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Estimation of Genetic Components Related to Infectious Bovine Keratoconjunctivitis Susceptibility in Angus and Angus Derived Cattle Produced in the Southern United States

Eric Oxford
University of Arkansas, Fayetteville

Estimation of Genetic Components Related to Infectious Bovine Keratoconjunctivitis Susceptibility in Angus and Angus Derived Cattle Produced in the Southern United States

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by

Eric Oxford
University of Arkansas
Bachelor of Science in Animal Science, 1996
University of Arkansas
Master of Science in Animal Science, 2003

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University of Arkansas, Fayetteville

This dissertation is approved for recommendation to the Graduate Council.

_____
Michael Looper, Ph. D.
Dissertation Director

_____
D. Wayne Kellogg, Ph. D
Committee Member

_____
Edward Gbur, Ph. D.
Committee Member

_____
Charles F. Rosenkrans, Ph. D
Committee Member

_____
Fred W. Pohlman, Ph. D.
Committee Member

ABSTRACT

The economic impact of infectious bovine keratoconjunctivitis (IBK) has been documented in many parts of the world. Many researchers have observed that prevention of this disease is very difficult given current methodologies. This is primarily due to the multifactorial nature of this disease. The objective of this dissertation was to determine the impact of IBK on calf performance and estimate genetic parameters, heritability and estimated breeding values for IBK susceptibility. Data were analyzed using PROC GLIMMIX of SAS; while genetic parameters were estimated using a linear animal model for both single- and two-traits through MTDFREML. Additional evaluations calculated heritability using a linear animal model in DMU and using a binary animal model in ASREML. Significant differences were observed between producer locations (PL) and season of birth for the incidence of IBK. Spring born Angus and Angus-derived calves were determined to be 12.5 times more susceptible to IBK ($P \leq 0.05$) than were fall born calves. Heritability for IBK susceptibility was estimated to be rather low using a linear animal model 0.11 ± 0.053 and 0.12 ± 0.003, MTDFREML and DMU, respectively. The binary animal model estimation of heritability was moderate 0.33 ± 0.150. Estimates of genetic, environmental, and phenotypic variances for IBK susceptibility were 0.0077, 0.0600, and 0.0677, respectively. Genetic and environmental correlations between IBK and BWT and WWT were estimated to be 0.45 and -0.08: and 0.61 and -0.15, respectively. Model selection proved to have a substantial influence on heritability estimates while the breeding software program utilized did not. Regardless of program or model utilized, the estimation of the breeding values was minimally affected. These results indicate that genetic improvement through selection of animals which are less susceptible to IBK can be beneficial; however, the overall progress would be rather slow. There is evidence in the literature that

coupling relationship information with genomic data can potentially increase estimates of genetic merit and reliability which could accelerate genetic improvement for this trait.

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DEDICATION

I would like to dedicate this dissertation to my father Lennis Oxford (You never lost hope - I think we are going to make it!), mother Donna Oxford, wife Elizabeth Oxford and my two children Emily Oxford and Ella Oxford. Your love and support though the years has made this possible. I would also like to dedicate this to the late Dr. A. H. Brown, Jr. He was a tremendous influence in my life and where I am today. Thank you all!

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INTRODUCTION

The current world population (June 2019) is estimated at just slightly over 7.71 billion inhabitants. In approximately 15 years, by 2035, the world population is expected to grow by an additional 1.1 billion inhabitants (Dadax, 2019). Consequently, during that same time it is expected grazing land will decrease due to conversion of some rural areas to urban areas as well as rotation of some areas into permanent crop production, among other things. So, it is easy to see there will be a substantial challenge for the world's protein supplies, in their current form, to meet this increased demand. Additionally, trends today indicate consumers are looking for animal proteins sourced from animals which have never been administered antibiotics.

Research needs to be conducted which minimizes disease impacts in current production programs. It has been shown infectious bovine keratoconjunctivitis (IBK), though not fatal in nature, does have a substantial impact on animal performance. Hansen (2001) and Richey (2003) estimated that 10 million calves were affected annually in the United States. It has been shown that the average weight difference between affected and unaffected calves ranges from 6 kg (Thomas et al., 1978) to 23 kg (Thrift and Overfield, 1974). That equated to potential loss of between 60 and 230 million kg of annual production.

Infectious bovine keratoconjunctivitis is a highly contagious ocular disease in cattle and other ruminants. It is believed to be caused by a gram-negative, rod-shaped bacterium, *Moraxella bovis,* since it has been isolated in many, but not all, ocular secretions from infected animals. It has been reported there are up to nine serogroups, based on pilin properties. These pili facilitate the attachment of the organism to the corneal surface. The presence of hemolytic factors disrupt the conjunctival surfaces as the disease progresses causing extreme irritation. It has been reported the Hereford breed has been observed to have a greater incidence of IBK

infections when compared to other breeds. This is believed to be due to the lack of pigmentation on the eyelids resulting in UV damage and subsequent bacterial infection and ultimately IBK symptom development.

Current control methodologies which are practiced by producers regularly are vaccination and physical hazard abatement. Several studies have investigated the efficacy of the current over the counter vaccines and found them to be somewhat inefficient due to the variation between stains on *M. bovis* (Burns and O'Connor, 2008). Additional effort toward developing effective vaccination programs against IBK have focused on the development of autogenous vaccines, which have been reported to have some limited success.

Research has shown that there are antibiotics which can effectively treat infected animals. Treatment can be administered intramuscularly, subcutaneously, or under the conjunctiva depending on the antibiotic labeling. Administration of the antibiotic can be stressful for the animal and time consuming and dangerous for the producer. Most often, a second treatment is required to further assist the animal in the healing process. Axford et al. (2000) reported there are strains of *M. bovis* which are becoming resistance to some antibiotics.

In the world of science, it has been shown there are lines within species which are resistance to certain diseases while other lines are not. It is sometimes shown lines with the higher production potential are often those which are more susceptible to an infection or disease. Plant breeders have been able to capitalize on these differences and produce lines with have an innate resistance with an improved production potential. So, given that genetic material is transmitted in a somewhat similar manner in animals, it stands to reason that there is genetic potential to select animals against being susceptible to disease.

Some evaluations have been conducted to estimate heritability, variances components (phenotypic, environmental, and genetic) and correlations between disease susceptibility and production traits in cattle produced in the upper Midwest, but little has been reported on animals raised in the Southern United States (Rodriguez, 2006). Snowder et al. (2005) reported heritability of cattle raised in the northern areas to be low to moderate, indicating that selection can help improve the trait of concern; however, progress would more than likely be slow. They also reported that they observed a large variation between heritability values estimated between within breeds. These values ranged from 0 for many of the Continental breeds to 0.25 for many of British breeds.

There are several versions of animal breeding software which can be utilized to calculate estimated breeding values. Each program has their own unique features and requirements which must be considered before they are utilized. Through these programs, breeding values can be predicted or estimated. Estimated breeding values and thus expected progeny differences (EPDs) aid producers in selecting animals for breeding purposes which potentially possess the genetic potential to influence the characteristic in the desired direction.

The purpose of this dissertation is to:

1) Estimate heritability; phenotypic, genetic, and environmental variances; phenotypic, genetic, and environmental covariances variances; and genetic and environmental correlations for IBK susceptibility and birth and weaning weight of beef cattle.
2) Evaluate estimates heritability and estimated breeding values from three breeding software programs for single-trait IBK analyses using two different models.

LITERATURE REVIEW

Animal wellbeing and herd health are very important issues with today's producers, consumers, and the public in general. In recent years the field of animal welfare has grown tremendously with focus on animal health and comfort. It is important perceptually as well as economically that animals are managed in a manner to promote general overall good health and wellbeing as to maximize production potentials, whether that be increased weight gain of calves or pounds of milk produced. Many diseases or inflictions adversely impact potential economic gains in cattle production (Brown et al., 1998; Snowder et al., 2005a; Snowder et al., 2006).

Given the substantial economic impact, much interest has been placed on how the animals respond to disease challenges. One disease which is of major concern is infectious bovine keratoconjunctivitis (IBK) or "pinkeye" as it is commonly called. Pinkeye has been around for centuries but is thought to have been first described first by Akkerman in 1886 and Schimmel in 1888 in the Netherlands, and by Billings in 1899 in Nebraska. The history of the disease and its close relationship to sunlight and other physical and microbial irritants were reviewed in depth by both Hughes et al. (1965) and Baptista (1979).

It has been reported by the National Animal Health Monitoring System (NAHMS) that greater than 29% of beef cattle operations feel IBK is a disease which has significant economic impact on their individual operation (NAHMS 1997a, b). It is estimated IBK affects approximately 10 million calves annually with an estimated economic loss of approximately $150 to 200 million in the United States (Hansen, 2001; Richey, 2003). Beef producers in the Midwestern United States have reported IBK is observed in almost 50% of herds with slightly less than 9% of the total animals being affected (Webber and Selby, 1981). The results of a survey of cattle producers conducted in Kansas in 1993 indicate IBK was the second most important

disease they encounter and deal with annually. In the neighboring state of Missouri, it has been reported 45.4% of cattle herds have been affected by IBK (Webber and Selby, 1981).

It has been well documented potential production and financial impacts of IBK are not just limited to the United States. In Australia, in the late 70's, economic losses were estimated to be at around 22 million dollars with 1.5 million dollars being spent annually on treatment options (Slatter et al., 1982). The results of an Australian postal survey indicated that 81.3% of the respondent producers reported IBK occurrence with 75% observing a substantial reduction in production weights (Slatter et al., 1982).

Infectious bovine keratoconjunctivitis can dramatically impact the production potential of young animals. Thrift and Overfield (1974) found Hereford yearling calves which had been affected by IBK were on average 23 kg lighter than their unaffected contemporaries. Similar differences were seen by Rodriguez et al. (2006), Thomas et al. (1978), and Frisch et al. (1975) 13.6 kg, 6.5 kg and 22.8 kg, respectively. Funk et al., (2009) found similar results with affected calves weighing 7 to 11 kg on average less at weaning than did their unaffected contemporaries. Interestingly, in the same study post-weaning average daily gain was determined to be greater for the affected calves by 0.02 kg/day; but, that advantage was not sufficient to offset the pre-weaning weight lost.

Many researchers have described IBK in-depth (Rodriguez et al., 2007; Snowder et al., 2005). They all agree IBK is a highly contagious, bacterial disease of the ocular surface and conjunctiva which can affect cattle of all ages; although it is more commonly observed in the younger animals (Chandler et al., 1979). This increased susceptibility of the younger animals has been attributed to the underdevelopment of immune factors, ocular antibodies, that are developed as a result of previous exposure to a challenge from the infectious agent.

For many animals, at the onset/initiation of the infection, only one eye is involved; but as the disease progresses it is not uncommon for infection from the first eye to migrate to the other eye resulting in an animal where both eyes are implicated (Bedford, 1992). Studies have shown that the production potential of animals where both eyes are affected is reduced more severely than those where only one eye in implicated (Killinger, 1977).

Clinical IBK symptoms are characterized by increased frequency of blinking and watering of the affected eye(s) because of the swelled conjunctiva and photophobia and increased sensitivity to light (Ward and Powell, 2017; Boileau et al., 2015). As the disease progresses toward the latter stages, one can notice the formation of a small opaque area on the cornea. If left untreated, the corneal swelling can lead to rupture of the cornea resulting in substantial discoloration of the cornea and potentially blindness (Brown et al., 1998).

Many of the current prevention/treatment methods utilized, vaccination, antibiotics and/or physical barriers, have been shown to have limited impact in preventing or curing the disease once it has been observed. So, other areas need to be explored.

Incidence

Incidences of IBK occurrence have been recorded in many countries of the world (Australia, New Zealand, India, Israel, Iran, United Stated, and Canada). Infectious bovine keratoconjunctivitis is a very contagious disease with outbreaks seen predominately in the warmer months for cattle grazing forages (Snowder et al., 2005; Burns et al., 1986; Bryan et al., 1973; Wilcox, 1969). The increased incidence of IBK during this time is believed to partially be due to the increased photoperiod seen during the warmer seasons. The increased photoperiod translates to longer exposure to the UV radiation source and has been shown to precede an increase in incidence of IBK (Hughes and Pugh, 1970; Lepper and Barton, 1987). It is suspected

the increased exposure results in cellular tissue damage and sloughing of the corneal epithelial cells thus providing the pathogen a means of potential infection.

In controlled experiments, researchers have shown that introducing *M. bovis* to the ocular surface after exposure to UV radiation can initiate infection and increase the disease severity (Lepper and Barton, 1987: Hughes et al., 1968). Research has shown that the ability of *M. bovis* to initiate infectious IBK is highly linked to the organism's ability to adhere to the corneal surface (Prietro et al., 1999). Vogelweid et al. (1986) was able to demonstrate similar results in pathogen attachment utilizing bovine corneas of six calves and sun lamps to replicate the UV source. Through evaluation of the corneal surface utilizing electron microscopy, they demonstrated that after exposure to an UV light source and inoculation with a pathogenic strain of *M. bovis,* those animals which exhibited symptoms of clinical IBK had a higher concentration of damaged corneal epithelial cells relative to the attachment areas.

Additional concerns for increased IBK occurrence during the warmer months are attributed the fly populations typically at their greatest incidence, hemolytic strains of *M. bovis* are more prevalent, and there are more opportunities for physical ocular damage due to poor forage management and production environment practices (Baptista, 1979).

Hubbert and Hermann (1970) and almost 40 years later, Staric et. al. (2008) reported observing winter outbreaks of an IBK like disease. Winter outbreaks do happen, but they are more localized, and they are much less frequent than those seen in the warmer months. Several of the observed winter cases differ from the summer cases in that *Listeria monocytogenes* was isolated as the primary causative microbial agent and not *M. bovis* as previously discussed. In these cases of IBK, it was determined that poorly fermented silage was the source of the microbial agent and thus termed "silage eye" and upon inspection of the corneal surface little to

no pitting was observed. However, in a few IBK winter occurrences, it has been documented that heavy snowfall has facilitated an increase in UV exposure resulting eye damage and infection from *M. bovis* (Staric et al., 2008; Lepper and Barton, 1987).

Research has shown all breeds are affected, but some breeds have more potential to be implicated than other breeds. In North American herds, *Bos indicus* breeds appear to be less susceptible to IBK than do the *Bos taurus* breeds. Snowder et al. (2005), Webber and Selby (1981), and Frisch (1978) have shown that of the *Bos taurus* breeds, Hereford and in some instances Jersey and Holstein breeds appear to be most susceptible to the infection. Brahman, Zebu, and respective crosses seem to be predisposed to resistance to IBK. One of the main differences that leads to the variation observed within the B*os taurus* breeds is suspected to be related to amount of eyelid pigmentation. Research has shown that those breeds which lack or have limited eyelid pigmentation have an increased risk of IBK (Ward and Nielson,1979; Caspair and Wood, 1980; Pugh et al., 1986).

