 ± 358.981	819.529 ± 248.342	4,008.300 ± 173.100	0.795 ± 0.066
Calm	3,232.310 ± 362.367	796.515 ± 249.691	4,029.800 ± 174.430	0.802 ± 0.066
Curious	3,258.090 ± 361.207	777.646 ± 248.449	4,036.700 ± 174.600	0.807 ± 0.066
Happy	3,265.090 ± 361.183	772.600 ± 248.424	4,038.700 ± 174.670	0.809 ± 0.066
Pos. occupied	3,265.400 ± 359.230	757.797 ± 246.038	4,024.200 ± 174.040	0.811 ± 0.065
Relaxed	3,235.460 ± 361.908	797.497 ± 249.999	4,034.000 ± 174.520	0.802 ± 0.066
Negative QBA				
Active	3,213.870 ± 360.704	809.787 ± 249.165	4,024.700 ± 173.910	0.799 ± 0.066
Agitated	3,246.150 ± 361.487	788.930 ± 248.874	4,036.100 ± 174.550	0.804 ± 0.066
Attentive	3,247.810 ± 360.868	779.421 ± 248.223	4,028.200 ± 174.260	0.806 ± 0.066
Distressed	3,244.270 ± 360.875	784.860 ± 248.373	4,030.100 ± 174.250	0.805 ± 0.066
Fearful	3,245.580 ± 360.220	785.070 ± 248.440	4,031.700 ± 174.270	0.805 ± 0.066
Irritated	3,241.000 ± 361.719	789.882 ± 249.174	4,031.900 ± 174.450	0.804 ± 0.066
TI[4]	3,186.170 ± 359.613	823.638 ± 248.833	4,010.800 ± 173.210	0.794 ± 0.066
TI positive	3,251.220 ± 360.846	781.506 ± 248.097	0.000 ± 4,033.700	0.806 ± 0.066
TI negative	3,267.330 ± 361.430	772.845 ± 248.503	4,041.200 ± 174.850	0.809 ± 0.066
SSD[5]	3,190.820 ± 356.118	780.967 ± 245.587	3,972.800 ± 171.810	0.803 ± 0.066
CVSSD[6]	3,261.550 ± 361.591	777.889 ± 248.527	4,040.400 ± 174.790	0.807 ± 0.066

[1]Variance components and genetic parameter were estimated ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, sex, year, weaning age; covariate of birth weight; and random effect of animal with known pedigree.

$\hat{\sigma}_a^2$ is estimated additive genetic variance, $\hat{\sigma}_e^2$= estimated residual variance, $\hat{\sigma}_p^2$ is estimated phenotypic variance, $\hat{h}^2$ is the estimated heritability.

[1]DS = Docility score.

[2]TS = Temperament score.

[3]QBA = QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.

[4]TI = Temperament index: the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

[5]SSD: standard deviation of total weight over time recorded by four-platform standing scale,

[6]CVSSD: coefficient of variation based on the SSD.

Table A15. Genetic parameters estimation ($\hat{\sigma}_a^2$, $\hat{\sigma}_e^2$, $\hat{\sigma}_p^2$, and $\hat{h}^2$) for weaning average daily gain (ADG) when including temperament in the model[1].

Method	$\hat{\sigma}_a^2$	$\hat{\sigma}_e^2$	$\hat{\sigma}_p^2$	$\hat{h}^2$
DS[1]	0.079 ± 0.009	0.026 ± 0.007	1.106 ± 0.005	0.072 ± 0.008
TS[2]	0.079 ± 0.009	0.026 ± 0.007	1.106 ± 0.005	0.072 ± 0.008
QBA[3]				
Positive QBA				
Apathetic	0.078 ± 0.009	0.027 ± 0.007	1.105 ± 0.004	0.071 ± 0.008
Calm	0.080 ± 0.009	0.026 ± 0.007	1.106 ± 0.005	0.072 ± 0.008
Curious	0.080 ± 0.009	0.026 ± 0.007	1.106 ± 0.005	0.072 ± 0.008
Happy	0.080 ± 0.009	0.026 ± 0.007	1.106 ± 0.005	0.072 ± 0.008
Pos. occupied	0.080 ± 0.009	0.026 ± 0.007	1.106 ± 0.005	0.072 ± 0.008
Relaxed	0.081 ± 0.009	0.025 ± 0.007	1.106 ± 0.005	0.073 ± 0.008
Negative QBA				
Active	0.079 ± 0.009	0.027 ± 0.007	1.106 ± 0.005	0.071 ± 0.008
Agitated	0.080 ± 0.009	0.026 ± 0.007	1.106 ± 0.005	0.072 ± 0.008
Attentive	0.080 ± 0.009	0.026 ± 0.007	1.105 ± 0.005	0.072 ± 0.008
Distressed	0.080 ± 0.009	0.026 ± 0.007	1.106 ± 0.005	0.072 ± 0.008
Fearful	0.079 ± 0.009	0.026 ± 0.007	1.105 ± 0.005	0.072 ± 0.008
Irritated	0.080 ± 0.009	0.026 ± 0.007	1.106 ± 0.005	0.072 ± 0.008
TI[4]	0.078 ± 0.009	0.027 ± 0.007	1.105 ± 0.004	0.070 ± 0.008
TI positive	0.080 ± 0.009	0.026 ± 0.007	1.106 ± 0.005	0.072 ± 0.008
TI negative	0.080 ± 0.009	0.026 ± 0.007	1.106 ± 0.005	0.073 ± 0.008
SSD[5]	0.077 ± 0.009	0.026 ± 0.007	1.104 ± 0.004	0.070 ± 0.008
CVSSD[6]	0.080 ± 0.009	0.026 ± 0.007	1.106 ± 0.005	0.072 ± 0.008

[1]Variance components and genetic parameter were estimated ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, sex, year, and random effect of animal with known pedigree.

$\hat{\sigma}_a^2$ is estimated additive genetic variance, $\hat{\sigma}_e^2$= estimated residual variance, $\hat{\sigma}_p^2$ is estimated phenotypic variance, $\hat{h}^2$ is the estimated heritability.

[1]DS = Docility score.

[2]TS = Temperament score.

[3]QBA = QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.

[4]TI = Temperament index: the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

[5]SSD: standard deviation of total weight over time recorded by four-platform standing scale,

[6]CVSSD: coefficient of variation based on the SSD.

Table A16. Genetic parameters estimation ($\hat{\sigma}_a^2$, $\hat{\sigma}_e^2$, $\hat{\sigma}_p^2$, and $\hat{h}^2$) for weight gain (WG) when including temperament in the model[1].

