EVALUATION OF PASSIVE TRANSFER IMMUNITY AND PREDICTING SURVIVABILITY IN NEWBORN WHITE-TAILED DEER FAWNS

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by

Elizabeth Erin Evers

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DEDICATION

I dedicate this thesis to the people I love most in this world. I dedicate this work to JJ Lambert for our invaluable intellectual discussions and debates. I dedicate this work to my parents, Joe and Jackie Evers, and my brothers, Andy and Matt Evers for their endless support and encouragement. May this thesis inspire them as much as they have inspired me.

ABSTRACT

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Industry standards for successful passive transfer have been established for major livestock species; however, benchmarks have yet to be determined for pen-raised white-tailed deer fawns (*Odocoileus virginianus*). The objectives of this study were to determine an on-farm methodology to indicate successful passive transfer of immunity and to identify physical characteristics that may be used to predict the survivability of pen-raised white-tailed deer fawns. Fawns (n = 153) born to 88 white-tailed does (1.5 to 7.5 yr; 40-80 kg) from an established herd were utilized in this study. Measurements including BW, body length, and cannon bone length were obtained biweekly from birth to six wk of age. At 24 h of age, blood samples were obtained via jugular venipuncture. Blood was analyzed on-farm using a handheld digital refractometer. Both whole blood and serum were analyzed for total protein concentration, IgG concentration, and a Brix value that was determined using a scale adapted for on-farm use on dairies. Serum IgG concentration was also quantified by radial immunodiffusion (RID). Data were analyzed using the LOGISTIC, MIXED, and CORR procedures of SAS. During the trial, fawn mortality rate was 21.6%. The logistic procedure indicated that serum Brix values ($P < 0.01$) and serum IgG concentration ($P < 0.02$) at birth were useful for predicting survivability of fawns. Fawns that survived had greater serum Brix values (8.93 ± 0.17 vs 7.55 ± 0.35 °Brix) and serum IgG concentrations (9.51 ± 0.66 vs 6.80 ± 1.40 g/L) than fawns that died. In addition, there was a strong positive relationship ($P < 0.01$) between all on-farm serum measurements and results of the RID (r = 0.87). Body measurements

obtained were not predictors of survivability ($P \geq 0.12$), however, there were differences between fawns that survived and those that died. Fawns that survived had a greater ($P < 0.02$) cannon length (18.39 ± 0.10 vs 17.79 ± 0.23 cm) and BW (2.74 ± 0.05 vs 2.33 ± 0.12 kg) at birth than fawns that died. These results indicate that on-farm measurements to estimate successful passive transfer immunity may be used to help predict survivability in white-tailed deer fawns.

KEY WORDS: White-tailed deer (*Odocoileus virginianus*), Immunoglobulin G (IgG), Refractometer measurements, Passive transfer immunity, Survivability

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PREFACE

Science is facts; just as houses are made of stone, so is science made of facts; but a pile of stones is not a house, and a collection of facts is not necessarily science.

Jules Henri Poincaré (1854-1912) French mathematician.

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CHAPTER I

Introduction

Background

Immunoglobulin gamma (IgG) is an antibody that is often used as a marker for the success or failure of passive transfer from mother to her offspring. Passive transfer is a form of acquired immunity that allows the neonate to be protected from pathogens while its own immune system is developing. The significance of the acquired immune system is the ability of the system to remember an invader and be able to respond sooner and more effectively to subsequent infections. The passive method of acquisition means that any invader that the mother is protected from either through natural exposure to the disease or through vaccination will temporarily protect the offspring. Inadequate passive transfer leaves the neonate vulnerable to infection and often results in its death.

Currently, industry standards for the measurement of successful passive transfer are established for the major ruminant livestock species, including bovine and ovine. However, expansion of agricultural enterprises into new directions was not met with an increase in research in those areas. A species that is growing in popularity that may benefit from additional work in passive transfer is the white-tailed deer (*Odocoileus virginianus*). Research conducted in this area would allow deer producers to more quickly identify fawns that are susceptible to potential infections that may affect survivability and increase the chance of returning the fawns to health.