Considerable variation within breed has been seen relative to geographic region. The Angus breed has been documented by many in the United States as a breed that is very low in susceptibility of IBK infections (Slatter et al., 1982). Snowder et al. (2008) reported that over a 20-year study for the Angus breed the average incidence in IBK was 3.7% which was well below the average of 6.5% for all breeds.

Epidemiology (Causation)

Infectious bovine keratoconjunctivitis has been classified by many as a very contagious multifactorial disease that spreads rapidly within the production environment. Many factors have been proposed as potential causative agents. In reviewing the pertinent literature many researchers indicated that at least one of the following was a potential contributor to the

occurrence and severity of an IBK infection: environment, season, physical injury, transmission vectors, other microbial challenges, the strain of *M. bovis*, dietary insufficiencies, and the host's immune system (Brown et al., 1998).

Vector transmission occurs when contact in made with ocular and nasal discharge from affected animals. Common vectors of transmission include: the face fly *(Musca autumnalis),* the house fly *(Musca domestica),* and the common barn fly *(Stomoxys calcitrans)* with the face fly be perceived by many as the most important transportation vector (Koepcky et al., 1986). These organisms can facilitate the rapid proliferation of pinkeye throughout the production environment by transporting the main causative microbiological agent, *Moraxella bovis*. In 1982, Gerhardt reported a positive correlation between IBK infection rate and the number of flies recorded per animal. It has also been mentioned an adequate and effective fly control program does reduce the incidence of IBK by potentially impeding transmission.

Moraxella bovis (*M. bovis*), a gram-negative coccobacillus, is the most common opportunistic pathogen observed in association with IBK outbreaks and it is the only known microorganism to meet the requirements of Koch's postulate (Henson and Grumbles, 1960, George, 1984).

Moraxella bovis has been observed in ocular and nasal discharge of animals which show no clinical signs of infection (Pugh and McDonald, 1986; Bedford, 1976; Marr, 1977). Cattle are the only known carrier of the *M. bovis* organism. Researchers throughout the years have determined that there are other suspected potential causative organisms with in the *Moraxella* family. These include *Moraxella bovoculi (M. bovoculi)* as well as *Moraxella ovis (M. ovis). Moraxella bovoculi* has been isolated from inflicted ocular environments where IBK symptoms were exhibited (Angelos et al., 2007a; 2007b; 2010; 2011). It is important to note that it is

possible that a large portion of the *M. ovis* recovered from affected eyes prior to the identification of *M. bovoculi*, could now be attributed to *M. bovoculi*.

Research has shown that *M. bovoculi* has been observed in animals which are exhibiting clinical signs of IBK. Rather recently, Loy and Broderson (2014) observed that *M. bovoculi* was observed in a majority of the submitted samples evaluated with less than one third containing *M. bovis.* This finding is rather interesting because Gould et al. (2013) determined that *M. bovoculi* introduction onto compromised corneas did not induce IBK in young dairy calves.

The physical/production environment coupled with management practices have been suspected to have a major impact on the occurrence and severity of IBK. Improper pasture management is suspected to have an impact on the incidence of IBK. Those pastures which are comprised of tall grasses and weeds tend to become dry in the warmer seasons and can irritate the ocular areas of grazing animals. Additionally, the dry seed head and stems provide additional vectors for potential transmission the *M. bovis* from unhealthy or carrier animals to those which are unaffected.

Substantial year to year differences have been seen in the prevalence of IBK (Snowder et al., 2005; Aikman 1985). It has also been well documented that seasonal prevalence of the disease varies greatly for different geographic regions (Loy and Broderson, 2014).

Other organisms as well as *M. bovis* have been identified in the conjunctiva of cattle exhibiting symptoms of clinical IBK. It remains to be determined if the presence of these organisms in any way inhibit the host systems from functioning properly and thus facilitates the development of IBK.

Other bacteria have been isolated from eyes of animals displaying clinical IBK in the absence of *M. bovis*. Other potential documented isolates from pinkeye outbreaks are:

Branhamella ovis (Elad et al., 1988), *Neisseria ovis* (Nagy et al., 1989), infectious bovine rhinotracheitis (IBR), and *Mycoplasma bovoculi* (Nicolet et. al., 1976). These cases are unusual but give some credence other bacteria may be associated as an additional etiological agent in some cases of IBK.

From literature, IBR and *Mycoplasma* spp. have been determined to have an increased potential for causing IBK (Timoney and O'Conner, 1971). Cattle infected with IBR sometimes display clinical signs similar to those observed in IBK outbreaks: however, there is no documentation of ulceration of the corneal surface. Since the clinical indications are so similar, Whittier (2000) indicated that vaccination for IBR with a modified live vaccine might facilitate a pinkeye outbreak by making the ocular area more susceptible to *M. bovis*. Research has established a potential relationship between IBR vaccination and a greater incidence of IBK. Webber and Selby (1981) suspected that the relationship is the result of a secondary infection, as opposed to being directly related to the IBR vaccine.

Rosenbusch (1983), Friis and Pendersen (1979), Nicolet et al. (1976) and Langford and Leach (1973) identified a concentrated presence of *Mycoplasma* spp. in unhealthy IBK subjects where *Mycoplasma bovoculi* was the most predominately observed bacterium. Whether *Mycoplasma bovoculi* can cause IBK alone or there is a communal or opportunistic relationship between it and *M. bovis* remains to be seen. Research has demonstrated after vaccination, *Mycoplasma bovoculi* could be isolated during the whole period. Once the calves were challenged by administering the live bacteria the eyes were all free of the organism at day 10 while most were free at day 3 (Salih et al., 1987).

Nagy et al. (1989) reported 224 samples collected from animals which displayed symptoms consistent with clinical IBK, 56.2% were attributed to *M. bovis* while 28.5% were

attributed *Neisseria ovis* (later termed *Branhamella ovis*). Similarly, *Neisseria ovis* findings have been reported in sheep (Lindqvist, 1960) and sheep and cattle in Scotland (Fairlie, 1966). While these results are interesting, they are contradictory to what Chandler et al. (1985) reported. They questioned the ability of *Neisseria ovis* to be a causative agent in clinical IBK but did prove it had the ability to bind to the corneal surface. Baptista (1979) indicated in previous inoculation experiments with *Neisseria ovis* at a high level led only too a few test subjects demonstrating signs of mild conjunctivitis. This information leads one to question if the *Neisseria ovis* samples were collected from subjects where the disease had progressed to the latter stages or if the *Neisseria ovis* infection is just an invasion by an opportunistic organism which could out compete *M. bovis*. It is also important to note the biochemical and morphological characteristics of these two microbes are quite different (Nagy et al., 1989).

Disease Identification

For IBK, many researchers have provided similar clinical descriptions (Davidson and Pickett, 2009; Kopecky et al., 1986; Baptistia 1989). They stated diagnosing IBK can be accomplished by using the common clinical signs. At the initial onset of an IBK infection one can identify an affected subject by profuse wet ocular discharge and blepharospasm. As the infection progresses one can notice epiphora and intense photophobia followed by increased discharge and discoloration of the preorbital corneal surface. In the latter stages, the conjunctiva is observed to be increasingly swollen with further corneal edema and clouding of the corneal surface develops within 2 to 4 days. The final stages of the infection for some individuals includes corneal ulceration which can result in temporary or in the more severe cases permanent blindness. In cases which are mild in severity, limited corneal involvement is observed. The cloudiness of the cornea should improve if not disappear in a few weeks. Individuals which are

bilaterally challenged have been observed to be rather sedentary. It is important to note there is considerable variation between individuals for disease progression (Davidson and Pickett, 2009). It is truly not understood why in some subjects the disease progresses rapidly while others progress through the stages slowly.

Culturing of implicated animals is recommended in outbreaks to determine the strain of bacteria involved and to propose the best treatment options. Collection of the conjunctival swabs and lacrimal secretions are believed to be best methods for collecting samples to submit evaluation (Burns and O'Connor, 2007).

Bacterial Challenges

The eye is a very delicate environment and has many defense mechanisms which are designed to prevent incidental contact with hazards and minimize the risk of those hazards becoming problematic. These mechanism(s) are instrumental in preventing and minimizing IBK infections and they are: the eye lid, tear film, chemical composition of the tears, conjunctival and corneal epithelial, as well as the submucosal immunoglobulin system (Eichenbaum et al., 1996). It has been observed, the rapid regeneration of the corneal and conjunctival epithelial cells serves to deter adhesion by microbial entities while the tears provide a transport function where compounds which are antimicrobial in nature (i.e. beta-lysine, lactoferrin, and transferrin) are delivered to sites of damage and infection.

The method in which contact with the *M. bovis* organism results in symptomatic IBK is still only partially understood; however, given the complexity of the ocular environment's defense mechanisms the initiation of an infection is more than likely multifactorial in nature.

Research has shown the presence of fimbriae (primarily a type IV pili) or the ability of the organism to express them as well as the ability to produce and secret hemolysin or cytotoxin

are required characteristics for the *M. bovis* strain to be considered virulent. More specifically, Marrs et. al (1985) further divided the pili into different categories (Q and I) based on their functionality which led to Ruehl et al. (1993) determining the Q pili was implicated in the initiation of the infection while the I pili was important for maintaining the infection.

Evidence of the relationship between these characteristics has been proven through inoculation experiments where both hemolytic and nonhemolytic strains of fimbriated *M. bovis* were administer and only those subjects receiving the hemolytic strains exhibited clinical IBK symptoms (Rogers et al., 1987). Additionally, hemolytic strains have been identified individuals with IBK while nonhemolytic stains have been observed in asymptomatic carriers (Cox et al., 1984; Lepper and Barton, 1987)

Brown et al. (1998) has described the in vitro morphology of the *M. bovis* colonies as either rough or smooth in appearance. The rough appearance of the colonies is attributed to the surface characteristics or pili. Those colonies which contain the pili being described as rough while those lacking the surface pili being described as smooth. Early observations of some *M. bovis* colony morphology was described as either smooth and later changed to rough or rough and later changed to smooth (McMichael, 1992). These differences between colonies can been observed through crystal violet staining (Brown et al., 1998). These pili have long been considered vitally important by researchers for managing and potentially controlling IBK through vaccination, but due to the different serotype observed this has proven highly problematic and questionable to say the least.

Different strains of *M. bovis*, based on fimbrial expression and characteristics, were initially divided into nine serogroups (Lepper and Hermans, 1986) based solely on ELISA; but, have since been reclassified into seven distinctive serotype groupings (A-G) based on the pili

(Atwell et al., 1994). These groupings are based on their evaluations of the variable fimbrial antigens using combined enzyme-linked immunosorbent assay ELISA, whole cell slide agglutination and tandem-crossed immune-electrophoresis (TCIE) (Moore and Lepper, 1991).

As stated previously, the presence of pili or fimbria are a very important indicator and determinant of virulence (Annuar and Wilcox, 1985; Jackman and Rosenbusch, 1984). They allow the pathogen to bind to the corneal surface facilitating microbial growth and thus allowing the pathogen to establish an infection by circumventing the eye's natural defense mechanism (Moore and Rutter, 1989; Chandler et al., 1979; Ruehl et al., 1988). Research has determined fimbrial proteins have immunogen genic properties with many different variations observed between the different strains of *M. bovis* (Moore and Lepper, 1991; Lehr et al., 1985; Pugh et al., 1984; Pugh et al., 1977).

Moraxella bovis is known to produce a cytotoxin/hemolysin which has been determined to be hemolytic in nature (Billson et al., 2000). The hemolysin has been classified as a toxin which is produced by the bacterium. As the infection progresses the hemolysin attacks the cornea and conjunctiva and erodes the surface, which results in severe inflammation and discomfort. It is suspected that this hemolysin has a major function in the ulceration of the afflicted corneal surface (Frank, and Gerber, 1981). The presence of the hemolysin, which is believed to contain both a protein and an enzyme (Ostle and Rosenbusch, 1984), is believed to inhibit the hosts response to the infection by damaging leukocytes and degrading the corneal epithelial cells (Beard and Moore, 1994; Rogers et al., 1987).

To further validate hemolysin involvement, in an *in vitro* setting, Chandler et al. (1985) observed "pit-like" areas on the corneal surfaces with which clinical IBK isolates of *M. bovis* bacteria had associated. For those isolates which were collected from asymptomatic carriers and

classified as nonpathogenic little to no corneal pitting was observed. Additionally, Arora et al. (1976) observed a positive correlation associated with the presence of some hemolytic strains of *M. bovis* and IBK prevalence. In the same *in vitro* study, it was shown these hemolytic strains would kill corneal epithelial cells.

It has been observed *M. bovis* produces an abundance of other lytic enzymes which are suspected to be involved with IBK infections. It has also been observed that phospholipase B is present as well (Shiell et al., 2007; Farn et al. 2001). Phospholipase B (a formation comprised of phospholipase A_1 and phospholipase A_2) is believed to function as conventional autotransporter protein has been linked to lipolytic functions. Further evaluation by Farn et al. (2001) indicated the identified phospholipase B was present in each of the known *M. bovis* serotypes which could assist in the development of vaccines which target all strains.

Prevention, Control, and Treatment

Moraxella bovis has been shown to exist in ocular and nasal samples collected from asymptomatic individuals, so complete eradication of the disease is impractical if not impossible. One must understand currently there are no control methodologies which are 100% effective at controlling IBK. Given this information it is understandable that the logical course of action is to focus on combining treatment methods to prevent, control, and treat affected individuals.

First and foremost, many researchers have stated the best way manage and control an IBK outbreak is to effectively quarantine affected individuals as soon as they are identified (Brown et al., 1998). This should be done in manner which would limit the potential of cross-contamination of healthy individuals since IBK is highly contagious and can be transmitted by a variety of small mobile vectors.

Vaccinations have effectively been utilized in both human and animal medicine throughout the years. Effective vaccination programs have proven their crucial role in the eradication of many diseases. For instance, illnesses related to polio and small pox outbreaks are virtually unheard of today, when only a few years they were highly problematic. The same can be said for brucellosis in the cattle industry, which has been effectively controlled through the utilizations of a government sponsored vaccination program of young breeding animals.

Many agree a vaccination program should be utilized with good physical hazard management practices. Many of the commercially available vaccines are comprised of inactivated pili antigen(s) (di Girolamo et al., 2012; Lepper et al., 1993; Lepper et al., 1992). The effectiveness of vaccination programs in relation to prevalence of pinkeye has been highly debatable (Burns and O'Connor et al., 2008; Jayappa and Hehr, 1986). It has been shown IBK can be caused by a number of different *M. bovis* strains, so selection of an effective vaccine is crucial. The vaccines which have been shown to be the most effective are those that contain pili from multiple isolates, multivalent (Jayappa and Hehr, 1986). These are expected to improve the level of protection within the herd.