Method	$\hat{\sigma}_a^2$	$\hat{\sigma}_e^2$	$\hat{\sigma}_p^2$	$\hat{h}^2$
DS[1]	3,094.270 ± 359.381	880.190 ± 250.766	3,975.500 ± 171.780	0.778 ± 0.068
TS[2]	3,115.760 ± 360.203	864.025 ± 251.170	3,980.800 ± 172.210	0.783 ± 0.068
QBA[3]				
Positive QBA				
Apathetic	3,058.050 ± 357.249	895.900 ± 250.251	3,955.000 ± 170.730	0.773 ± 0.068
Calm	3,091.320 ± 360.714	880.600 ± 251.600	3,972.900 ± 171.920	0.778 ± 0.068
Curious	3,131.920 ± 359.577	851.002 ± 250.295	3,983.900 ± 172.320	0.786 ± 0.067
Happy	3,138.440 ± 359.913	847.356 ± 249.958	3,986.800 ± 172.460	0.787 ± 0.067
Pos. occupied	3,144.700 ± 357.352	827.163 ± 247.654	3,972.900 ± 171.810	0.792 ± 0.067
Relaxed	3,098.850 ± 360.331	878.677 ± 251.770	3,978.500 ± 172.090	0.779 ± 0.068
Negative QBA				
Active	3,075.870 ± 358.911	891.588 ± 251.152	3,968.500 ± 171.420	0.775 ± 0.068
Agitated	3,116.090 ± 360.242	865.903 ± 250.986	3,983.000 ± 172.230	0.782 ± 0.068
Attentive	3,114.560 ± 359.234	858.034 ± 250.156	3,973.600 ± 171.870	0.784 ± 0.068
Distressed	3,113.030 ± 359.058	862.450 ± 249.986	3,976.500 ± 171.920	0.783 ± 0.068
Fearful	3,119.030 ± 358.922	859.675 ± 249.906	3,979.700 ± 172.030	0.784 ± 0.067
Irritated	3,107.410 ± 360.071	867.518 ± 250.728	3,975.900 ± 172.010	0.782 ± 0.068
TI[4]	3,195.020 ± 368.514	900.521 ± 257.292	4096.500 ± 176.660	0.780 ± 0.067
TI positive	3,123.190 ± 359.400	856.023 ± 250.299	3,980.200 ± 172.150	0.785 ± 0.067
TI negative	3,139.940 ± 360.085	847.556 ± 250.017	3,988.500 ± 172.590	0.787 ± 0.067
SSD[5]	3,070.400 ± 354.550	851.858 ± 246.915	3,923.300 ± 169.640	0.783 ± 0.068
CVSSD[6]	3,133.090 ± 360.125	853.384 ± 250.259	3,987.500 ± 172.480	0.786 ± 0.067

[1]Variance components and genetic parameter were estimated ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, sex, year, and random effect of animal with known pedigree.
$\hat{\sigma}_a^2$ is estimated additive genetic variance, $\hat{\sigma}_e^2$= estimated residual variance, $\hat{\sigma}_p^2$ is estimated phenotypic variance, $\hat{h}^2$ is the estimated heritability.
[1]DS = Docility score.
[2]TS = Temperament score.
[3]QBA = QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.
[4]TI = Temperament index: the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).
[5]SSD: standard deviation of total weight over time recorded by four-platform standing scale,
[6]CVSSD: coefficient of variation based on the SSD.

Table A17. Least squares means and standard errors for primary breed effect on calf docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) on heifer pregnancy (HPG)[1].

Method[1]	Primary Breed				
	Angus	**N**	**Hereford**	**N**	**P-value[3]**
DS	0.83 ± 0.06	370	0.92 ± 0.04	61	0.012
TS	0.75 ± 0.08	370	0.87 ± 0.06	61	0.017
QBA					
Positive QBA					
Apathetic	0.76 ± 0.05	370	0.88 ± 0.05	61	0.034
Calm	0.79 ± 0.03	370	0.89 ± 0.04	61	0.032
Curious	-	370	-	61	-
Happy	0.77 ± 0.06	370	0.88 ± 0.05	61	0.034
Pos. occupied	-	370	-	61	-
Relaxed	0.78 ± 0.04	370	0.89 ± 0.04	61	0.034
Negative QBA					
Active	0.76 ± 0.05	370	0.88 ± 0.04	61	0.026
Agitated	0.97 ± 0.50	370	0.99 ± 0.50	61	0.014
Attentive	0.96 ± 0.50	370	0.98 ± 0.50	61	0.030
Distressed	-		-		-
Fearful	-		-		-
Irritated	0.98 ± 0.50	370	0.99 ± 0.50	61	0.023
TI	0.79 ± 0.03	370	0.89 ± 0.04	61	0.031
TI positive	0.79 ± 0.03	370	0.89 ± 0.03	61	0.033
TI negative	0.79 ± 0.03	370	0.89 ± 0.04	61	0.033
SSD	0.79 ± 0.03	370	0.90 ± 0.04	61	0.030
CVSSD	0.79 ± 0.03	370	0.89 ± 0.04	61	0.028

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, year, random effect of animal with known pedigree and breeding age as covariate.

[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[3]*P* < 0.05 within row is significant. "_" means no data.

Table A18. Least squares means and standard errors for year effect on calf docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) on heifer pregnancy (HPG)[1].

Method[2]	**Year**								
	2014	**N**	**2015**	**N**	**2016**	**N**	**2017**	**N**	**P-value**[3]
DS	0.99 ± 0.01	78	0.73 ± 0.09	131	0.76 ± 0.09	97	0.81 ± 0.07	125	<0.001
TS	0.98 ± 0.02	78	0.62 ± 0.10	131	0.66 ± 0.09	97	0.72 ± 0.09	125	<0.001
QBA									
Positive QBA									
Apathetic	0.98 ± 0.01	78	0.63 ± 0.08	131	0.66 ± 0.08	97	0.75 ± 0.05	125	<0.001
Calm	0.98 ± 0.01	78	0.66 ± 0.05	131	0.70 ± 0.05	97	0.77 ± 0.04	125	<0.001
Curious		78		131		97		125	<0.001
Happy	0.99 ± 0.01	78	0.59 ± 0.10	131	0.64 ± 0.0964	97	0.76 ± 0.07	125	<0.001
Pos. occupied	-	78	-	131	-	97	-	125	-
Relaxed	0.98 ± 0.01	78	0.66 ± 0.05	131	0.69 ± 0.06	97	0.77 ± 0.05	125	<0.001
Negative QBA		78		131		97		125	
Active	0.98 ± 0.02	78	0.63 ± 0.06	131	0.68 ± 0.06	97	0.74 ± 0.05	125	<0.001
Agitated	1.00 ± 0.50	78	0.95 ± 0.50	131	0.96 ± 0.50	97	0.97 ± 0.50	125	<0.001
Attentive	1.00 ± 0.50	78	0.92 ± 0.50	131	0.94 ± 0.50	97	0.95 ± 0.50	125	<0.001
Distressed	-	-	-	-	-	-	-	-	-
Fearful	-	-	-	-	-	-	-	-	-
Irritated	1.00 ± 0.50	78	0.96 ± 0.50	131	0.96 ± 0.50	97	0.98 ± 0.50	125	<0.001
TI	0.98 ± 0.01	78	0.66 ± 0.05	131	0.70 ± 0.05	97	0.77 ± 0.04	125	<0.001
TI positive	0.98 ± 0.01	78	0.67 ± 0.05	131	0.71 ± 0.05	97	0.78 ± 0.04	125	<0.001
TI negative	0.98 ± 0.01	78	0.67 ± 0.05	131	0.70 ± 0.05	97	0.77 ± 0.04	125	<0.001
SSD	0.98 ± 0.01	78	0.67 ± 0.05	131	0.70 ± 0.05	97	0.77 ± 0.04	125	<0.001
CVSSD	0.98 ± 0.01	78	0.66 ± 0.05	131	0.71 ± 0.05	97	0.77 ± 0.05	125	<0.001