Objective

The objectives of this research are:

- To establish successful passive transfer immunity standards in pen-raised white-tailed deer neonatal fawns.
- To evaluate a digital handheld refractometer (MISCO PA201, Solon, OH) in the measurement of IgG present in fawns.
- To determine on-farm methods for evaluating health that are inexpensive and easily accessible to industry members.

These data are expected to show the birth weight and measurements of growth as an easily accessible indicator of health. It is also expected that fawns with higher serum IgG levels will show higher health and survivability and that the refractometer reading of serum IgG concentration will be highly correlated to radial immunodiffusion (RID) measurements. These data are expected to allow for a more effective health program which includes the early identification of fawns that are more susceptible to disease.

CHAPTER II

Literature Review

The White-tailed Deer

There are 38 subspecies of white-tailed deer that vary in size, limb length, and color, but all have the characteristic white noseband, eye rings, chin and throat patch. The northern subspecies are larger and darker in color than their southern counterparts. Ontario boasts the largest deer which range from 90.72-136.08 kg while Peru has the smallest white-tailed deer at 24.95-29.48 kg. Texas white-tailed deer range from 36.74-77.11 kg, have long limbs, are a reddish brown color, and are generally considered one subspecies. White-tailed deer are hardy, adaptable animals that can withstand the presence of internal and external parasites when adequate nutrition is available. However, diseases generally have a larger impact than parasites (Hiller, 1996). Tularemia, anthrax, and deer tumor virus can affect deer (Hiller, 1996) however, the main diseases of concern in Texas pen-raised deer include epizootic hemorrhagic disease (EHD), bluetongue virus (BTV), Lumpy Jaw (*Fusobacterium necrophorum*), diarrheal diseases, and pneumonia (Deer Breeders Corp., Mesquite, TX).

The white-tailed deer is the most popular big game animal in North America and possibly in the world. Though many hunters appreciate the white-tailed deer for its ability to stock their freezer with venison, many others seek trophy bucks with impressive antlers. This alert and agile animal is a member of the only phylogenetic family that produces antlers. Typical antlers appear in three varieties; wide, high, and basket, while non-typical antlers may appear asymmetrical with or without drop tines and forks. Antler size and shape depend on age genetics, and nutrition. Illness and injury can also affect

antler appearance as they may cause a reduction in feed intake as well as a diversion of nutrients to the healing process. Healthy bucks with good genetics and nutrition will sport their largest set of antlers in their 5th or 6th year (Hiller, 1996).

Economic Impact

Texas white-tailed deer breeding is a significant industry that has been around for at least the last 30 years. The economic impact of this industry has increased rapidly in the last 15 years and represents one of the largest portions of the cervid farming industry in the United States. The term "cervid" refers to any one of the various members of the cervidae family, including white-tailed deer, elk, fallow, mule deer, axis, sika, and red deer among others (Frosch et al., 2008). According to the Texas Parks and Wildlife Department (2015), there are over 1,300 deer farms in Texas raising and caring for approximately 111,000 total deer. Texas landowners devote over 17,000 acres to these operations, which are considered a major component of the rural economy. The Agricultural and Food Policy Center at Texas A&M University (Anderson et al., 2007) states that the direct and indirect economic impact of the farming industry for all cervids in the United States was an estimated $2.3 billion in 2007 in addition to the generation of approximately 30,000 jobs. As early as 1991, packaged hunts cost upwards of $3,000 and a lease to hunt in areas with a concentration of trophy bucks cost upwards of $5,000 (Hiller, 1996).