The most predominant treatment for pinkeye infections is the parenteral administration of antibiotics. Typically, only those animals which display symptoms that are consistent with clinical IBK are treated leaving those animals which are could be considered carriers untreated (McConnel et al., 2007; George et.al. 1988; Punch et al., 1985). For the best results, the treatment administered should target the suspected bacterium and completely eradicated it from the ocular environment. This is critical since disease reoccurrence has been observed in animals during post-treatment recovery period (George and Wilson, 1984). It is critical the operator/manager identifies the correct causative agent so the correct treatment regimen can be

utilized and limit the potential for reoccurrence, minimize treatment costs and minimize animal stress.

Parenteral injection (subconjunctival, subcutaneous, intramuscular, and intravenous) of antimicrobial compounds is commonly used by produces to treat IBK (Brown et al., 1998). Antibiotic injections (intramuscular, subcutaneous, or subconjunctival) are the most commonly utilized treatment methods to combat the detrimental effects of an IBK outbreak. The antibiotics must display a lipophilic behavior, so they can diffuse into the tear film in a high concentration in order to be effective are treating the infection. Erythromycin is one example of an antibiotic which is successful at diffusing into the tear film through a normal injection. These drugs are very expensive are not extremely effective at controlling *M. bovis*. Long-acting oxytetracycline is a parenteral drug with limited diffusion into the tear film but has been shown to be effective in treating *M. bovis* infection.

The reliance on antibiotics and poor adherence to follow-up/subsequent administration has led to increased selection opportunities on bacterial populations and the evolution of resistant strains to the chemicals utilized (Axford et al. 2000). Some of the reported strains of *M. bovis* are becoming resistant to some antibiotics in the United States (tylosin, lincomycin, and tetracycline) (McConnel et at., 2007; Shyrock et al., 1998; Pugh and McDonald, 1977).

There two common ways which the antibiotics can be administered (injection and topical application). Each of which has its own distinct advantages and disadvantages. Injections of long-acting tetracycline compounds are widely used in production schemes today. These are easy to administer and can reduce the carrier stage of the disease when administered to all

animals, not just those with IBK symptoms (George, 1990; George et al., 1988; George et al., 1984).

Common antibiotics which are utilized in topical treatment regimens are benzathine and cloxacillin (both of which are oil based), oxytetracycline hydrochloride, neomycin, and furazolidone are common antibiotics which are commonly utilized for pinkeye control. These are typically not as widely used due to the excessive tearing which is induced by treatment. The excessive tearing leads to an elevated reduction through dilution of the antimicrobial compound thus requiring multiple treatments to achieve appropriate concentrations in the eye (McConnel et al., 2007). Some of the topical treatments require multiple daily treatments over multiple days to maintain the level necessary to effectively control the infection which can be cost as well as time inhibitive.

Until recently, researchers have not focused on breeding and selection schemes which are focused on disease resistance. Their major concerns were focused on growth and production traits which were considered of high economic importance at the time (Cundiff et al., 1982; Martinez et al., 2004; Kaps et al., 1999; Hassen et al., 1999). But interest in building disease resistance into selection programs has increased since other methods have been shown to have limited impact on control.

Due to the multifactor nature of an IBK infection, current production programs focus treating affected individuals with antibiotics and prevention through a structured vaccination program which have questionable success.

The primary reason for evaluating disease resistance in selection programs is to exploit genetic variation, between and within breeds. Among the approaches utilized in quantitative genetics for improvement of traits through selection are the identification and utilization of

additive gene action, as well as non-additive gene action (Falconer and McKay, 1997). There are many examples of disease traits in cattle where additive genetic variation has been documented. Several disease traits include: mastitis in dairy cattle (Heringstad et al., 2003; Mrode and Swanson, 1996), bovine respiratory diseases (Muggli-Cockett et al., 1992; Snowder et al. 2005b), internal parasites – fecal egg counts (FEC) (Leighton et al., 1989; Morris et al., 2003; Henshall, 2004), external parasites – ticks ((Frisch and Vercoe, 1984; Henshall, 2004), and eye diseases (Webber and Shelby, 1981; Snowder et al., 2005a) just to name a few.

Effective estimation of the heritability for disease resistance is essential to determine the response to selection for disease resistant animals. Several studies have described the heritability estimates for production traits and for disease traits (Ali et at., 2012; Snowder et al., 2006). Rodriguez (2006) reported direct heritability of IBK in several midwestern herds to be 0.071 ± 0.048 which is substantially lower than what Snowder et al., (2005a) reported for the Angus breed, 0.25 ± 0.04. However, the differences observed between these 2 studies were reversed with Snowder et al., (2005a) reporting a maternal heterosis value of 0.10 ± 0.03 and Rodriguez (2006) reporting a slightly larger maternal heterosis value of 0.11 ± 0.077. These studies indicate that heritability of IBK resistance/susceptibility is low; however, there appears to still be an opportunity to drive change through artificial selection although progress may be slow in appearance within the population.

Several studies have determined there was substantial importance to evaluating the general immune response, which would aid in predicting the overall response in animals (Wilkie and Mallard, 1999: Gavora and Spencer, 1983). These studies indicate selection for resistant to disease is a realistic opportunity for producers, although progress may be slow.

Genetic Characteristics, Their Estimation and Binary Data Challenges

When selection for disease resistance becomes a common selection criterion it will be interesting to see if any production traits are negatively impacted. If the two types are negatively correlated options need to be explored whereby, they can coexist and prove beneficial to producers.

There are two types of data collected which are used to evaluate traits of economic importance. The two types of data are continuous (quantitative) and discrete (categorical). Most production traits are quantitative in nature. Threshold traits typically considered to be discrete in nature (i.e. the meet one of at least 2 classifications). These traits are generally polygenic traits and are expressed in a categorical manner (Lynch and Walsh, 1998; Bourdon, 2000). Flight speed (Turner et al., 2011, Gibbons et al., 2009), fertility (Kadarmideen, et al., 2000): milking temperament (Hoppe et al., 2010); IBK resistance (Snowder et al., 2005), and calving difficulty (Ghiasi et al., 2014) are just a few examples traits which are evaluated using categorical data.

Some traits which are classified as affected or unaffected (binary) are referred to as dichotomous traits; while those with more than two categories are referred to as polychotomous. Given that binary traits are not quantitative in nature, the standard linear model methodology is problematic (Gianola, 1982). Several issues are observed in the analysis of categorical traits and can be problematic given conventional, linear, evaluation methodology. Gianola, (1980) stated the scores assigned to categorical traits are done in a subjective manner and have the potential to over-estimate the heritability. Additionally, they impose no restriction on the sum of probabilities, the variance scale varies, and it is highly dependent on the genotypic values of the animals. An additional issue, in the outward scale, is the assumption of statistical independence

between genetic and environmental effects is invalid given a fixed genotypic value for threshold traits (Dempster and Lerner, 1950).

The genetic value of an individual as a parent is known as the estimated breeding value (EBV) which is estimated through statistical procedures and calculations. Estimated breeding values are used to calculate expected progeny differences which give producers the ability to compare an individual's performance within a breed relative to the breed average for that trait. It is important to note these comparisons are valid within breed; which is important to understand given our earlier statements regarding breed differences relative to IBK susceptibility.

In artificial selection, knowing an individual's potential genetic impact as a parent is crucial for driving herd improvement in a desirable direction. The accuracy associated with a breeding value improves/increases as the amount of information on progeny and relative performance is added. Rodriguez (2006) reported an average EBV for IBK susceptibility of -0.058 with a range from -11.35 to 11.02.

More recently, science has developed procedures and processes to incorporated chromosomal information in association with the breeding value estimate. These estimates utilize genome-wide association (GWA), regional heritability mapping (RHM), and other chromosomal identification to strengthen the relationship between the estimated the breeding values and the actual genetic makeup of the individual. VanRaden (2008 and 2009) indicated that the incorporation of genomic information improved the average reliability dramatically when compared to traditional processes which incorporate parental averages alone.

LITERATURE CITED

Aikman J. and A. Selman. 1985. Experimental production of infectious bovine keratoconjunctivitis. Vet. Rec. 117:234-239.

Ali, A. A., C. J. O'Neill, P. C. Thomson, and H. N. Kadarmideen. 2012. Genetic parameters of infectious bovine keratoconjunctivitis and its relationship with weight and parasite infestations in Australian tropical *Bos taurus* cattle. Genetics Selection Evolution 44:22

Angelos, J. A., L. M. Ball, and J. F. Hess. 2007a. Identification and characterization of complete RTX operons in Moraxella bovoculi and Moraxella ovis. Vet. Microbiol. 125:73–79.

Angelos, J. A., P. Q. Spinks, L. M. Ball, and L. W. George. 2007b. *Moraxella bovoculi* sp. nov. isolated from calves with infectious bovine keratoconjunctivitis. Int. J. Syst. Evol. Microbiol. 57:789–795.

Angelos, J. A. 2010. Moraxella bovoculi and infectious bovine keratoconjunctivitis: Cause or coincidence? Veterinary Clinics of North America - Food Animal Practice 26(1):73-78.

Angelos, J. A., L. M. Ball and B. A. Byrne. 2011. Minimum inhibitory concentrations of selected antimicrobial agents for *Moraxella bovoculi* associated with infectious bovine keratoconjunctivitis. J. Vet. Diagn. Invest. 23:552-555.

Annuar, B. O. and G. E. Wilcox. 1985. Adherence of *Moraxella bovis* to cell cultures of bovine origin. Res. Vet. Sci. 39:241–246.

Arora, A. K., A H. Killinger, and M.E. Mansfield. 1976. Bacteriologic and vaccination studies in a field epizootic of infectious bovine keratoconjunctivitis in calves. Am. J. Vet. Res. 37: 803-805.

Atwell, J. L., J. M. Tennent, A. W. D. Lepper, and T. C. Elleman, 1994. Characterization of pilin genes from seven serologically defined prototype strains of *Moraxella bovis.* J. Bacteriol. 176:4875-4882.

Axford, R. F. E., S. C. Bishop, F. W. Nicholas, and J. B. Owen. (Editor), 2000. Breeding for Disease Resistance in Farm Animals. CABI, Wallingford.

Baptista P. J. H. P., 1979. Infectious bovine keratoconjunctivitis: a review. Br. Vet. J. 135(3):225–242.

Beard M. K. and L. J. Moore. 1994. Reproduction of bovine keratoconjunctivitis with a purified haemolytic and cytotoxic fraction of *Moraxella bovis.* Vet Microbiol 42: 15-33.

Bedford, P. G. C., (1992) Ocular diseases. Bovine Medicine: Diseases and Husbandry, *Wiley-Blackwell, Oxford*, *UK* 712-721

Bedford, P. G. C. 1976. Infectious bovine keratoconjunctivitis. Vet. Rec. 98(7):134-139.

Billson, F. M., C. Harbour, W. P. Michalski, J. M. Tennent, J. R. Egerton, and J. L. Hodgson. 2000. Characterization of haemolysin of *Moraxella bovis* using a hemolysin-neutralizing monoclonal antibody. Inf. and Immun. 3469-3474

Bioleau, M., E. J. Giedt, D. Lalman, and B. Whitworth. 2015. Pinkeye. Oklahoma Coop. Ext. Ser. VTMD-9128. http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-2689/VTMD-9128web2015.pdf Accessed May 15, 2017.

Brown, M. H., A. L. Brightman, B. W. Fenwick, and M. A. Rider. 1998. Infectious bovine keratoconjunctivitis: A review. J. Vet. Intern. Med. 12:259–266.

Bryan., H. S., L. C. Helper, A. H. Killinger, and M. E. Mansfield. 1973. Some bacteriologic and ophthalmic observations on bovine infectious keratoconjunctivitis in an Illinois beef herd. J. Am. Vet. Med. Assoc. 163(7):739-741.

Burns, B. M., C. J. Howitt, and C. R. Esdale, 1986. Bovine infectious keratoconjunctivitis in different cattle breeds. Proc. Aust. Soc. Anim. Prod. 17:150-153.

Burns M. J. and A. M. O'Connor. 2008. Assessment of methodological quality and sources of variation in the magnitude of vaccine efficacy: a systematic review of studies from 1960 to 2005 reporting immunization with *Moraxella bovis* vaccines in young cattle. Vaccine 26:144–152.

Caspair, E. L., and P. P. Wood. 1980. Eyelid pigmentation and the incidence of infectious bovine keratoconjunctivitis in Hereford-Friesian crossbred calves. Br. Vet. J. 136:210–212.

Chandler, R. L., P. J. H. P. Baptista, B. A. Turfrey. 1979. Studies on the pathogenicity of *Moraxella bovis* in relation to infectious bovine keratoconjunctivitis. J. Comp. Path. 89:441-448.

Chandler, R L, K. Smith, and B. A. Turfrey. 1985. Exposure of bovine cornea to different strains of *Moraxella bovis* and to other bacterial species in vitro. J. Comp. Pathol. 9:415-423.

Cox, P.J, J. S. Liddell, and A. D. Mattinson. 1984. Infectious bovine keratoconjunctivitis: Isolation of *Moraxella bovis* from two groups of young beef cattle in fly control field trials during 1981. Vet. Rec. 115:29-32.

Cundiff, L.V., K. E. Gregory and R. M. Roch. 1982. Selection for increased survival from birth to weaning. *Proc. 2nd World Congress on Genetics Applied to Livestock Production.* Vol. V. pp. 310-337.

Dadax. 2019. World Population Clock. https://www.worldometers.info/world-population/. Accessed June 15, 2019.

Davidson, H. J. and J. P. Picket. 2009. Selected Eye Diseases of Cattle: Food Animal Practice (Fifth edition). Penny Rudolph. Ch. 85. pp 421-427.

Dempster E. R., and I. M. Lerner. 1950. Heritability of threshold characters. Genetics. 35:212-236.

di Girolamo, F. A., D. J. Sabatini, R. A. Fasan, M. Echegoyen, M. Vela, C. A. Pereira, P. Maure. 2012. Evolution of cytokines as adjuvants of bovine keratoconjunctivitis vaccines. Vet. Immunol. Immunopathol. 145:563-566.

Eichenbaum J. D., J. D. Lavach, G. A. Severin, and M. E. Paulsen. 1996. Immunology of ocular surface. In: Ophthalmology in small animal practice. The compendium collection. NJ: Vet. Learning Systems 99–106.

Elad, D., I. Yeruham, and M. Bernstein. 1988. *Moraxella ovis* in cases of infectious bovine keratoconjunctivitis (IBK) in Israel. Zoonoses and Public Health. 35:431-434.

Fairlie, G. 1966. The isolation of a haemolytic *Neisseria* from cattle and sheep in the North of Scotland. Vet. Rec. 78:649-650.