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, year, random effect of animal with known pedigree and breeding age as covariate.

[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive. [2]Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[3]Within a row and a given scoring method that are different, differ ($P < 0.05$). "-" indicates no data.

Table A19. Least squares means and standard errors for primary breed effect on calf docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) on calving success (CS)[1].

Method[2]	Primary Breed				
	Angus	N	Hereford	N	P-value[3]
DS	0.98 ± 0.50	294	0.99 ± 0.50	49	0.019
TS	0.97 ± 0.50	294	0.99 ± 0.50	49	0.027
QBA					
Positive QBA					
Apathetic	0.84 ± 0.06	294	0.95 ± 0.03	49	0.019
Calm	0.78 ± 0.03	294	0.92 ± 0.04	49	0.024
Curious	-	294	-	49	-
Happy	0.82 ± 0.06	294	0.93 ± 0.04	49	0.025
Pos. occupied	0.63 ± 0.10	294	0.85 ± 0.08	49	0.024
Relaxed	0.80 ± 0.04	294	0.93 ± 0.04	49	0.023
Negative QBA					
Active	0.97 ± 0.50	294	0.99 ± 0.50	49	0.057
Agitated	0.97 ± 0.50	294	0.99 ± 0.50	49	0.026
Attentive	0.98 ± 0.50	294	0.99 ± 0.50	49	0.026
Distressed	0.08 ± 0.50	294	0.21 ± 0.50	49	0.026
Fearful	-	294	-	49	-
Irritated	0.98 ± 0.50	294	0.99 ± 0.50	49	0.019
TI	0.79 ± 0.03	294	0.92 ± 0.04	49	0.023
TI positive	0.79 ± 0.03	294	0.92 ± 0.04	49	0.023
TI negative	0.79 ± 0.03	294	0.92 ± 0.04	49	0.022
SSD	0.78 ± 0.03	294	0.93 ± 0.04	49	0.019
CVSSD	0.80 ± 0.03	294	0.93 ± 0.03	49	0.027

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, year, weaning age, random effect of animal with known pedigree, and breeding age as covariate.

[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[3]Within a row and a given scoring method that are different, differ ($P < 0.05$)

Table A20. Least squares means and standard errors for year effect on calf docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) on calving success (CS)[1].

Method[2]	**Year**								
	2014	**N**	**2015**	**N**	**2016**	**N**	**2017**	**N**	**P-value**[3]
DS	1.00 ± 0.50	76	0.98 ± 0.50	113	0.95 ± 0.50	65	0.99 ± 0.50	89	<0.001
TS	1.00 ± 0.50	76	0.98 ± 0.50	113	0.95 ± 0.50	65	0.98 ± 0.50	89	<0.001
QBA									
Positive QBA									
Apathetic	0.98 ± 0.0	76	0.88 ± 0.06	113	0.73 ± 0.11	65	0.89 ± 0.05	89	<0.001
Calm	0.98 ± 0.02	76	0.82 ± 0.05	113	0.64 ± 0.09	65	0.85 ± 0.05	89	<0.001
Curious	-	-	-	-	-	-	-	-	-
Happy	0.98 ± 0.02	76	0.86 ± 0.07	113	0.70 ± 0.13	65	0.87 ± 0.06	89	0.006
Pos. occupied	0.97 ± 0.02	76	0.65 ± 0.13	113	0.41 ± 0.15	65	0.70 ± 0.13	89	<0.001
Relaxed	0.98 ± 0.01	76	0.83 ± 0.05	113	0.66 ± 0.09	65	0.86 ± 0.05	89	<0.001
Negative QBA									
Active	1.00 ± 0.50	76	0.97 ± 0.50	113	0.93 ± 0.50	65	0.98 ± 0.50	89	<0.001
Agitated	1.00 ± 0.50	76	0.97 ± 0.50	113	0.93 ± 0.50	65	0.98 ± 0.50	89	<0.001
Attentive	1.00 ± 0.50	76	0.98 ± 0.50	113	0.96 ± 0.50	65	0.99 ± 0.50	89	<0.001
Distressed	0.50 ± 0.50	76	0.09 ± 0.50	113	0.04 ± 0.50	65	0.12 ± 0.50	89	<0.001
Fearful	-	-	-	-	-	-	-	-	-
Irritated	1.00 ± 0.50	76	0.98 ± 0.50	113	0.96 ± 0.50	65	0.99 ± 0.50	89	<0.001
TI	0.98 ± 0.01	76	0.83 ± 0.05	113	0.63 ± 0.08	65	0.85 ± 0.05	89	<0.001
TI positive	0.98 ± 0.02	76	0.83 ± 0.05	113	0.64 ± 0.08	65	0.85 ± 0.05	89	<0.001
TI negative	0.98 ± 0.01	76	0.82 ± 0.05	113	0.63 ± 0.08	65	0.85 ± 0.05	89	<0.001
SSD	0.98 ± 0.01	76	0.82 ± 0.05	113	0.64 ± 0.08	65	0.85 ± 0.05	89	<0.001
CVSSD	0.98 ± 0.01	76	0.83 ± 0.05	113	0.68 ± 0.07	65	0.85 ± 0.05	89	<0.001

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, year, weaning age, random effect of animal with known pedigree, and breeding age as covariate.

[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[3]Within a row and a given scoring method that are different, differ ($P < 0.05$). "-" indicates no data.

Table A21. Least squares means and standard errors for primary breed effect on calf docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) on weaning success (WS)[1].