Falconer, D. S. and T. F. C. Mackay. 1997. Introduction to Quantitative Genetics. 4th Ed., Longman Group Ltd., London.

Farn J. L., R. A. Strugnell, P. A. Hoyne, W. P. Michalski, and J. M. Tennent. 2001. Molecular characterization of a secreted enzyme with phospholipase B activity from *Moraxella bovis*. J. Bacteriol. 183(22): 6717–6720.

Frank, S. K. and J. D. Gerber. 1981. Hydrolytic enzymes *of Moraxella bovis*. J. Clin. Microbiol. 13:269-271.

Friis N. F. and K. B. Pedersen. 1979. Isolation of *Mycoplasma bovoculi* from cases of infectious bovine keratoconjunctivitis. Acta Vet. Scand. 20:51-59.

Frisch, J. E. 1975. The relative incidence and effect of bovine infectious keratoconjunctivitis in *Bos indicus* and *Bos taurus* cattle. Anim. Prod. 21:265–74.

Frisch, J. E. and J. E. Vercoe. 1984. An analysis of growth of different cattle genotypes reared in different environments. J. Agri. Sci. 103:137–153.

Funk, L., A. M. O'Connor, M. Maroney, T. Engelken, V. L. Cooper, J. Kinyon, and P. Plummer. 2009. A randomized and blinded field trial to assess the efficacy of an autogenous vaccine to prevent naturally occurring infectious bovine keratoconjunctivitis (IBK) in beef cattle. Vaccine 27:4585-4590.

Gavora, J. J., and J. L. Spencer. 1983. Breeding from immune responsiveness and disease resistance. Anim. Blood Groups and Biochem. Genetics 14:159-180.

George L. 1984. Clinical infectious bovine keratoconjunctivitis. Compend. Cont. Educ. Pract. Vet. 6:712-720.

George, L., and W. Wilson. 1984. Antibiotic treatment of M*oraxella bovis* infection in cattle. J. Am. Vet. Med. Assoc. 185:1206-1209.

George, L. W., A. Ardans, J. Mihalyi, and M. R. Guerra. 1988. Enhancement of infectious bovine keratoconjunctivitis by modified-live infectious bovine rhinotracheitis virus vaccine. Am. J. Vet. Res. 49: 1800-1806.

George, L. W., A. J. Borrowman, and J. A. Angelos. 2005. Effectiveness of cytolysin-enriched vaccine for protection of cattle against infectious bovine keratoconjunctivitis. Am. J. Vet. Res. 66:136-142.

George, L., J. Mihalyi, A. Edmondson, J. Daigneault, G. Kagonyera, N. Willits, and M. Lucas. 1988. Topically applied furazolidone or parenterally administered oxytetracycline for the treatment of infectious bovine keratoconjunctivitis. J. Am. Vet. Med. Assoc. 192: 1415-1422.

George, L. W. 1990. Antibiotic treatment of infectious bovine keratoconjunctivitis. Cornell Vet. 80: 229-235.

Gerhardt R. and J. Allen. 1982. The role of face flies in an episode of infectious bovine keratoconjunctivitis. J. Am. Vet. Med. Assoc. 180:156-159.

Ghiasi, H., M. Khaldari, and R. Taherkhani. 2014. Genetic parameters and calving ability index for direct and maternal calving difficulty and stillbirth in Iranian Holstein cows. Livestock Sci. 165:22-26.

Gianola, D. 1980. A method of sire evaluation for dichotomies. J. Anim. Sci. 51(6):1266-1271.

Gianola, D. 1982. Theory and analysis of threshold characters. J. Anim. Sci. 54 (5):1079-1096.

Gibbons, J. M., M. J. Haskell, and A. B. Lawrence. 2009. Consistency of aggressive feeding behavior in dairy cows. Appl. Anim. Behav. Sci. 121(1):1-7.

Gould S, R. Dewell, K. Tofflemire R. D. Whitley, S. T. Millman, T. Opriessnig, R. Rosenbusch, J. Trujillo, and A. M. O'Connor. 2013. Randomized blinded challenge study to assess association between *Moraxella bovoculi* and infectious bovine keratoconjunctivitis in dairy calves. Vet. Microbiol. 164:108–115.

Hansen, R. 2001. New tools in the battle against pinkeye. Proc. Nevada Livest. Prod. Annu., Univ. of Nevada – Reno. UNR Coop. Ext. SP 01-01.

Hassen, A., D. E. Wilson, and G. H. Rouse. 1999. Evaluation of carcass, live, and real-time ultrasound measures in feedlot cattle: I. Assessment of sex and breed effects. J. Anim. Sci. 77:273-282.

Henson, J. B. and L. C. Grumbles. 1960. Infectious bovine keratoconjunctivitis. I. Etiology. Am. J. Vet. Res. 21:761-766.

Henshall, J. M., 2004. A genetic analysis of parasite resistance traits in a tropically adapted line of *Bos taurus*. Aust. J. Agri. Res. 55:1109–1116.

Heringstad, B., G. Klemetsdal, and T. Steine. 2003. Selection responses for clinical mastitis and protein yield in two Norwegian dairy cattle selection experiments. J. Dairy Sci. 86:2990–2999.

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(6)1982–1989.

Hubbert W. T. and G. J. Hermann. 1970. A winter epizootic of infectious bovine keratoconjunctivitis. J. Am. Vet. Med. Assoc. 157**:**452-454.

Hughes, D. E., and G. W. Pugh. 1970. A five-year study of infectious bovine keratoconjunctivitis in a beef herd. J. Am. Vet. Med. Assoc. 157:443-451.

Hughes, D. E., G. W. Pugh, and T. J. McDonald. 1965. Ultraviolet radiation and *Moraxella bovis* in the etiology of bovine infectious keratoconjunctivitis. Am. J. Vet. Res. 26:1331-1338.

Hughes, D.E., G. W. Pugh, and T. J. McDonald. 1968. Experimental bovine infectious keratoconjunctivitis caused by sunlamp irradiation and *Moraxella bovis* infection: determination of optimal irradiation. Am. J. Vet. Res. 29(4):821-827.

Jackman, S. H. and R. F. Rosenbusch. 1984. In vitro adherence of *Moraxella bovis* to intact corneal epithelium. Curr. Eye Res. 3:1107–1112.

Jayappa, H. G, and C. Lehr. 1986. Pathogenicity and immunogenicity of piliated and nonpiliated phases of *Moraxella bovis* in calves. Am. J. Vet. Res. 47: 2217-2221.

Kadarmideen, H. N., R. Thompson, and G. Simm. 2000. Linear and threshold model genetic - parameters for disease, fertility and milk production in dairy cattle. J. Anim. Sci. 71:411-419.

Kaps, M., W. O. Herring, and W. R. Lamberson. 1999. Genetic parameters for mature weight in Angus cattle. J. Anim. Sci. 77:569-574.

Killinger, A. 1977. Economic impact of infectious bovine keratoconjunctivitis in beef calves. Vet. Med. Small Anim. Clin. Agric. Pract. 618-620.

Kopecky, K. E., G. W. Pugh and T. J. Mc Donald. 1986. Infectious bovine keratoconjunctivitis: contact transmission. Am. J. Vet. Res. 47:622–624.

Langford, E. V., and R. H. Leach. 1973. Characterization of a mycoplasma isolated from infectious bovine keratoconjunctivitis, *M. bovoculi* sp. nov. Can. J. Microbiol. 19:1435-1444.

Lehr, C. H., H. G. Jayappa and R. A. Goodnow. 1985. Serologic and protective characterization of *Moraxella bovis* pili. Cornell Vet., 75: 484-492.

Leighton, E. A., K. D. Murrell, and L. C. Gasbarre. 1989. Evidence for genetic control of nematode egg-shedding rates in calves. J. Parasitol. 75:498–504.

Lepper, A. W. and L. R. Hermans. 1986. Characteristics and quantification of pilus antigens of Moraxella bovis by ELISA. Aust. Vet. J. 63:401-405.

Lepper A. W. and I. J. Barton. 1987. Infectious bovine keratoconjunctivitis: seasonal variation in cultural, biochemical and immunoreactive properties of *Moraxella bovis* isolated from the eyes of cattle. Aust. Vet. J. 64(2):33–39.

Lepper, A. W. D., L. J. Moore, J. L. Atwell, and J. M. Tennent. 1992. The protective efficacy of pili from different strains of *Moraxella bovis* within the same serogroup against infectious bovine keratoconjunctivitis. Vet. Microbiol., 32: 177-187.

Lepper, A. W. D., T. C. Elleman, P. A. Hoyne, P. R. Lehrbach, J. L. Atwell, J. R. Egerton, L. C. Schwartzkoff and J. M. Tennent. 1993. A *Moraxella bovis* pili vaccine produced by recombinant DNA technology for the prevention of infectious bovine keratoconjunctivitis. Vet. Microbiol. 36: 175-183.

Lindqvist, K. 1960. A *Neisseria* Species Associated with Infectious Keratoconjunctivitis of Sheep *Neisseria Ovis* Nov. Spec. J. Infect. Dis. 106:162-165.

Loy J. D. and B. W. Brodersen. 2014. *Moraxella* spp. isolated from field outbreaks of infectious bovine keratoconjunctivitis: a retrospective study of case submissions from 2010 to 2013. J. Vet. Diagn. Invest. 26:761–768.

Marr, A. 1977. *The Veterinary Annual. Seventeenth Issue.* Grunsell, C. S. G., and F. W. G. Hill. Wright-Scientechnica Ltd. Published: January. p. 48.

Marrs C. F., G. Schoolnik, J. M. Koomey, J. Hardy, J. Rothbard, and S. Falkow. 1985. Cloning and sequencing of a *Moraxella bovis* pilin gene. J. Bacteriol. 163(1):132–1399.

Martinez, G. E., R. M. Koch, L. V. Cundiff, K. E. Gregory, and L. V. Van Vleck. 2004. Genetic parameters for six measures of length of productive life and three measures of lifetime production by 6 yr after first calving for Hereford cow. Anim. Sci. 82(7):1912-1918.

McConnel, C. S., L. Shum, and J. K. House. 2007. Infections bovine keratoconjunctivitis antimicrobial therapy. Aust. Vet. J. 85:65-69.

McMichael, J. C. 1992. Bacterial differentiation of *Moraxella bovis* colonies growing at the interface of the agar medium with the petri dish. J. Gen. Microbiol., 138: 2687-2695.

Moore, L. J., and J. M. Rutter. 1989. Attachment of *Moraxella bovis* to calf corneal cells and inhibition by antiserum. Aust. Vet. J. 66:39–42.

Moore, L. J., and A. W. D. Lepper. 1991. A unified serotyping scheme for *Moraxella bovis*. Vet. Microbiol. 29: 75-83.

Morris, C. A., R. S. Green, N. G. Cullen, and S. M. Hickey. 2003. Genetic and phenotypic relationships among faecal egg count, anti-nematode antibody level and live weight in Angus cattle. Anim. Sci. 76:167–174.

Mrode, R. A. and G. J. T. Swanson. 1996. Genetic and statistical properties of somatic cell count and its suitability as an indirect means of reducing the incidence of mastitis in dairy cattle. Anim. Breeding Abstr. 64:847–857.

Muggli-Cockett, N. E., L. V. Cundiff, and K. E. Gregory. 1992. Genetic analysis of bovine respiratory disease in beef calves during the first year of life. J. Anim. Sci. 70:2013–2019.

Nagy, A., E. Vandersmissen, and P. Kapp. 1989. Further data to the aetiology, pathogenesis and therapy of infectious bovine keratoconjunctivitis. Comp. Immun. Microbiol. Infect. Dis. 12(4):115-127.

NAHMS, 1997a. Part II. Reference of 1997 beef cow-calf health and health management practices. USDA, APHIS. National Animal Health Monitoring System. Available www.aphis.usda.gov /animal health/nahms/beefcowcalf/downloads/beef97/Beef97_dr_PartII.pdf. Accessed September 17, 2012.

NAHMS, 1997b. Part III. Reference of 1997 beef cow-calf production and disease control. USDA, APHIS. National Animal Health Monitoring System. Available www.aphis.usda.gov/animal health/nahms/beefcowcalf/downloads/beef97/Beef97_dr_PartIII.pdf. Accessed September 17, 2012.

Nicolet, J., M. Dauwalder, P. H. Boss, and J. Anetzhofer. 1976. Primary infectious keratoconjunctivitis of cattle. Possible etiological role of M*ycoplasma bovoculi*. SAT Schweiz. Arch. fur Tierheilkunde. 118(4):141-150.

Ostle, A. G., and R. F. Rosenbusch. 1984. *Moraxella bovis* hemolysin. Am. J. Vet. Res. 45:1848-1851.

Prieto, C. I., O. M. Aguilar, and O. M. Yantorno. 1999. Analyses of lipopolysaccharides, outer membrane proteins and DNA fingerprints reveal intraspecies diversity in Moraxella bovis isolated in Argentina. Vet. Microbiol. 70(3/4):213-223; 36

Prieto, C. I., A. Bosch, G. Zielinski, J. Cuneo, and O. M. Yantorno. 2008. Vaccine against infectious bovine keratoconjunctivitis: A new approach to optimize the production of highly palliated *Moraxella bovis* cells. Vaccine 26:6542-6549.

Pugh, G. W., D. E. Hughes and G. D. Booth. 1977. Experimentally induced infectious bovine keratoconjunctivitis: effectiveness of a pilus vaccine against exposure to homologous strains of *Moraxella bovis.* Am. J. Vet. Res., 38:1519-1522.

Pugh, G. W., K. E. Kopecky, and T. J. McDonald. 1984. Infectious bovine keratoconjunctivitis: enhancement of *Moraxella bovis* pili immunogenicity with diphtheria-tetanus toxoids and pertussis vaccine. Am. J. Vet. Res., 45:661-665.

Pugh G. W. Jr., and T. J. McDonald. 1986. Identification of bovine carriers of *Moraxella bovis* by comparative cultural examinations of ocular and nasal secretions. Am. J. Vet. Res. 47:2343-2345.

Pugh G. W. Jr. and T. J. McDonald. 1977. Infectious bovine keratoconjunctivitis: treatment of *Moraxella bovis* infections with antibiotics. Proc. Annu. Meet. US Anim. Health Assoc. 120-130.

Punch, P. I., N. D. Costa, E. D. Chambers, D. H. Slatter, and G. E. Wilcox. 1985. Plasma and tear concentrations of antibiotic administered parenterally to cattle. Res. Vet. Sci. 39:179-187

Richey, E. J. 2003. Herd Health Issues: Pinkeye. The Florida Cattleman, October 2003 Issue, p. 118. Florida Cattleman's Assoc., Kissimmee.

Rodriguez, J. E. 2006. Infectious Bovine Keratoconjunctivitis in Angus cattle. (Thesis). https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1855&context=rtd. Accessed: June 27, 2015.

Rodriguez, J. E., A. Hassen, R. G. Tait Jr., and J. M. Reecy. 2007. "IBK (pinkeye) in Black Angus Cattle". Iowa State Res. Farm Prog. Rep. 889.

Rogers, D. G., N. F. Cheville, and G. W. Pugh. 1987. Pathogenesis of corneal lesions caused by *Moraxella bovis* in gnotobiotic calves. Vet. Pathol. 24:287-295.

Rosenbusch, R. F. 1983. Influence of mycoplasma preinfection on the expression of *Moraxella bovis* pathogenicity. Am. J. Vet. Res. 44:1621-1624.

Ruehl, W. W., C.F. Marrs, R. Fernandez, S. Falkow, and G.K. Schoolnik. 1988. Purification, characterization, and pathogenicity of *Moraxella bovis* pili. J. Exp. Med., 168:983-1002.

Ruehl, W. W., C. Marrs, L. George, S. Banks, and G. K. Schoolnik. 1993. Infection rates, disease frequency, pilin gene rearrangement, and pilin expression in calves inoculated with Moraxella bovis pilin-specific isogenic variants. Am. J. Vet. Res. 54(2):248–53.

Salih, B. A., A. G. Ostle, and R. F. Rosenbusch. 1987. Vaccination of cattle with Mycoplasma bovoculi antigens: Evidence for field immunity. Comp. Immun. Microbial. Infect. Dis. 10:109-116.

Shiell, B. J., M. Tachedjian, K. Bruce, G. Beddome, J. L. Farn, P. A. Hoyne, and W. J. Michalkski. 2007. Expression, purification, and characterization of recombinant phospholipase B from Moraxella bovis with anomalous electrophoretic behavior. Protein Expression & Purification. 55:262-272.

Shyrock, T. R., D. W. White, and C. S. Werner. 1998. Antimicrobial susceptibility of *Moraxella bovis*. Vet. Microbiol. 61(4):305-309.

Slatter, D. H., M. E. Edwards, and C. D. Hawkins. 1982. A national survey of the clinical features, treatment and importance of infectious bovine keratoconjunctivitis. Aust. Vet. J. 59:69-72.

Snowder, G. D., L. D. Van Vleck, L. V. Cundiff, and G. L. Bennett. 2005a. Genetic and environmental factors associated with incidence of infectious bovine keratoconjunctivitis in pre-weaned beef calves. J. Anim. Sci. 83:507–518.

Snowder, G. D., L. D. Van Vleck, L. V. Cundiff, and G. L. Bennett. 2005b. Influence of breed, heterozygosity, and disease incidence on estimates of variance components of respiratory disease in preweaned beef calves. J. Anim. Sci. 83:1247–1261.

Snowder, G. D., L. D. Van Vleck, L. V. Cundiff, and G. L. Bennett. 2006. Bovine respiratory disease in feedlot cattle: Environmental, genetic, and economic factors. J. Anim. Sci. 84:1999-2008.

Staric, J., F. Krizanec, and T. Zandis. 2008. Listeria monocytogenes keratoconjunctivitis and uveitis in dairy cattle. Bull. Vet. Inst. Pulawy. 52:351-355.

Thomas, L. H., P. D. P. Wood, and J. M. Longland. 1978. The influence of disease on the performance of beef cattle. Br. Vet. J. 134:152-161.

Thrift, F., and J. Overfield. 1974. Impact of pinkeye (infectious bovine keratoconjunctivitis) on weaning and postweaning performance of Hereford calves. J. Anim. Sci. 38:1179-1184.

Timoney, P. J., and P. J. O'Connor. 1971. An outbreak of the conjunctival form of infectious bovine rhinotracheitis virus infection. Vet. Rec. 89(123)170-172.

Turner, S. P., E. A. Navajas, J. J. Hyslop, D. W. Ross, R. I. Richardson, and N. Prieto. 2011. Associations between response to handling and growth and meat quality in frequently handled *Bos Taurus* beef cattle. J. Anim. Sci. 89:4239–4248.

VanRaden P. M. 2007. Genomic measures of relationship and inbreeding. Interbull. Bull. 37: 33–36.

VanRaden P. M. 2008. Efficient methods to compute genomic predictions. J. Dairy Sci. 91: 4414–4423.

Vogelweid, C. M., R. B. Miller, J. N. Berg, and D. A. Kindem. 1986. Scanning electron microscopy of bovine corneas irradiated with sunlamps and challenge exposed with Moraxella bovis. Am. J. Vet. Res. 47(2): 378–84.

Ward, J. K., and M. K. Neilson. 1979. Pinkeye (bovine infectious keratoconjunctivitis) in beef cattle. J. Anim. Sci. 49(2):361-366.

Ward, H., and J. Powell. 2017. Livestock Health Series FSA3087. University of Arkansas Division of Agriculture. https://www.uaex.edu/publications/pdf/FSA-3087.pdf. Accessed April 4, 2017.

Webber, J., and L. Selby. 1981. Risk factors related to the prevalence of infectious bovine keratoconjunctivitis. Am. J. Vet. Res. 179:823-826.

Whittier, W. D. 2000. Winter pinkeye in cattle: Livestock update. Virginia Coop. Ext. Serv. https://www.sites.ext.vt.edu/newsletter-archive/livestock/aps-00_01/aps-0161.html. Accessed September 7, 2017.

Wilkie, B., and B. Mallard. 1999. Selection for high immune response: an alternative approach to animal health maintenance? Vet. Immunity Immunopathology. 72:231-235.

Wilcox, G. E. 1969. Isolation of the adenoviruses from cattle with conjunctivitis and kerato-conjunctivitis. Aust. Vet. J. 45(6):265-270.

CHAPTER 2

Pre-weaning production impacts and genetic parameter estimates for susceptibility/resistance to Infectious Bovine Keratoconjunctivitis (IBK) in Angus calves produced in a Southern environment

ABSTRACT

The objective of this study was to determine the impact of IBK on calf performance and estimate genetic parameters associated with infectious bovine keratoconjunctivitis (IBK) resistance/susceptibility. Pre-weaning records on 1530 Angus and Angus-derived calves were used to evaluate pre-weaning performance and genetic parameter estimates for susceptibility/resistance to IBK in a southern United States environment. Data were analyzed using PROC GLIMMIX of SAS and genetic parameters were estimated using an animal model for both single- and two-traits through MTDFREML. Differences between producer locations (PL) and season of birth were observed for the incidence of IBK. Spring born calves were 12.6 times more likely ($P \leq 0.05$) to have evidence of ocular scaring than were calves born in the fall season. There was no statistically significant difference in weaning weights (WWT) between affected and non-affected calves; however, a trend was observed ($P = 0.1125$) where affected calves were 9.5 kg lighter at weaning than unaffected contemporaries. The estimation of heritability for IBK resistance/susceptibility was rather low, 0.11 ± 0.053. Single trait estimates of genetic, environmental, and phenotypic variances for IBK resistance/susceptibility were 0.0077, 0.0600, and 0.0677, respectively. For IBK resistance/susceptibility and BWT, genetic and environment correlations were estimated to be 0.45 and -0.08, respectively. Additionally, the genetic and environment correlations were estimated to be 0.61 and -0.15 between IBK

resistance/susceptibility and WWT. These results indicate that progress can be made through selection, but it will be slow.

Keywords: genetic correlation, heritability, IBK

INTRODUCTION

Infectious bovine keratoconjunctivitis is a serious ocular disease that affects cattle of all ages with its greatest impact being observed on performance characteristics of young animals during the preweaning period (Snowder et al., 2005). Researchers have reported that approximately 10 million calves annually with an estimated economic loss of approximately 150-200 million dollars in the United States can be attributed to IBK affects (Hansen, 2001; Richey, 2003). The National Animal Health Monitoring System (NAHMS) historically reported that greater than 29% of beef cattle operations feel that IBK is a disease which has had a significant economic impact on their individual operation (NAHMS 1997a, b). The issue of IBK in not localized to the United States. An Australian postal survey indicated that 81.3% of the respondent producers reported IBK occurrence with 75% observing a substantial reduction in production weights (Slatter et al., 1982). The marketability and efficiency of breeding males can be significantly impacted due to IBK. Geary and Reeves (1992) reported the importance of the vision in detecting females exhibiting signs of estrus. In previous research, Snowder et al. (2005) had reported heritability of IBK resistance/susceptibility was 0.25 ± 0.04 for the Angus breed, while the overall study estimate of heritability of 0.22 ± 0.02 was reported for all breeds combined. The impact of IBK outbreaks on weaning weight has been well documented over time, with few exceptions. Thrift and Overfield (1974), Rodriguez et al. (2006), Thomas et al. (1978) and Frisch et al., (1975) found that calves impacted by IBK were anywhere from 23 to 6.5

kg lighter at weaning when compared to their unaffected contemporaries. Control of IBK has been attempted through vaccination programs; but the results are sometime inconsistent, and the overall success has proven to be challenging, unreliable and debatable (Burns and O'Connor et al., 2008; Jayappa and Hehr, 1986). The agriculture in the southern United States is comprised of many cow-calf producers with many of these producers relying on the Angus breed to provide a quality offspring that is highly desired by others for their performance as well as their quality carcass characteristics. The objectives of this study were to determine the heritability of IBK resistance/susceptibility and the genetic correlation between IBK and weaning weight for Angus sired cattle raised in the southern United States.

MATERIALS AND METHODS

Spring and fall born calves (n = 1530) raised at 3 Arkansas locations in three contiguous years were utilized in this study. Locations were within a 20-mile radius of the University of Arkansas Beef Research unit at Savoy, AR. The distribution of calves by birth season and producer location are shown in table 1. All calves utilized in this study were sired by purebred Angus sires which were registered with the American Angus Association (Kansas City, MO). During the trial period, no artificial selection was utilized for IBK resistance/susceptibility at any of the producing locations. The in common sire utilized in all 3 herds was Bon View New Design 878. This study contained progeny from 209 different Angus sires with 52 sires contributing 10 or more progeny. The in common sire contributed 46 total offspring between the 3 different producer locations through the duration of the study period.

All calves were evaluated at weaning by the same inspector and IBK scores were determined. The scoring system utilized was subjective and binary in nature. Individuals were assigned a score of 0 if no visible evidence was observed of an IBK occurrence while a score of

1 was assessed if there was visual evidence of and IBK infection in either 1 or both eyes. No data were recorded to indicate severity/longevity of the IBK infection or whether the disease was bilateral in nature.

Producers were located in the northwest Arkansas area with 2 herds consisting of purebred Angus dams while the third location was considered a commercial herd with a high percentage of Angus ancestry. The production herds utilized in this study would be considered very comparable to those which are observed in normal production programs in the southern United States producing either purebred offspring or commercial calves. Cattle were maintained separately but managed similarly. Prior to the breeding season, dams were dewormed and vaccinated against IBV, BRD PI3, BRVS and 5 strains of Leptospirosis (Pyramid 10, Boehringer Ingelheim); calves were vaccinated against IBV, BRD PI3, and BRVS (Pyramid 5 + Presponse, Boehringer Ingelheim). Spring born calves were weaned in late September and fall born calves were weaned in late May.

Data recorded in the field records included: Sire identification, dam identification, calf identification, date of birth, birth weight (BWT), dam birth date, producer location (PL), production year, season of birth, sex of calf, weaning weight (WWT), weaning date, inspection date, and eye scaring score (ESS). Age of dam at birth and weaning, age of calf at inspection and age of calf at weaning were all calculated from the respective dam date of birth or calf date of birth, where appropriate. Birth weight and WWT were adjusted for age of dam and sex of calf based on adjustment factor information from the Beef Improvement Federation (BIF, 1996). The recorded results were analyzed using the GLIMMIX procedure of the SAS statistical software package (SAS 9.3.1, SAS Inst. Inc., Cary, NC, USA). Models were fit based on the classification of the response variable. Eye scaring score (ESS), which is categorical and

subjective in nature, was treated as a binary variable and thus evaluated using a binary distribution through the utilization of a logit link function. Eye scaring prevalence was modeled using the fixed effects of producing location, year, season of birth, sex, sire, and appropriate two- and three-way interactions. Age at inspection was included in the model as a covariate. Production traits, BWT and WWT, which are quantitative and continuous in nature, were evaluated using a gamma distribution with a log link function. Denominator degrees of freedom were determined using the Kenward-Rogers approximation. The effects of producer location, year, season of birth, sex of calf and sire were included in the model as fixed effects while age of calf at weaning/inspection were included as covariates where appropriate.

An animal model was utilized for determining single- and two-trait component characteristics. For estimation of the genetic components, the data were recoded slightly to meet requirements of the estimation program. The linear animal model used to estimate heritability, genetic, environmental, and phenotypic correlations in MTDFREML (Boldman et al., 1993) was $Y= \mu + CG_i$ + Age at inspection + animal + e_{ik}. Contemporary group (which was comprised of producer location and year of birth) was the only fixed effect included in the model, while age at inspection/weaning was included as a covariate and an animal effect was included as a random effect. To verify that the estimates were accurate, the MTDFREML program was run twice after the models converged, criterion on 1×10^{-9} and estimates were confirmed.

RESULTS AND DISCUSSION

Evidence of IBK impairment through visual examination was observed in calves in all years, at all three locations and within each of the two calving seasons. For IBK ESS, the effects of producer location, year of birth and birth season proved to be significant ($P \leq 0.05$) sources of variation. Infectious bovine keratoconjunctivitis scaring was observed on the ocular surface of

11.6% of the animals evaluated in this study. A difference ($P \leq 0.05$) in ocular scaring was associated with IBK was observed between the two birth seasons. This study indicated that individuals born in the spring calving season were 12.6 times more likely to display ocular evidence of an IBK infection during their pre-weaning period than were their fall born contemporaries. Overall, evidence of IBK was observed in 2.4% of fall born calves while 20.7% of spring born calves had evidence of clinical IBK (Table 2). The incidence of IBK in spring born calves by producer ranged from a high of 60.7% down to 9.0%. Snowder et al. (2005) demonstrated, in a multiyear evaluation, that the incidence of IBK observance started increase after calves reached 45 d of age, then peaked around 105 d of age and levelized at a lower incidence at around 168 d of age. Some have suggested that phenomenon could be the result of the younger animal's immune system not being completely developed (Baptista, 1979). The initial low incidence until around d 45 could be explained that calves receiving passive immunity through the mother while the lower incidence after 160 days could be explained by the animal's immune system functioning more effectively. For calves born in the spring time, the infestation of face flies intensifies due to their life cycle (Baptista, 1979; Gehrhardt, 1982). An additional challenge seen by spring born calves is an increase in UV light exposure due to the lengthening daylight hours. Peak solar radiation exposure in the central United States ranges from June through August. Hughes et al. (1965), Thrift and Overfield (1974), Kopecky et al. (1986), and Lepper and Barton (1987) have shown that UV radiation may have an impact on IBK incidence by damaging the ocular and/or conjunctival surfaces, thus allowing colonization of problematic bacteria.