Method[2]	**Primary Breed**				
	Angus	**N**	**Hereford**	**N**	**P-value[3]**
DS	1.00 ± 0.50	222	1.00 ± 0.50	45	0.737
TS	1.00 ± 0.50	222	1.00 ± 0.50	45	0.740
QBA					
Positive QBA					
Apathetic	1.00 ± 0.50	222	1.00 ± 0.50	45	0.706
Calm	1.00 ± 0.03	222	1.00 ± 0.13	45	0.703
Curious	-	-	-	-	-
Happy	1.00 ± 0.32	222	1.00 ± 0.46	45	0.747
Pos. occupied	1.00 ± 0.50	222	1.00 ± 0.50	45	0.749
Relaxed	1.00 ± 0.03	222	1.00 ± 0.06	45	0.697
Negative QBA		222		45	
Active	1.00 ± 0.36	222	1.00 ± 0.36	45	0.718
Agitated	1.00 ± 0.50	222	1.00 ± 0.50	45	0.733
Attentive	1.00 ± 0.50	222	1.00 ± 0.50	45	0.724
Distressed	-	-	-	-	-
Fearful	-	-	-	-	-
Irritated	1.00 ± 0.50	222	1.00 ± 0.50	45	0.725
TI	1.00 ± 0.03	222	1.00 ± 0.25	45	0.735
TI positive	1.00 ± 0.06	222	1.00 ± 0.31	45	0.712
TI negative	1.00 ± 0.01	222	1.00 ± 0.10	45	0.717
SSD	1.00 ± 0.05	222	1.00 ± 0.38	45	0.725
CVSSD	1.00 ± 0.06	222	1.00 ± 0.33	45	0.714

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, year, and random effect of animal with known pedigree.

[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[3]Within a row and a given scoring method that are different, differ ($P < 0.05$)

Table A22. Least squares means and standard errors for year effect on calf docility score (DS) and temperament score (TS), QBA qualitative behavior attributes (QBA) and temperament index (TI) on weaning success (WS)[1].

Method[2]	**Year**								
	2014	**N**	**2015**	**N**	**2016**	**N**	**2017**	**N**	**P-value**
DS	1.00 ± 0.50	74	1.00 ± 0.50	76	1.00 ± 0.00	45	1.00 ± 0.00	72	0.828
TS	1.00 ± 0.50	74	1.00 ± 0.50	76	1.00 ± 0.50	45	1.00 ± 0.50	72	0.843
QBA									
Positive QBA									
Apathetic	1.00 ± 0.50	74	1.00 ± 0.50	76	1.00 ± 0.50	45	1.00 ± 0.50	72	0.960
Calm	1.00 ± 0.37	74	1.00 ± 0.37	76	1.00 ± 0.13	45	1.00 ± 0.08	72	0.943
Curious	-	-	-	-	-	-	-	-	-
Happy	0.99 ± 0.49	74	0.99 ± 0.49	76	1.00 ± 0.50	45	1.00 ± 0.47	72	0.957
Pos. occupied	1.00 ± 0.50	74	1.00 ± 0.50	76	1.00 ± 0.50	45	1.00 ± 0.50	72	0.958
Relaxed	1.00 ± 0.11	74	1.00 ± 0.11	76	1.00 ± 0.20	45	1.00 ± 0.03	72	0.931
Negative QBA	0.00 ± 0.00	74	0.00 ± 0.00	76	0.00 ± 0.00	45	0.00 ± 0.00	72	
Active	1.00 ± 0.46	74	1.00 ± 0.46	76	1.00 ± 0.46	45	1.00 ± 0.26	72	0.861
Agitated	1.00 ± 0.50	74	1.00 ± 0.50	76	1.00 ± 0.50	45	1.00 ± 0.50	72	0.883
Attentive	1.00 ± 0.50	74	1.00 ± 0.50	76	1.00 ± 0.50	45	1.00 ± 0.00	72	0.879
Distressed	-	-	-	-	-	-	-	-	-
Fearful	-	-	-	-	-	-	-	-	-
9Irritated	1.00 ± 0.50	74	1.00 ± 0.50	76	1.00 ± 0.00	45	1.00 ± 0.00	72	0.857
TI	1.00 ± 0.30	74	1.00 ± 0.30	76	1.00 ± 0.47	45	1.00 ± 0.17	72	0.386
TI positive	1.00 ± 0.24	74	1.00 ± 0.24	76	1.00 ± 0.49	45	1.00 ± 0.30	72	0.935
TI negative	1.00 ± 0.17	74	1.00 ± 0.17	76	1.00 ± 0.22	45	1.00 ± 0.04	72	0.526
SSD	1.00 ± 0.30	74	1.00 ± 0.30	76	1.00 ± 0.48	45	1.00 ± 0.29	72	0.902
CVSSD	1.00 ± 0.26	74	1.00 ± 0.26	76	1.00 ± 0.49	45	1.00 ± 0.29	72	0.917

[1]Least square means and standard errors were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, year, and random effect of animal with known pedigree.

[2]Docility score: scale of 1 to 6 with 1= docile and 6 = very aggressive. Temperament score: scale of 1 to 5, with no intermediate score; 1 = animal walks slowly while allowing close approximation with the observer and 5 = runs the entire time of the observation, jumps against the fence and tries to attack the observer. QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior. A low value (towards zero) indicates no or little expression, where a high value (towards 136) would indicate high or maximum expression. Temperament index (TI): the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.). SSD: standard deviation of four-platform standing scale. CVSSD: coefficient of variation based on the SSD.

[3]Within a row and a given scoring method that are different, differ ($P < 0.05$). "-" indicates no data.

Table A23. Genetic parameters estimation ($\hat{\sigma}_a^2$, $\hat{\sigma}_e^2$, $\hat{\sigma}_p^2$, and $\hat{h}^2$) for heifer pregnancy (HPG) when including temperament in the model.

Method	$\hat{\sigma}_a^2$	$\hat{\sigma}_e^2$	$\hat{\sigma}_p^2$	$\hat{h}^2$
DS[1]	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
TS[2]	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
QBA[3]				
Positive QBA				
Apathetic	0.052 ± 0.324	1.000 ± 0.000	2.052 ± 0.326	0.025 ± 0.155
Calm	0.024 ± 0.341	1.000 ± 0.000	2.024 ± 0.323	0.012 ± 0.158
Curious	0.025 ± 0.311	1.000 ± 0.000	2.025 ± 0.321	0.012 ± 0.156
Happy	0.084 ± 0.335	1.000 ± 0.000	2.084 ± 0.330	0.040 ± 0.152
Pos. occupied	0.006 ± 0.295	1.000 ± 0.000	2.006 ± 0.317	0.003 ± 0.158
Relaxed	0.052 ± 0.326	1.000 ± 0.000	2.052 ± 0.327	0.025 ± 0.155
Negative QBA				
Active	0.009 ± 0.305	1.000 ± 0.000	2.009 ± 0.323	0.005 ± 0.160
Agitated	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
Attentive	0.009 ± 0.296	1.000 ± 0.000	2.009 ± 0.320	0.004 ± 0.159
Distressed	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
Fearful	0.015 ± 0.306	1.000 ± 0.000	2.015 ± 0.321	0.008 ± 0.158
Irritated	0.006 ± 0.297	1.000 ± 0.000	2.006 ± 0.320	0.003 ± 0.159
TI[4]	0.034 ± 0.309	1.000 ± 0.000	2.034 ± 0.322	0.017 ± 0.156
TI positive	0.012 ± 0.311	1.000 ± 0.000	2.012 ± 0.323	0.006 ± 0.160
TI negative	0.023 ± 0.330	1.000 ± 0.000	2.023 ± 0.322	0.011 ± 0.157
SSD[5]	0.039 ± 0.322	1.000 ± 0.000	2.039 ± 0.324	0.019 ± 0.156
CVSSD[6]	0.039 ± 0.322	1.000 ± 0.000	2.026 ± 0.323	0.013 ± 0.157

Variance components and genetic parameters were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, year, random effect of animal with known pedigree and breeding age as covariate.
$\hat{\sigma}_a^2$ is estimated additive genetic variance, $\hat{\sigma}_e^2$= estimated residual variance, $\hat{\sigma}_p^2$ is estimated phenotypic variance, $\hat{h}^2$ is the estimated heritability.
[1]DS = Docility score.
[2]TS = Temperament score.
[3]QBA = QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.
[4]TI = Temperament index: the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).
[5]SSD: standard deviation of total weight over time recorded by four-platform standing scale,
[6]CVSSD: coefficient of variation based on the SSD.

Table A24. Genetic parameters estimation ($\hat{\sigma}_a^2$, $\hat{\sigma}_e^2$, $\hat{\sigma}_p^2$, and $\hat{h}^2$) for calving success (CS) when including temperament in the model.

Method	$\hat{\sigma}_a^2$	$\hat{\sigma}_e^2$	$\hat{\sigma}_p^2$	$\hat{h}^2$
DS[1]	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
TS[2]	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
QBA[3]				
Positive QBA				
Apathetic	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
Calm	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
Curious	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
Happy	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
Pos. occupied	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
Relaxed	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
Negative QBA				
Active	1.583 ± 0.838	1.000 ± 0.000	3.583 ± 0.836	0.442 ± 0.130
Agitated	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
Attentive	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
Distressed	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
Fearful	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
Irritated	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
TI[4]	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
TI positive	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
TI negative	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
SSD[5]	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
CVSSD[6]	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable

Variance components and genetic parameters were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, year, weaning age, random effect of animal with known pedigree, and breeding age as covariate.

$\hat{\sigma}_a^2$ is estimated additive genetic variance, $\hat{\sigma}_e^2$= estimated residual variance, $\hat{\sigma}_p^2$ is estimated phenotypic variance, $\hat{h}^2$ is the estimated heritability.

[1]DS = Docility score.

[2]TS = Temperament score.

[3]QBA = QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.

[4]TI = Temperament index: the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

[5]SSD: standard deviation of total weight over time recorded by four-platform standing scale,

[6]CVSSD: coefficient of variation based on the SSD.

Table A25. Genetic parameters estimation ($\hat{\sigma}_a^2$, $\hat{\sigma}_e^2$, $\hat{\sigma}_p^2$, and $\hat{h}^2$) for weaning success (WS) when including temperament in the model.

Method	$\hat{\sigma}_a^2$	$\hat{\sigma}_e^2$	$\hat{\sigma}_p^2$	$\hat{h}^2$
DS[1]	0.028 ± 2.843	1.000 ± 0.000	2.028 ± 3.301	0.014 ± 1.605
TS[2]	0.305 ± 3.053	1.000 ± 0.000	2.305 ± 3.092	0.132 ± 1.164
QBA[3]				
Positive QBA				
Apathetic	0.099 ± 3.304	1.000 ± 0.000	2.099 ± 2.967	0.047 ± 1.347
Calm	0.228 ± 2.856	1.000 ± 0.000	2.229 ± 2.987	0.103 ± 1.203
Curious	0.247 ± 3.086	1.000 ± 0.000	2.247 ± 3.038	0.110 ± 1.204
Happy	0.098 ± 3.258	1.000 ± 0.000	2.098 ± 3.300	0.047 ± 1.500
Pos. occupied	0.095 ± 3.178	1.000 ± 0.000	2.095 ± 3.259	0.046 ± 1.485
Relaxed	0.037 ± 3.732	1.000 ± 0.000	2.037 ± 2.810	0.018 ± 1.354
Negative QBA				
Active	0.282 ± 2.818	1.000 ± 0.000	2.282 ± 2.750	0.124 ± 1.057
Agitated	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
Attentive	0.144 ± 2.886	1.000 ± 0.000	2.144 ± 3.193	0.067 ± 1.389
Distressed	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
Fearful	0.128 ± 3.204	1.000 ± 0.000	2.128 ± 3.206	0.060 ± 1.416
Irritated	0.000 ± 0.000	1.000 ± 0.000	Non estimable	Non estimable
TI[4]	0.713 ± 2.640	1.000 ± 0.000	2.713 ± 2.636	0.263 ± 0.716
TI positive	0.274 ± 3.048	1.000 ± 0.000	2.274 ± 3.093	0.121 ± 1.196
TI negative	0.712 ± 2.454	1.000 ± 0.000	2.712 ± 2.476	0.263 ± 0.673
SSD[5]	0.189 ± 3.158	1.000 ± 0.000	2.190 ± 3.070	0.087 ± 1.281
CVSSD[6]	0.375 ± 2.884	1.000 ± 0.000	2.375 ± 2.959	0.158 ± 1.049

Variance components and genetic parameters were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, year, and random effect of animal with known pedigree.

$\hat{\sigma}_a^2$ is estimated additive genetic variance, $\hat{\sigma}_e^2$= estimated residual variance, $\hat{\sigma}_p^2$ is estimated phenotypic variance, $\hat{h}^2$ is the estimated heritability.

[1]DS = Docility score.

[2]TS = Temperament score.

[3]QBA = QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.

[4]TI = Temperament index: the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

[5]SSD: standard deviation of total weight over time recorded by four-platform standing scale,

[6]CVSSD: coefficient of variation based on the SSD.

Table A26. Genetic parameters estimation ($\hat{\sigma}_a^2$, $\hat{\sigma}_e^2$, $\hat{\sigma}_p^2$, and $\hat{h}^2$) for reproductive success (RS) when including temperament in the model.