Significant differences were observed between producer locations for the incidence of IBK scaring. Calves raised at PL 2 were 2.25 times more likely to develop IBK eye scaring than

calves raised at PL 1. Producer location 1 had the lowest incidence of IBK scaring and location 2 had the highest incidence of IBK scaring, (Table 2). The percentage of calves with ocular lesions at PL 3 was intermediate to both locations 1 and 2 and was not significantly different from either of them. These differences are not totally unexpected given that IBK is a highly contagious disease which can be easily spread by very tiny mobile vectors. A review article by Brown et al. (1998) reported on many of the challenging scenarios and attributes that have been observed in IBK research. Among those reported, animal management, environmental conditions, and pasture management practices, among many other things, have been suggested as potential contributors to an increase in the occurrence and possibly severity of IBK outbreaks.

There were no observed gender differences relative to the incidence on IBK ($P > 0.10$). Davidson and Stokka (2003) report significant differences between sexes where heifer calves had a higher incidence of IBK symptoms, which was shown to correspond to higher rates of bacteria recovered from cultures of the ocular fluid.

In this study, PL, season and sex of calf had significant effects ($P \leq 0.05$) on BWT, while ESS and birth year did not. Birth weights for calves born at PL 1 and PL 2, the purebred breeders, were the heaviest ($P \leq 0.05$); while the commercial herd, comprised of commercial grade dams with Angus ancestry, had the lower ($P \leq 0.05$) mean BWT (Table 3). Birth weights were observed to be different between the sexes. At birth, male calves were significantly heavier than female contemporaries. Season proved to have a significant impact on birth weight with calves born during the spring calving season weighing approximately 1.6 kg more than those born during the fall season.

The analysis of WWT revealed that sex of calf was a significant source of variation as well as the three-way interaction of PL*birth season*ESS, while year was trending toward

significance (P = 0.1254). Over the 3 yr of this study, the WWT least squares means and standard errors by birth year were 224.8 kg ± 3.42 in 2009, 224.8 kg ± 3.62 in 2010, and 230.8 kg ± 3.66 in 2011. At weaning, male calves were significantly heavier than female contemporaries. Heifer and steer calves were shown to be lighter than their intact male contemporaries. Bull calves had the greatest ($P \leq 0.05$) mean weight at weaning, 237.0 kg ± 2.60: while no statistically significant difference was observed between the heifers and steers, 224.4 kg ± 3.21 and 223.5 kg ± 4.14. One possible explanation for the similarity between mean WWT of heifers and steers would be that since two of the three locations are purebred breeders, most of the higher performing animals are left intact while the lower performers are castrated.

Overall, there was no significant difference ($p > 0.05$) observed between ESS and WWT. The was a slight numerical trend (P =0.1125) observed with calves which had evidence of an IBK infection being on average 9.5 kg lighter than their nonaffected contemporaries (226.2 kg vs. 235.7 kg, respectively), which tends to agree with other published results. Funk et al. (2009) found similar results with affected calves weighing 7 to 11 kg on average less at weaning than did their unaffected contemporaries. Similar differences were reported by Rodriguez et al. (2006), Thomas et al. (1978) and Frisch et al., (1975) where unaffected animals were heavier when compared to those which were affected.

The three-way interaction of PL*birth season*ESS was highly significant ($P < 0.0001$) for WWT (Table 4). The PL 1 fall born calves with no observed evidence IBK had the greatest mean WWT ($P \leq 0.05$) when compared to the other groupings. No other statistically significant differences were observed for comparisons made within producer and season between ESS. However, it is interesting to note that there was a numerical trend in WWT for fall born calves with evidence of IBK at PL 2 and PL 3 to have a slightly larger mean weaning weight than did

their unaffected contemporaries. This numerical difference may be due to the smaller numbers of affected fall born animals, but further exploration may be warranted. Additionally, the severity of the IBK infections in the fall born calves may have been less and thus the impacts to performance and gain are not as pronounced.

Genetic, environmental, and phenotypic variances for the IBK resistance/susceptibility for the single trait model were 0.0077, 0.0600, and 0.0677, respectively using the single trait model (Table 5). Heritability and environmental portion of the total variance were estimated to be 0.11 ± 0.053 and 0.89 ± 0.053. Our estimate of heritability was smaller than what was observed in Angus cattle by Snowder et al. 2005 (0.22 ± 0.04). These results do agree with the Rodriguez (2006) were heritability of IBK resistance/susceptibility was estimated to be 0.11 ± 0.077. From the two-trait analysis of IBK resistance/susceptibility and BWT; genetic, environmental, and phenotypic variances for the IBK resistance/susceptibility were estimated to be 0.006, 0.062 and 0.067. The two-trait analysis of IBK resistance/susceptibility and BWT indicated that the genetic, environmental, and phenotypic variances for the IBK resistance/susceptibility were very similar to those seen in the previous two-trait analysis. Genetic and environment correlations were 0.45 and 0.57 between IBK resistance/susceptibility and BWT and 0.61 and -0.08 between IBK resistance/susceptibility and WWT.

Genetic correlations between ESS and BWT, and ESS and WWT were positive and moderate in strength (0.45 and 0.61, respectively). The environmental correlations between ESS and BWT, and ESS and WWT were determined to be negative and relatively weak (-0.08 and -0.15, respectively). The weak negative correlation value between ESS and BWT and ESS and WWT would indicate that animals which have been shown to have IBK tend to have lower weights, birth or weaning, than would their unaffected contemporaries due to environmental

effects. The weak negative environmental correlation coupled with the moderate positive genetic correlation and low heritability would tend to phenotypic correlations that would be intermediate.

IMPLICATIONS

This study did not show IBK to have a statistically significant impact on weaning weight yet a numerical trend towards significance was observed. Heritability for IBK resistance/susceptibility has been shown here to be rather low so potential progress through artificial selection will be slow. This does not mean that it should be ignored in selection altogether; rather it should be considered in conjunction with other economically important traits. It also would benefit the breed association to implement programs to capture IBK resistance/susceptibility information on progeny as it may be necessary in the future to control this disease.

LITERATURE CITED

Baptista P. J. H. P., 1979 Infectious bovine keratoconjunctivitis: a review. Br. Vet. J. 135(3):225–242.

BIF. 1996. Guidelines for Uniform Beef Improvement Programs. Beef Improvement Federation. 7th ed. P. 141.

Boldman, K. G., L. A. Kriese, L. D. Van Vleck, and S. D. Kachman. 1993. A manual for use of MTDFREML. USDA-ARS, Clay Center, Nebraska.

Brown, M. H., A. L. Brightman, B. W. Fenwick, and M. A. Rider. 1998. Infectious bovine keratoconjunctivitis: A review. J. Vet. Intern. Med. 12:259–266.

Burns M. J., and A. M. O'Connor. 2008. Assessment of methodological quality and sources of variation in the magnitude of vaccine efficacy: a systematic review of studies from 1960 to 2005 reporting immunization with *Moraxella bovis* vaccines in young cattle. Vaccine 26:144–152.

Davidson, H. J., and G. L. Stoka. 2003. A field trail of autogenous *Moraxella bovis* bacterin administered through either subcutaneous or subconjunctival injection on the development of keratoconjunctivitis in a beef herd. Can. Vet. J. 44(7):577-580.

Frisch, J.E. 1975. The relative incidence and effect of bovine infectious keratoconjunctivitis in *Bos indicus* and *Bos taurus* cattle. Anim. Prod. 21:265–74.

Geary, T. W. and J. J. Reeves. 1992. Relative importance of vision and olfaction for detection of estrus by bulls. J. Anim. Sci. 70:2726-2731.

Gerhardt R., and J. Allen. 1982. The role of face flies in an episode of infectious bovine keratoconjunctivitis. J. Am. Vet. Med. Assoc. 180:156-159.

Hansen, R. 2001. New tools in the battle against pinkeye. Proc. Nevada Livest. Prod. Annu., Univ. of Nevada – Reno. UNR Coop. Ext. SP 01-01.

Hughes, D. E., G. W. Pugh and T. J. McDonald. 1965. Ultraviolet radiation and *Moraxella bovis* in the etiology of bovine infectious keratoconjunctivitis. Am. J. Vet. Res. 26:1331-1338.

Jayappa, H. G, and C. Lehr. 1986. Pathogenicity and immunogenicity of pileated and nonpiliated phases of *Moraxella bovis* in calves. Am. J. Vet. Res. 47: 2217-2221.

Kopecky, K. E., G. W. Pugh, and T. J. Mc Donald. 1986. Infectious bovine keratoconjunctivitis: contact transmission. Am. J. Vet. Res. 47:622–624.

Lepper, A. W., and I. J. Barton. 1987. Infectious bovine keratoconjunctivitis: seasonal variation in cultural, biochemical and immunoreactive properties of *Moraxella bovis* isolated from the eyes of cattle. Aust. Vet. J. 64(2):33–39.

NAHMS, 1997a. Part II. Reference of 1997 beef cow-calf health and health management practices. USDA, APHIS. National Animal Health Monitoring System. Available www.aphis.usda.gov /animal health/nahms/beefcowcalf/downloads/beef97/Beef97_dr_PartII.pdf. Accessed September 17, 2012.

NAHMS, 1997b. Part III. Reference of 1997 beef cow-calf production and disease control. USDA, APHIS. National Animal Health Monitoring System. Available www.aphis.usda.gov/animal health/nahms/beefcowcalf/downloads/beef97/Beef97_dr_PartIII.pdf. Accessed September 17, 2012.

Richey, E. J. 2003. Herd Health Issues: Pinkeye. The Florida Cattleman, October 2003 Issue, p. 118. Florida Cattleman's Assoc., Kissimmee.

Rodriguez, J. E. 2006. Infectious Bovine Keratoconjunctivitis in Angus cattle. (Thesis). https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1855&context=rtd. Accessed: June 27, 2015.

SAS Institute Inc., 2015. SAS 9.3.1 User's Guide Statistics. SAS Institute Inc., Cary, NC

Slatter, D. H., M. E. Edwards, and C. D. Hawkins. 1982. A national survey of the clinical features, treatment and importance of infectious bovine keratoconjunctivitis. Aust. Vet. J. 59:69-72.

Snowder, G. D., L. D. Van Vleck, L. V. Cundiff, and G. L. Bennett. 2005. Genetic and environmental factors associated with incidence of infectious bovine keratoconjunctivitis in preweaned beef calves. J. Anim. Sci. 83:507-518.

Thomas, L. H., P. D. P. Wood, and J. M. Longland. 1978. The influence of disease on the performance of beef cattle. Br. Vet. J. 134:152-161.

Thrift, F., and J. Overfield. 1974. Impact of pinkeye (infectious bovine keratoconjunctivitis) on weaning and postweaning performance of Hereford calves. J. Anim. Sci. 38:1179-1184.

Ward, J. K., and M. K. Nielson. 1979. Pinkeye (bovine infectious keratoconjunctivitis) in beef cattle. J. Anim. Sci. 49:361-366.

TABLES AND FIGURES

Table 1. Distribution of Angus and Angus-derived calves evaluated within each season at each producer location in the southern United States

Location	Fall	Spring	Total
Producer 01	458	506	1014
Producer 02	58	96	154
Producer 03	240	112	362
Total	756	714	1530

Table 2. The percentage of Angus and Angus-derived calves exhibiting clinical signs of IBK impairment by season at each producer location in the southern United States

Location	Fall	Spring	Overall
Producer 01	2.8	9.0	6.4[x]
Producer 02	6.9	37.5	26.0[y]
Producer 03	0.4	60.7	20.7[xy]
Total	2.4[a]	20.7[b]	11.6

[ab] Percentage within the total row with different superscripts were significantly different ($P \leq 0.05$).

[xy] Percentage within the overall column with different superscripts were significantly different ($P \leq 0.05$).

Table 3. Least squares means of birth weight (kg) and standard errors for calves at each producer location, sex, and birth season

Producer Location	
01	33.3 ± 0.36[a]
02	34.1 ± 0.52[a]
03	32.1 ± 0.30[b]
Sex	
Heifers	32.0 ± 0.29[b]
Bulls	34.1 ± 0.35[a]
Steers	33.4 ± 0.53[a]
Season	
Spring	34.0 ± 0.37[a]
Fall	32.4 ± 0.27[b]

[ab] Mean weights within effect (PL, sex and season) with different superscripts were significantly different ($P \leq 0.05$).

Table 4. Least squares means of weaning weight (kg) and standard errors for calves exhibiting and not exhibiting clinical signs of IBK impairment by producer location for each season

Producer Location	Season	IBK Eye Scarring Score	
		Yes (1)	No (0)
01	Fall	289.7 ± 3.05^{b}	304.8 ± 3.05^{a}
01	Spring	292.2 ± 6.76^{bc}	285.7 ± 2.62^{c}
02	Fall	194.2 ± 15.56^{de}	190.2 ± 4.37^{e}
02	Spring	225.87 ± 6.19^{d}	236.9 ± 5.09^{d}
03	Fall	197.0 ± 31.44^{de}	194.5 ± 2.21^{e}
03	Spring	209.4 ± 4.16^{d}	222.0 ± 5.31^{d}
Overall	Combined	226.2 ± 6.20	235.7 ± 4.66

[abcde] Mean weights with different superscripts were significantly different ($P \leq 0.05$).

Table 5. Estimates of genetic variance (V_g), environmental variance (V_e), and phenotypic variance (V_p) and IBK heritability from single- and two-trait models.

	Additive Genetic		Environmental		Phenotypic		Heritability
Single-trait	V_{g1}		V_{e1}		V_{p1}		h^2_1
IBK_1	0.0077		0.0600		0.0677		0.11 ± 0.053
Two-trait	V_{g1}	V_{g2}	V_{e1}	V_{e2}	V_{p1}	V_{p2}	h^2_1
$IBK_1 – BWT_2$	0.0059	41.281	0.0618	54.322	0.0677	95.602	0.09 ± 0.042
$IBK_1 – WWT_2$	0.0075	2812.19	0.0604	5350.87	0.0679	8163.05	0.11 ± 0.057

Subscripts on trait indicate appropriate column for variance component and heritability

Table 6. Estimates of genetic, environmental and phenotypic covariances, genetic and environmental correlations from two-trait models.