Method	$\hat{\sigma}_a^2$	$\hat{\sigma}_e^2$	$\hat{\sigma}_p^2$	$\hat{h}^2$
DS[1]	0.281 ± 0.268	1.000 ± 0.000	2.281 ± 0.269	0.123 ± 0.103
TS[2]	0.312 ± 0.274	1.000 ± 0.000	2.312 ± 0.274	0.135 ± 0.103
QBA[3]				
Positive QBA				
Apathetic	0.332 ± 0.276	1.000 ± 0.000	2.332 ± 0.276	0.142 ± 0.102
Calm	0.323 ± 0.276	1.000 ± 0.000	2.323 ± 0.275	0.139 ± 0.102
Curious	0.298 ± 0.271	1.000 ± 0.000	2.298 ± 0.271	0.130 ± 0.103
Happy	0.348 ± 0.276	1.000 ± 0.000	2.348 ± 0.277	0.148 ± 0.101
Pos. occupied	0.315 ± 0.272	1.000 ± 0.000	2.315 ± 0.272	0.136 ± 0.102
Relaxed	0.334 ± 0.276	1.000 ± 0.000	2.334 ± 0.277	0.143 ± 0.102
Negative QBA	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Active	0.300 ± 0.273	1.000 ± 0.000	2.300 ± 0.274	0.131 ± 0.103
Agitated	0.312 ± 0.276	1.000 ± 0.000	2.312 ± 0.276	0.135 ± 0.103
Attentive	0.304 ± 0.271	1.000 ± 0.000	2.304 ± 0.272	0.132 ± 0.103
Distressed	0.307 ± 0.269	1.000 ± 0.000	2.307 ± 0.270	0.133 ± 0.101
Fearful	0.303 ± 0.271	1.000 ± 0.000	2.303 ± 0.272	0.132 ± 0.103
Irritated	0.342 ± 0.276	1.000 ± 0.000	2.342 ± 0.276	0.146 ± 0.101
TI[4]	0.338 ± 0.275	1.000 ± 0.000	2.339 ± 0.276	0.145 ± 0.101
TI positive	0.339 ± 0.278	1.000 ± 0.000	2.339 ± 0.277	0.145 ± 0.101
TI negative	0.335 ± 0.277	1.000 ± 0.000	2.335 ± 0.276	0.144 ± 0.101
SSD[5]	0.327 ± 0.275	1.000 ± 0.000	2.327 ± 0.275	0.141 ± 0.101
CVSSD[6]	0.311 ± 0.273	1.000 ± 0.000	2.311 ± 0.274	0.135 ± 0.103

Variance components and genetic parameters were calculated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of methods of temperament measurement, primary breed, year, and random effect of animal with known pedigree. $\hat{\sigma}_a^2$ is estimated additive genetic variance, $\hat{\sigma}_e^2$= estimated residual variance, $\hat{\sigma}_p^2$ is estimated phenotypic variance, $\hat{h}^2$ is the estimated heritability.

[1]DS = Docility score.

[2]TS = Temperament score.

[3]QBA = QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.

[4]TI = Temperament index: the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

[5]SSD: standard deviation of total weight over time recorded by four-platform standing scale,

[6]CVSSD: coefficient of variation based on the SSD.

Table A27. Genetic parameters estimation ($\hat{\sigma}_a^2$, $\hat{\sigma}_{me}^2$, $\hat{\sigma}_e^2$, $\hat{\sigma}_p^2$, and $\hat{h}^2$) for adjusted birth weight (ABW) when including sire and dam temperament in the model.

Method	$\hat{\sigma}_a^2$	$\hat{\sigma}_{me}^2$	$\hat{\sigma}_e^2$	$\hat{\sigma}_p^2$	$\hat{h}^2$
DS[1]	73.083 ± 31.099	0.00004 ± 0.000	45.027 ± 22.291	118.110 ± 13.135	0.619 ± 0.213
TS[2]	67.121 ± 29.310	0.00007 ± 0.000	47.350 ± 21.233	114.470 ± 12.508	0.586 ± 0.211
QBA[3]					
Positive QBA					
Apathetic	55.738 ± 27.189	0.00002 ± 0.00000	56.288 ± 20.321	112.030 ± 11.814	0.498 ± 0.208
Calm	69.431 ± 30.319	0.00002 ± 0.00000	47.629 ± 21.848	117.060 ± 12.869	0.593 ± 0.212
Curious	70.649 ± 30.584	0.00003 ± 0.00000	46.773 ± 21.959	117.420 ± 12.940	0.602 ± 0.213
Happy	70.215 ± 30.135	0.00002 ± 0.00000	46.87 ± 21.699	117.080 ± 12.830	0.600 ± 0.210
Pos. occupied	68.343 ± 29.332	0.00000 ± 0.00000	47.426 ± 21.172	115.770 ± 12.588	0.590 ± 0.208
Relaxed	73.978 ± 31.083	0.00004 ± 0.00000	44.133 ± 22.177	118.110 ± 13.143	0.626 ± 0.212
Negative QBA					
Active	71.941 ± 30.613	0.00003 ± 0.00000	45.890 ± 22.063	117.830 ± 13.017	0.611 ± 0.212
Agitated	70.252 ± 30.281	0.00002 ± 0.00000	46.991 ± 21.856	117.240 ± 12.884	0.599 ± 0.211
Attentive	75.440 ± 31.303	0.00003 ± 0.00000	43.213 ± 22.275	118.650 ± 13.275	0.636 ± 0.212
Distressed	70.943 ± 30.189	0.00002 ± 0.00000	46.100 ± 21.745	117.040 ± 12.858	0.606 ± 0.211
Fearful	70.382 ± 30.337	0.00003 ± 0.00000	46.890 ± 21.809	117.270 ± 12.874	0.600 ± 0.211
Irritated	68.016 ± 29.832	0.00002 ± 0.00000	48.403 ± 21.609	116.420 ± 12.712	0.584 ± 0.211
TI[4]	68.207 ± 29.785	0.00001 ± 0.00000	48.245 ± 21.635	116.450 ± 12.737	0.586 ± 0.211
TI positive	69.156 ± 30.465	0.00003 ± 0.00000	47.912 ± 21.978	117.070 ± 12.892	0.591 ± 0.214
TI negative	67.209 ± 29.607	0.00002 ± 0.00000	47.879 ± 21.470	115.090 ± 12.610	0.584 ± 0.212
SSD[5]	73.100 ± 30.586	0.00000 ± 0.00000	44.765 ± 21.944	117.860 ± 13.044	0.620 ± 0.210
CVSSD[6]	71.058 ± 30.109	0.00002 ± 0.00000	45.160 ± 21.608	116.220 ± 12.841	0.611 ± 0.211

Variance components and genetic parameter are estimated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of dam temperament, sire docility expected progeny difference (EPD), primary breed, sex, random effect of animal with known pedigree, and maternal effect.

$\hat{\sigma}_a^2$ = estimated additive genetic variance, $\hat{\sigma}_{me}^2$ = estimated maternal effect variance, $\hat{\sigma}_e^2$ = residual variance, $\hat{\sigma}_p^2$ = estimated phenotypic variance, and $\hat{h}^2$ = estimated heritability.

[1]DS = Docility score.

[2]TS = Temperament score.

[3]QBA = QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.

[4]TI = Temperament index: the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

[5]SSD: standard deviation of total weight over time recorded by four-platform standing scale, [6]CVSSD: coefficient of variation based on the SSD.

Table A28. Genetic parameters estimation ($\hat{\sigma}_a^2$, $\hat{\sigma}_{me}^2$, $\hat{\sigma}_e^2$, $\hat{\sigma}_p^2$, and $\hat{h}^2$) for adjusted 205 weaning weight (205-d WW) when including sire and dam temperament in the model.

Method	$\hat{\sigma}_a^2$	$\hat{\sigma}_{me}^2$	$\hat{\sigma}_e^2$	$\hat{\sigma}_p^2$	$\hat{h}^2$
DS[1]	1071.17 ± 787.625	605.636 ± 465.874	2160.61 ± 574.630	3837.400 ± 371.400	0.279 ± 0.192
TS[2]	1521.55 ± 922.152	466.879 ± 462.256	1908.50 ± 613.666	3896.900 ± 395.720	0.390 ± 0.213
QBA[3]					
Positive QBA					
Apathetic	1115.09 ± 813.934	604.848 ± 480.038	2161.12 ± 585.669	3881.100 ± 377.350	0.287 ± 0.196
Calm	1458.60 ± 894.847	460.086 ± 489.453	2055.46 ± 620.985	3974.100 ± 396.470	0.367 ± 0.204
Curious	1022.97 ± 769.150	582.999 ± 462.698	2157.69 ± 566.323	3763.700 ± 362.940	0.272 ± 0.192
Happy	1263.76 ± 831.421	450.947 ± 460.150	2053.50 ± 588.395	3768.200 ± 372.240	0.335 ± 0.202
Pos. occupied	909.081 ± 757.567	668.285 ± 470.623	2205.81 ± 561.275	3783.200 ± 361.850	0.240 ± 0.190
Relaxed	1357.50 ± 864.650	505.615 ± 486.168	2107.70 ± 614.490	3970.800 ± 392.590	0.342 ± 0.200
Negative QBA					
Active	1331.60 ± 864.675	551.183 ± 483.494	2094.04 ± 606.968	3976.800 ± 392.510	0.335 ± 0.199
Agitated	1423.30 ± 884.037	494.178 ± 479.784	2064.27 ± 618.045	3981.700 ± 396.270	0.358 ± 0.203
Attentive	958.796 ± 754.958	798.237 ± 475.141	2106.81 ± 548.648	3863.800 ± 370.530	0.248 ± 0.185
Distressed	1360.22 ± 860.899	451.290 ± 480.096	2143.86 ± 616.052	3955.400 ± 389.430	0.344 ± 0.199
Fearful	1433.66 ± 874.183	437.991 ± 470.958	2057.81 ± 614.272	3929.500 ± 390.470	0.365 ± 0.202
Irritated	1438.39 ± 877.067	462.399 ± 476.700	2068.78 ± 615.708	3969.600 ± 394.110	0.362 ± 0.202
TI[4]	1306.84 ± 854.144	537.315 ± 484.068	2099.03 ± 603.170	3943.200 ± 388.580	0.331 ± 0.199
TI positive	1421.89 ± 899.930	469.931 ± 489.511	2100.19 ± 626.922	3992.000 ± 398.090	0.356 ± 0.205
TI negative	1143.43 ± 810.943	646.295 ± 471.748	2097.51 ± 576.239	3887.200 ± 378.360	0.294 ± 0.194
SSD[5]	1480.10 ± 886.287	293.154 ± 480.580	2178.76 ± 631.525	3952.000 ± 393.280	0.375 ± 0.203
CVSSD[6]	1417.64 ± 864.415	379.967 ± 469.095	2112.51 ± 612.322	3910.100 ± 388.120	0.363 ± 0.201

Variance components and genetic parameter are estimated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of dam temperament, sire docility expected progeny difference (EPD), primary breed, sex, random effect of animal with known pedigree, and maternal effect.

$\hat{\sigma}_a^2$ = estimated additive genetic variance, $\hat{\sigma}_{me}^2$ = estimated maternal effect variance, $\hat{\sigma}_e^2$ = residual variance, $\hat{\sigma}_p^2$ = estimated phenotypic variance, and $\hat{h}^2$ = estimated heritability.

[1]DS = Docility score.

[2]TS = Temperament score.

[3]QBA = QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.

[4]TI = Temperament index: the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

[5]SSD: standard deviation of total weight over time recorded by four-platform standing scale, [6]CVSSD: coefficient of variation based on the SSD.

Table A29. Genetic parameters estimation ($\hat{\sigma}_a^2$, $\hat{\sigma}_{me}^2$, $\hat{\sigma}_e^2$, $\hat{\sigma}_p^2$, and $\hat{h}^2$) for weaning average daily gain (ADG) when including sire and dam temperament in the model.

Method	$\hat{\sigma}_a^2$	$\hat{\sigma}_{me}^2$	$\hat{\sigma}_e^2$	$\hat{\sigma}_p^2$	$\hat{h}^2$
DS[1]	0.070 ± 0.026	0.0000 ± 0.0000	0.055 ± 0.019	0.125 ± 0.013	0.560 ± 0.174
TS[2]	0.082 ± 0.028	0.0000 ± 0.0000	0.046 ± 0.020	0.128 ± 0.013	0.640 ± 0.175
QBA[3]					
Positive QBA					
Apathetic	0.078 ± 0.028	0.0000 ± 0.0000	0.051 ± 0.020	0.129 ± 0.013	0.604 ± 0.177
Calm	0.081 ± 0.028	0.0000 ± 0.0000	0.049 ± 0.020	0.131 ± 0.014	0.623 ± 0.174
Curious	0.074 ± 0.027	0.0000 ± 0.0000	0.051 ± 0.020	0.125 ± 0.013	0.591 ± 0.176
Happy	0.078 ± 0.028	0.0000 ± 0.0000	0.047 ± 0.020	0.125 ± 0.013	0.628 ± 0.176
Pos. occupied	0.072 ± 0.027	0.0000 ± 0.0000	0.053 ± 0.020	0.125 ± 0.013	0.5771 ± 0.178
Relaxed	0.080 ± 0.028	0.0000 ± 0.0000	0.051 ± 0.020	0.131 ± 0.135	0.610 ± 0.175
Negative QBA					
Active	0.080 ± 0.028	0.0000 ± 0.0000	0.051 ± 0.020	0.131 ± 0.014	0.615 ± 0.174
Agitated	0.080 ± 0.028	0.0000 ± 0.0000	0.050 ± 0.020	0.131 ± 0.013	0.615 ± 0.174
Attentive	0.076 ± 0.028	0.0000 ± 0.0000	0.053 ±0.020	0.129 ± 0.013	0.592 ± 0.176
Distressed	0.078 ± 0.028	0.0000 ± 0.0000	0.052 ± 0.020	0.130 ± 0.133	0.602 ± 0.173
Fearful	0.080 ± 0.028	0.0000 ± 0.0000	0.050 ± 0.020	0.130 ± 0.013	0.617 ± 0.173
Irritated	0.080 ± 0.028	0.0000 ± 0.0000	0.050 ± 0.020	0.131 ± 0.013	0.617 ± 0.173
TI[4]	0.080 ± 0.028	0.0000 ± 0.0000	0.051 ± 0.020	0.131 ± 0.013	0.609 ± 0.174
TI positive	0.082 ± 0.029	0.0000 ± 0.0000	0.050 ± 0.021	0.132 ± 0.136	0.622 ± 0.175
TI negative	0.078 ± 0.028	0.0000 ± 0.0000	0.051 ± 0.020	0.130 ± 0.013	0.603 ± 0.174
SSD[5]	0.078 ± 0.028	0.0000 ± 0.0000	0.051 ± 0.020	0.129 ± 0.013	0.601 ± 0.173
CVSSD[6]	0.078 ± 0.027	0.0000 ± 0.0000	0.051 ± 0.020	0.130 ± 0.013	0.604 ± 0.172