	Covariances			Correlations	
	Genetic	Environmental	Phenotypic	Genetic	Environmental
IBK – BWT	0.2211	-0.1492	0.0718	0.45	-0.08
IBK – WWT	2.7814	-2.6595	0.1219	0.61	-0.15

CHAPTER 3

Estimation of Estimated Breeding Values (EBVs) and heritability for Infectious Bovine Keratoconjunctivitis (IBK) in Angus calves produced in a Southern environment using three breeding software programs

ABSTRACT

The objective of this study was to calculate the heritability and estimate the breeding values for infectious bovine keratoconjunctivitis (IBK) of Angus cattle produced in a southern environment utilizing 3 commercially available breeding software programs. Eye scaring data on 1,530 calves from three producer locations in the southern United States born during spring or summer from 2009, 2010, and 2011 were utilized in this study. Data were analyzed using a linear animal model in MTDFREML and DMU and a binary logit model in ASREML. The model consisted of the fixed effect of contemporary group (location and birth year), age at inspection as a covariate, and animal id as a random effect. Coefficients of heritability from the linear animal model were 0.11 ± 0.005 and 0.12 ± 0.003, MTDFREML and DMU, respectively; while the estimate was determined to be 0.33 ± 0.15 using ASREML and a binary animal model. Estimated breeding values using the linear animal model ranged from a maximum value of 0.1761 to a minimum value of -0.1079 using DMU and ranged from a maximum value of 0.1735 to a minimum value of -0.1099 using MTDFREML. Estimated breeding values using a binary animal model ranged from a maximum value of 0.8321 to a minimum value of -0.5789 with a mean of -0.0048 and a standard deviation of 0.155. Software application did have a small effect on which animals were observed in the extremes for EBV. This study indicates that selections against IBK susceptibility is possible; but the progress is expected to be rather slow.

Keywords: binary trait, estimated breeding values, IBK

INTRODUCTION

Infectious bovine keratoconjunctivitis (IBK) is a serious, yet non-fatal illness which has substantial economic impact on cattle production in the United States (Hansen 2001; NAHMS, 1997a; NAHMS, 1997b; Baptista 1979). Current control methods, primarily vaccination and physical hazard abatement, have proven to be somewhat ineffective and problematic. Within the last 10 y, research has become more focused on identifying individuals within the Angus breed which offer a greater resistance to the mechanisms of the occurrence of IBK.

Effective and accurate evaluation of genetic information from populations is critical for both producers and researchers to facilitate breeding programs which can drive improvement through genetic means. There are several breeding software programs available, either for purchase or free, which can be utilized to evaluate population information to estimate genetic characteristics and predict genetic potential. Some programs are species specific, while others can be used in a wide variety of situations (Misztal, 1994).

Estimations of heritability and other genetic characters is based on the assumption of the traits being somewhat normally distributed. Normality is expected when the research is dealing with categorical traits; however, problems are routinely encountered when the trait(s) of interest are categorical in nature. To facilitate genetic analysis of "non-normal" data, it has become common practice to transform the data to give the appearance of normality (Gianola, 1982). Falconer and Mackay (1997) indicated there are 3 reasons to make scale transformations: First, to "make the distribution normal"; second, to "make the variance independent of the mean"; and third, to "reduce non-additive interactions". It is important to note that one must be very observant when interpreting scaled data so that differences are truly due to the data and not the scaling effect.

MATERIALS AND METHODS

Herd health data collected on 1,542 spring and fall born calves produced at three Arkansas locations in three contiguous years were utilized in this evaluation. The distribution of calves by birth season and producer location are shown in a previous article (Oxford et al., 2019). Calves were sired by purebred Angus sires which were registered with the American Angus Association (Kansas City, MO). It is important to note that during the study, IBK resistance/susceptibility of any parental contributors was not considered in any breeding decisions at any of the producing locations. Two hundred and eight unique sires are represented in this data set where fifty-two individuals contributed at least 10 offspring.

Inspections were conducted on all contributing animals at weaning by the same inspector and IBK scores were assessed. Individuals were assigned a score of 0 if no visible evidence was observed of an IBK occurrence while a score of 1 was assessed if there was visual evidence of and IBK infection in either 1 or both eyes. No data were recorded to indicate severity/longevity of the IBK infection or whether the disease was bilateral in nature.

Producers were located in the northwest Arkansas area with two herds consisting of purebred Angus dams while the third location was considered a commercial herd with a high percentage of Angus ancestry. All locations were within a 20-mile radius of the University of Arkansas Beef Research Unit at Savoy, AR. The production herds utilized in this study would be considered very comparable to those which are observed in normal production programs in the southern area producing either purebred offspring or commercial calves.

Data recorded in the field records, was utilized in this experiment included: Sire identification, dam identification, calf identification, date of birth, producer location (PL),

production year, inspection date, and eye scaring score (ESS). Age of calf at inspection/weaning was calculated from the calf date of birth.

Three different, readily available, breeding software programs were utilized to calculate variance components and estimate heritability for this data set. The three software programs utilized were multiple trait derivative-free restricted maximum likelihood (MTDFREML) (Boldman et al., 1993), derivative-free multivariate analysis by restricted maximum likelihood (DMU) (Madsen and Jensen, 2013) and average information algorithm-spatial analysis of field experiments-restricted maximum likelihood (ASREML) (Gilmour et al., 2009). All programs are written in Fortran language and require data to be presented in "free format". Both DMU and ASREML are readily equipped to evaluate rather lager data sets with relative ease. Multiple trait derivative free restricted maximum likelihood requires the utilization of a Fortran compiler to restructure the matrices to accommodate the larger data sets if the need arises.

A linear animal model was fit for determining single-trait variance components and heritability estimates was utilized using both MTDFREML and DMU. The data were slightly modified to meet the requirements of the pedigree file for each of the estimation programs. For both MTDFREML and DMU, within the pedigree file, the sire, dam and individual identities were reassigned to meet computing requirements. These programs do not allow an individual to have an identification smaller than either the sire or the dam. Additionally, DMU requires an additional sort term in the pedigree. Birth year was included as the sorting term for all the analyses where required.

The linear animal model used to estimate heritability, genetic, environmental, and phenotypic variances in MTDFREML and DMU was:

$$\mathbf{Y} = \mathbf{X\beta} + \mathbf{Z\mu} + \mathbf{e}$$

Where, **Y** is vector of trait untransformed observations, **X** is a matrix of association observations with **β** which is a vector of fixed effects, **Z** is a matrix of association observations with μ which is a vector of random effects, and **e** is a vector of residuals.

Contemporary group (which was comprised of producer location and year of birth) was the only fixed effect included in the model, while age at inspection/weaning was included as a covariate and an animal effect was included as a random effect. To verify the estimates were accurate, the MTDFREML program was run twice after the models converged. Convergence criterion was user specified at 1×10^{-9} for estimate to be confirmed (i.e. the variance of the simplex function values was equal to or less than 1×10^{-9}). The exact model was executed in DMU where the convergence criteria was specified to be 1×10^{-6}. Utilizing MTDFREML on large data sets can be very time consuming due to a large amount of local memory required to effectively process the algorithms; however, it does provide very accurate solutions for smaller systems of mixed model equations (Misztal, 1994). DMU on the other hand utilizes an iterative method through ITPACK solvers, Jacobi conjugate gradient (JCG), successive overrelaxation (SOR), and reduced system conjugate gradient (RSCG) to name a few, which can trade computation speed for accuracy. The DMU program also utilizes Average Information (AI), Expectation Maximization (EM) or combined AI-EM to speed up the convergence process.

The binary animal model used to estimate heritability, genetic, environmental, and phenotypic variances in ASREML (which is very similar to a threshold model) was

$$\mathbf{Logit(y) = X\beta + Z\mu + e}$$

Where, Logit(**y**) is vector of trait observations (logit probability of IBK being present), **X** is a matrix of association observations with **β** which is a vector of fixed effects, **Z** is a matrix of association observations with **μ** which is a vector of random effects, and **e** is a vector of residuals (Ali et al., 2012).

The model components fit is ASREML were the same as described above; except for defining the response variable as binary in nature and utilizing a transformation using the logit link function. Three link functions, probit ($\phi^{-1}(\mu_i)$), logit ($\ln(\mu_i/1-(\mu_i))$), and gompit (complementary log-log) ($\ln(-\ln(1-(\mu_i))$) have been shown to be appropriate in transforming binary data. The logit and probit transformations have be utilized substantially in genetic evaluations to normalize dichotomous data (Gianola, 1982). Probit and logit are very similar and will give very similar results the major difference between the two link

functions is distribution of the error terms of these models. Logit model error terms follow the logistic distribution while the error terms of the probit models assumed follow the normal distribution.

RESULTS AND DISCUSSION

Phenotypic, genetic, and environmental variances were estimated utilizing all three breeding software programs. Phenotypic variances were determined to be smaller utilizing a univariate model in both MTDFREML and DMU, 0.0677 and 0.0680, respectively (Table 1). The phenotypic variance was observed to be larger when estimated ASREML using a binary animal model with a logit transformation. Genetic and environmental variances were determined to be smaller utilizing a univariate model in both MTDFREML (0.0077 and 0.0600, respectively) and DMU (0.0082 and 0.0598, respectively). The genetic and environmental variances were observed to be larger when estimated ASREML (0.4962 and 1.0000, respectively). The differences described above were most likely due to the models utilized and not the statistical software providing the estimates. Gianola (1982 and 1980) and Dempster and Lerner (1950) have illustrated that the utilization linear models of which assume the data to be normally distributed are not well suited or modeling binary data. They have shown that utilizing models which transform the data in a manner to more closely resemble a normal distribution to be more realistic. Additionally, the transformation removes the association between the mean and standard deviation which also reduces the potential of estimations of component outside of the 0 and 1 bounds (Kadarmideen et al., 2000). This is especially evident where the prevalence of the trait in question is either very high or low in occurrence.

Coefficient of heritability and standard error estimated using a linear animal model were determined to be 0.11 ± 0.053 and 0.12 ± 0.055 for MTDFREML and DMU, respectively. The coefficient heritability and standard (0.33 ± 0.15) were also estimated using a binary animal model in ASREML. These results are in the same order of magnitude which are typically seen in

the literature. Snowder et al., 2005 reported breed or breed grouping estimates using a linear animal model. The heritability of IBK susceptibility was determined to be low with estimates of heritability of more than 45,000 animals ranging from a minimum of 0, most breeds with low heritability were Continental (Frisch 1975), to a maximum 0.25, which were mostly British breeds. Rodriquez (2006) reported similar estimates from MTDFREML; however, the binary ASREML model gave a much lower estimation of heritability (0.071 ± 0.048). This difference in heritability estimates and standard errors could possibly be due to the wide range of incidence data observed in out data set. The incidence rates of the animals in this study ranged from a low of 0.4% to a high of 60.7% while the incidence observed in Rodriguez (2005) trial ranged from 0% to 17.5%.

Estimated breeding values were estimated for susceptibility to IBK using each of the 3 statistical programs (Table 3). Estimates using the linear model from DMU and MTDFREML were very similar in magnitude and directionality. Estimated breeding values calculated in DMU ranged from a maximum value of 0.1761 to a minimum value of -0.1079 with a mean of -0.0008 and a standard deviation of 0.033; while; estimated breeding values from MTDFREML were estimated to range from a maximum value of 0.1735 to a minimum value of -0.1099 with a mean of -0.0005 and a standard deviation of 0.032. Estimates using the threshold type model in ASREML were larger in magnitude than those estimated using DMU or MTDFREML. Estimated breeding values calculated in ASREML, using a binary animal model, were observed to range from a maximum value of 0.8321 to a minimum value of -0.5789 with a mean of -0.0048 and a standard deviation of 0.155. Directionality was very similar between all three programs. These results are very similar to those reported by Ali et al., (2012) where they observed a range of estimated breeding values from 0.5 to -0.5 on calves evaluated pre-weaning.

Distributions of estimated breeding values are shown in Figures 1, 2, and 3. All three distributions show very similar results if the scaling factor difference is ignored. The distributions appeared to be rather normal with a longer, more defined, tail towards the positive estimated breeding values. This would indicate that there were more extreme individuals in that direction which were genetically predisposed to being susceptible to showing signs if IBK.

Extreme estimated breeding values were evaluated between the three programs to determine if there were any major differences in the tails of the distributions. Ten percent of the observations (n=260) with the largest and smallest estimated values form each program were evaluated to determine if the same individuals were present (Table 3). When estimated breeding values from all three breeding programs were evaluated, 78.8%, or 205 individuals, were observed in the top 10% of while 82.3% or 214 individuals were observed in the bottom 10%. So, regardless of the statistical model proposed or breeding software program utilized many of the same individuals are estimated to be in the extremes, both top and bottom. The percentages when extremes from only two breeding programs were evaluated ranged from a high of 92.3%, or 240 individuals, for a comparison between DMU and MTDFREML to a low of 83.5%, or 217 individuals, for a comparison between ASREML and MTDFREML. The highest agreement percentage was observed between the larger breeding values which were estimated using a linear animal model.

During evaluation of the animals, evaluators must classify the animal as either 1 has evidence of IBK scaring or 0 no evidence of IBK scaring since a binary scale was utilized. In the above analysis we are making a huge assumption that those individuals which are scored as a 0 are “resistant” to IBK manifestation. This assumption is problematic in that we have no logical way to prove that assumption is correct or justified. One wat to justify this assumption would be

to evaluate the antibodies present in all animals in the study to determine if they have been exposed, but if they were vaccinated then the antibodies should be present with out exposure. One could alternatively assume that since IBK is "highly contagious" the indigenous vectors should expose all animals in the herd to the causative microbe.

IMPLICATIONS

Since infectious bovine keratoconjunctivitis (IBK) has been determined to be multifactorial in nature, improvement through selection activities may prove beneficial. Genetic parameter estimates associated with IBK estimated in this study indicate that susceptibility is low to moderate in heritability (0.11 ± 0.005, 0.12 ± 0.003, and 0.33 ± 0.15, MTDFREML, DMU, and ASREML, respectively) depending on which model and breeding software program is used to estimate the variance components. Similar results have been reported where other disease traits were evaluated. Calculation and utilizations of estimated breeding values and thus expected progeny differences (EPDs) could substantially impact breeding decisions and selection programs focused on minimizing the impact of IBK within their herds.

LITERATURE CITED

Ali, A. A., C. J. O'Neill, P. C. Thomson, and H. N. Kadarmideen. 2012. Genetic parameters of infectious bovine keratoconjunctivitis and its relationship with weight and parasite infestations in Australian tropical *Bos taurus* cattle. Genetics Selection Evolution. 44:22

Baptista, P. J. H. P., 1979. Infectious bovine keratoconjunctivitis: a review. Br. Vet. J. 135(3):225–242.

Boldman, K. G., L. A. Kriese, L. D. Van Vleck, and S. D. Kachman. 1993. A manual for use of MTDFREML. USDA-ARS, Clay Center, Nebraska.

Dempster E. R. and I. M. Lerner. 1950. Heritability of threshold characters. Genetics. 35:212-236.

Falconer, D. S, and T. F. C. Mackay. 1997. Introduction to Quantitative Genetics. 4th Edition, Longman Group Ltd., London.