Variance components and genetic parameter are estimated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of dam temperament, sire docility expected progeny difference (EPD), primary breed, sex, random effect of animal with known pedigree, and maternal effect.

$\hat{\sigma}_a^2$ = estimated additive genetic variance, $\hat{\sigma}_{me}^2$ = estimated maternal effect variance, $\hat{\sigma}_e^2$ = residual variance, $\hat{\sigma}_p^2$ = estimated phenotypic variance, and $\hat{h}^2$ = estimated heritability.

[1]DS = Docility score.

[2]TS = Temperament score.

[3]QBA = QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.

[4]TI = Temperament index: the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

[5]SSD: standard deviation of total weight over time recorded by four-platform standing scale,

[6]CVSSD: coefficient of variation based on the SSD.

Table A30. Genetic parameters estimation ($\hat{\sigma}_a^2$, $\hat{\sigma}_{me}^2$, $\hat{\sigma}_e^2$, $\hat{\sigma}_p^2$, and $\hat{h}^2$) for weight gain (WG) when including sire and dam temperament in the model.

Method	$\hat{\sigma}_a^2$	$\hat{\sigma}_{me}^2$	$\hat{\sigma}_e^2$	$\hat{\sigma}_p^2$	$\hat{h}^2$
DS[1]	806.111 ± 644.889	498.365 ± 408.496	2008.960 ± 493.602	3313.400 ± 315.500	0.243 ± 0.184
TS[2]	1126.460 ± 746.000	439.025 ± 410.304	1811.590 ± 522.072	3377.1 ± 334.450	0.334 ± 0.203
QBA[3]					
Positive QBA					
Apathetic	843.254 ± 663.980	534.771 ± 421.080	1978.550 ± 499.634	3356.600 ± 320.920	0.251 ± 0.187
Calm	1126.990 ± 736.595	392.451 ± 426.577	1915.060 ± 533.443	3434.500 ± 336.830	0.328 ± 0.198
Curious	748.385 ± 623.654	521.793 ± 404.491	1972.880 ± 480.019	3243.100 ± 307.080	0.231 ± 0.182
Happy	925.846 ± 666.076	384.937 ± 400.976	1912.490 ± 498.044	3223.300 ± 311.450	0.287 ± 0.193
Pos. occupied	611.832 ± 594.012	585.135 ± 412.067	2038.600 ± 469.723	3235.600 ± 302.300	0.189 ± 0.176
Relaxed	1044.920 ± 715.699	402.134 ± 427.802	1984.510 ± 530.618	3431.600 ± 333.37	0.305 ± 0.193
Negative QBA					
Active	1014.020 ± 709.105	467.198 ± 424.725	1958.010 ± 522.136	3439.200 ± 333.440	0.295 ± 0.192
Agitated	1091.820 ± 727.880	418.786 ± 423.016	1933.510 ± 531.184	3444.100 ± 336.790	0.317 ± 0.196
Attentive	680.240 ± 601.982	735.179 ± 415.355	1915.370 ± 458.223	3330.800 ± 313.560	0.204 ± 0.173
Distressed	1041.700 ± 708.639	349.375 ± 420.934	2022.590 ± 532.261	3413.700 ± 330.040	0.305 ± 0.192
Fearful	1096.750 ± 716.830	355.508 ± 413.381	1937.050 ± 529.249	3389.300 ± 330.790	0.324 ± 0.192
Irritated	1112.250 ± 726.961	389.246 ± 418.544	1934.300 ± 531.401	3435.800 ± 335.420	0.324 ± 0.190
TI[4]	989.982 ± 702.115	450.925 ± 425.401	1957.500 ± 517.857	3398.400 ± 329.270	0.291 ± 0.193
TI positive	1108.670 ± 744.074	379.250 ± 430.966	1964.610 ± 541.215	3452.500 ± 338.570	0.321 ± 0.199
TI negative	851.244 ± 665.034	570.801 ± 419.707	1951.390 ± 495.277	3373.400 ± 322.890	0.252 ± 0.186
SSD[5]	1142.530 ± 727.726	216.240 ± 424.000	2052.270 ± 544.369	3411.000 ± 333.220	0.335 ± 0.196
CVSSD[6]	1091.640 ± 713.490	308.161± 416.434	1991.650 ± 528.289	3391.500 ± 330.410	0.322 ± 0.194

Variance components and genetic parameter are estimated using ASReml 4.2 (Gilmour et al., 2015) using fixed effects of dam temperament, sire docility expected progeny difference (EPD), primary breed, sex, random effect of animal with known pedigree, and maternal effect.

$\hat{\sigma}_a^2$ = estimated additive genetic variance, $\hat{\sigma}_{me}^2$ = estimated maternal effect variance, $\hat{\sigma}_e^2$ = residual variance, $\hat{\sigma}_p^2$ = estimated phenotypic variance, and $\hat{h}^2$ = estimated heritability.

[1]DS = Docility score.

[2]TS = Temperament score.

[3]QBA = QBA are grouped by positive (apathetic, calm, curious, happy, positively (pos.) occupied, and relaxed) and negative (active, agitated, attentive, distressed, fearful, and irritated) like behavior.

[4]TI = Temperament index: the first principal component score generated from QBA scores, TI positive: the first principal component score generated from positive QBA scores, and TI negative: the first principal component score generated from negative QBA scores using a Principal Component Analysis in SAS (SAS Institute, Inc., Cary, NC.).

[5]SSD: standard deviation of total weight over time recorded by four-platform standing scale,

[6]CVSSD: coefficient of variation based on SSD.