Frisch, J.E. 1975. The relative incidence and effect of bovine infectious keratoconjunctivitis in *Bos indicus* and *Bos taurus* cattle. Anim Prod. 21:265–74.

Gianola, D. 1980. A method of sire evaluation for dichotomies. J. Anim. Sci. 51(6):1266-1271.

Gianola, D. 1982. Theory and analysis of threshold characters. J. Anim. Sci. 54 (5):1079-1096.

Gilmour, A. R., B. J. Gogel, B. R. Cullis, and R. Thompson. 2009. ASReml User Guide Release 3.0 VSN International Ltd., Hemel Hempstead, UK.

Henderson, C. R. 1984 Application of Linear Models in Animal Breeding. Guelph, Ontario, Canada: University of Guelph.

Kadarmideen, H. N., R. Thompson, and G. Simm. 2000. Linear and threshold model genetic - parameters for disease, fertility and milk production in dairy cattle. J. Anim. Sci. 71:411-419.

Madsen P and J. Jensen. A user's guide to DMU—a package for analyzing multivariate mixed models. Version 6; release 5.2. 2013. http://dmu.agrsci.dk/DMU/Doc/Current/dmuv6_guide.5.2.pdf

Misztal, I. 1994. Software Packages in Animal Breeding. http://nce.ads.uga.edu/~ignacy/numpub/oldpapers/wc94.PDF . Access November 20, 2016.

NAHMS, 1997a. Part II. Reference of 1997 beef cow-calf health and health management practices. USDA, APHIS. National Animal Health Monitoring System. Available www.aphis.usda.gov /animal

health/nahms/beefcowcalf/downloads/beef97/Beef97_dr_PartII.pdf. Accessed September 17, 2012.

NAHMS, 1997b. Part III. Reference of 1997 beef cow-calf production and disease control. USDA, APHIS. National Animal Health Monitoring System. Available www.aphis.usda.gov/animal health/nahms/beefcowcalf/downloads/beef97/Beef97_dr_PartIII.pdf. Accessed September 17, 2012.

Rodriguez, J. E. 2006. Infectious Bovine Keratoconjunctivitis in Angus cattle. (Thesis). https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1855&context=rtd. Accessed: June 27, 2015.

Snowder, G. D., L. D. Van Vleck, L. V. Cundiff, and G. L. Bennett. 2005. Genetic and environmental factors associated with incidence of infectious bovine keratoconjunctivitis in pre-weaned beef calves. J. Anim. Sci. 83:507–518.

TABLES AND FIGURES

Table 1. Phenotypic variance (σ_p), genetic variance(σ_g), environmental variance(σ_e), heritability (h^2), and convergence -2 log likelihood (-2Loglike) for each breeding software program utilized

Program	σ_p	σ_g	σ_e	h^2	-2Loglike
MTDFREML	0.0677	0.0077	0.0600	0.11 ± 0.0053	-2521.89
DMU	0.0680	0.0082	0.0598	0.12 ± 0.0030	-2514.42
ASREML†	1.4962	0.4962	1.0000	0.33 ± 0.1500	-3297.34

† The model fit in the ASREML program was binary animal model using the logit link function

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Table 2. The minimum, average, standard deviation, and maximum predicted breeding values for each breeding software program utilized

Program	Minimum	Average	Standard Deviation	Maximum
MTDFREML	-0.1099	-0.0005	0.032	0.1735
DMU	-0.1079	-0.0008	0.033	0.1761
ASREML[†]	-0.5789	-0.0048	0.155	0.8321

[†] The model fit in the ASREML program was binary animal model using the logit link function.

Table 3. The number and percentage of individuals represented in the top and bottom 10% (n = 260) of estimated breeding values for susceptibility to IBK using different combinations of breeding software programs

Program	Top 10% of BVs	Bottom 10% of BVs
All three	205/260 (78.8)	214/260 (82.3)
DMU - MTDFREML	240/260 (92.3)	222/260 (85.3)
ASREML† - DMU	223/260 (85.7)	233/260 (89.6)
ASREML† - MTDFREML	225/260 (86.5)	217/260 (83.5)

† The model fit in the ASREML program was threshold model using the logit link function

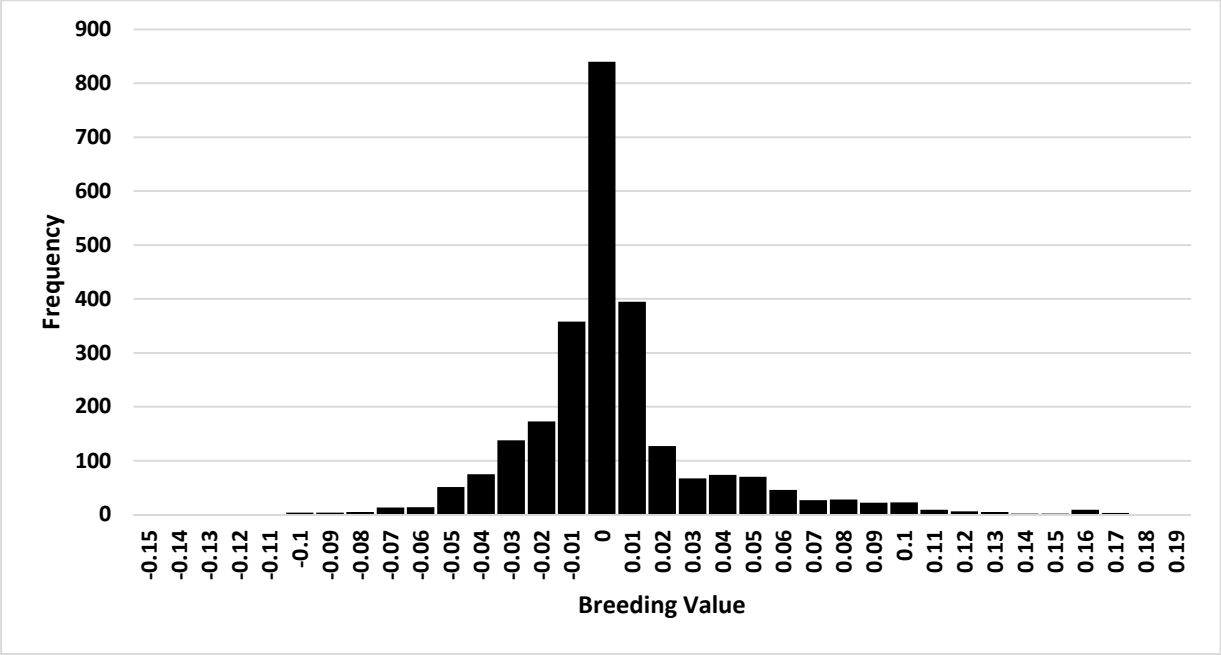

Figure 1. Distribution of estimated breeding values for Infectious Bovine Keratoconjunctivitis (IBK) susceptibility in Angus and Angus-derived cattle estimated using MTDFREML using a linear animal model

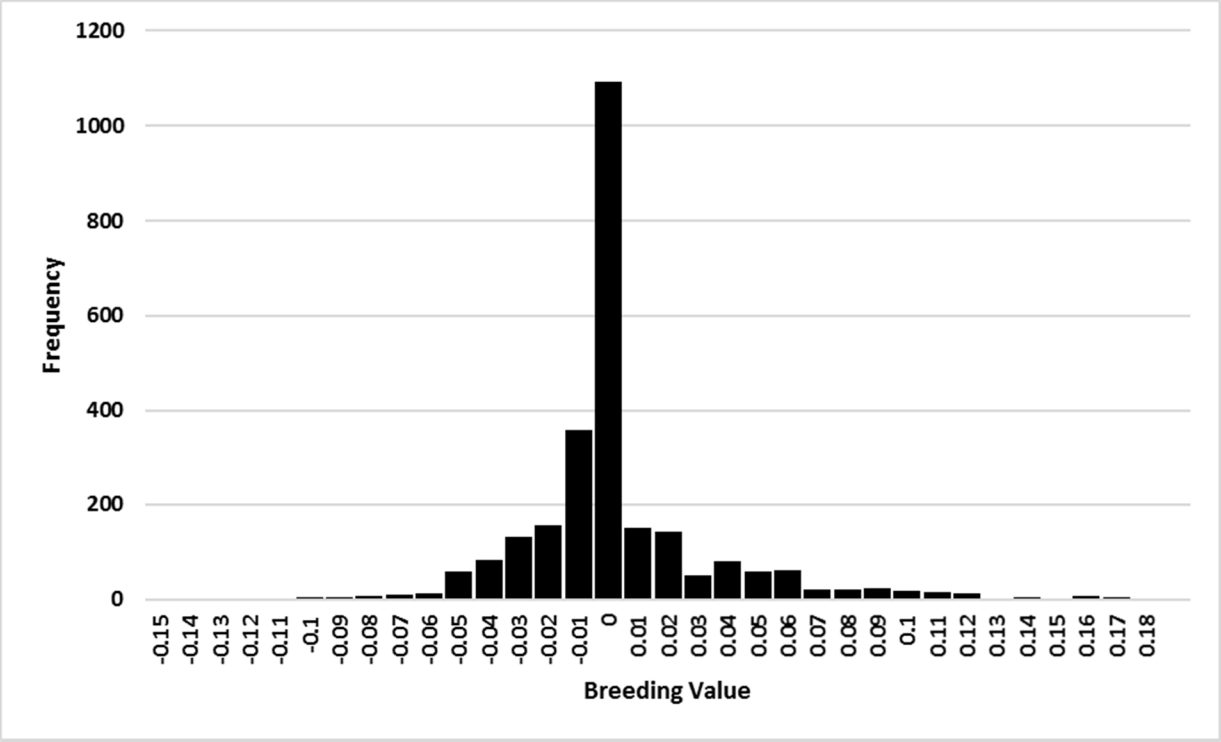

Figure 2. Distribution of estimated breeding values for Infectious Bovine Keratoconjunctivitis (IBK) susceptibility in Angus and Angus-derived cattle estimated using DMU using a linear animal model

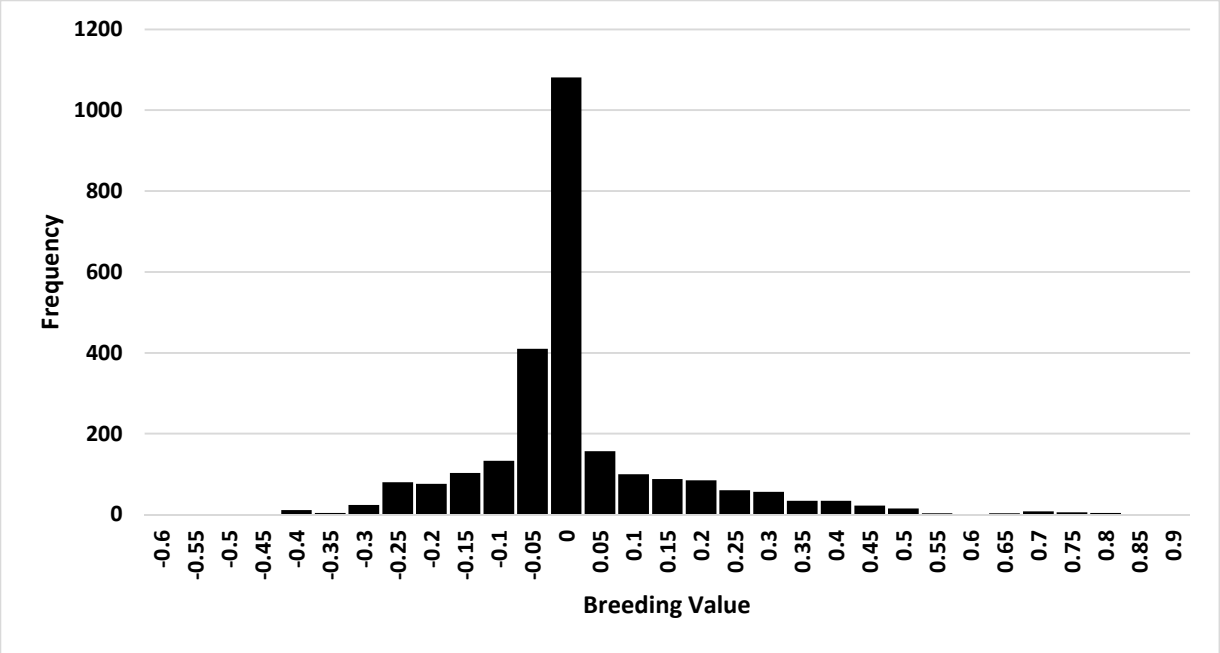

Figure 3. Distribution of estimated breeding values for Infectious Bovine Keratoconjunctivitis (IBK) susceptibility in Angus and Angus-derived cattle estimated using ASREML using an animal model with a logit transformation

GENERAL CONCLUSIONS

Incidences of IBK breakouts were determined to be very sporadic and variable, but predominately observed on calves which were born in the spring. The estimates of heritability calculated from data collected on Angus and Angus-derived animals produced in the southern United States were observed to be very similar to those seen in current literature; with the unique exception of the estimate from ASREML using a binary animal model, which were slightly higher than most. A statistically significant impact on weaning weight was not observed in this study, but this may be due to the producers having aggressive management programs once clinical signs were observed.

The estimations of heritability coupled with the estimations of the breeding values indicate that there is potential to select against IBK susceptibility. These data further indicate that inclusion of IBK susceptibility in performance records and routine collection of the prevalence on a regular basis would dramatically assist producers and improve estimates within the breed and improve the accuracy of the estimates.

APPENDIX

UNIVERSITY OF ARKANSAS

Office of Research Compliance

MEMORANDUM

TO: A. H. Brown

FROM: Craig N. Coon, Chairman
Institutional Animal Care
And Use Committee

DATE: July 3, 2013

SUBJECT: IACUC Protocol **APPROVAL**
Expiration date : **July 2, 2016**

The Institutional Animal Care and Use Committee (IACUC) has **APPROVED** Protocol **#13062 - "Genetic Considerations for Beef Cattle Production in Challenging Environments"**. You may begin this study immediately.

The IACUC encourages you to make sure that you are also in compliance with other UAF committees such as Biosafety, Toxic Substances and/or Radiation Safety if your project has components that fall under their purview.

In granting its approval, the IACUC has approved only the protocol provided. Should there be any changes to the protocol during the research, please notify the IACUC in writing [via the Modification Request form] **prior** to initiating the changes. If the study period is expected to extend beyond **07-02-2016** you must submit a new protocol. By policy the IACUC cannot approve a study for more than 3 years at a time.

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

cnc/car

cc: Animal Welfare Veterinarian

Administration Building 210 • 1 University of Arkansas • Fayetteville, AR 72701-1201 • 479-575-4572
Fax: 479-575-3846 • http://vpred.uark.edu/199