The cervid industry involves the production and consumption of products, as with other animal industries. Deer breeding facilities who occasionally partner with professional bottle-raisers comprise the production side who sell fawns, does, bucks, embryos and/or semen to the consumption side. This includes other breeders, trophy

hunting preserves or game ranches, and ultimately hunters. The industry also includes commercial venison producers, commercial urine collection operations, antler sheds, hides, velvet, and more. Within the industry, in Texas and nation-wide, white-tailed deer serve as the primary big game animal sought by hunters (Anderson et al., 2007; Frosch et. al, 2008). As hunters are the terminal consumer, producers select for genetics that result in high performing trophy white-tailed deer. With state regulation Title 31 Part 2 Chapter 65 Subchapter T Rule 65.611 (Texas Admistrative Code, 2010) preventing the sale of live deer across state lines, the use of reproductive technologies to provide highly marketable animals has flourished in the deer breeding industry. These technologies include fixed-time laparoscopic insemination, embryo transfer, and sex-sorted semen. This technology has created jobs for field technicians, lab technicians, veterinarians, and others to perform these services for the deer breeding industry, thus stimulating significant economic activity. As the cervid production industry has grown, the associated increases in the number of facilities as well as the number of animals have given rise to new challenges. Improving neonatal health and survivability is a notable challenge.

Immune System and IgG Pathway

The immune system is made of multiple biological systems with the purpose of preventing and destroying foreign body invaders. The first lines of defense in this complex are physical barriers which include unbroken skin, self-cleaning processes – coughing, vomiting, urinating – and the layer of commensal bacteria covering epithelial cells especially in the intestines and on the skin's surface. Many weaker pathogens are prevented in this way, and in fact many opportunistic pathogens can infect a host only

through a wound. The innate immune system is a collection of distinct subsytems including inflammation in response to infection or injury, and specialized cells and molecules, for example defensins and lysozyme respectively. The innate immune response responds to all invasions, new and subsequent, identically. Next, the adaptive immune system can remember antigens so that subsequent invasions can be more quickly addressed. This immune path has two major systems: 1) antibody production which is specialized for targeting bacteria and 2) cell-mediated immunity which is specialized in targeting abnormal cells such as those overtaken by virus. All together, these systems can protect against not only bacteria and viruses, but fungi, parasites, and tumors as well (Tizard, 2013).

Antibodies are proteins circulating in the body fluids, especially the bloodstream, searching for antigens to bind and mark for destruction. One such antibody, IgG, is produced in the spleen, lymph nodes, and bone marrow. It plays a major role in antibody mediated defenses as well as the innate inflammation response as it is a small enough protein to escape blood vessels. In the dam, colostrum is rich in IgG which accounts for 65-90% of the antibody content (Tizard, 2013). This colostral IgG and other proteins are actively transferred from the mammary blood vessels along with all mammary gland secretions over the last few weeks of pregnancy under the influence of estrogen and progesterone. Colostral IgG represents the whole of the dam's history of antigen exposure, B cell responses and somatic mutations. Once absorbed by the neonate through lacteals in the small intestine, this form of passive transfer immunity exerts a lifelong influence on the neonate's immune system that may be even stronger than genetic predisposition (Matte et al., 1982; Tizard, 2013). It is defined as passive

immunization as the protection is derived from the antibodies of another animal and not the neonate's own immune system. Vaccines, on the other hand, are a method of active immunization defined as a suspension of living or inactivated organisms used as an antigen to confer immunization. A live vaccine is more effective at producing an effective immune response, i.e. the appropriate antibodies in appropriate amounts, but a killed vaccine is somewhat safer from adverse reactions. There are other varieties of vaccines as well. Several things can prevent a vaccine from providing immunity including improper injection method, excessive stress, and improper vaccine storage. The dam's vaccinations will also result in passive transfer immunity provided to her neonate (Tizard, 2013). Information about the diseases important in the deer industry is located in appendix A.

The structure of the placenta in ruminant mammals is syndesmochorial which means that the chorionic epithelium and uterine tissues are in direct contact with each other. However, immunoglobulins are completely prevented from transferring through the placenta by six layers in the placental barrier region and thus the absorption of colostrum is essential for offspring to receive such antibodies (Tizard, 2013; Borghesi et al., 2014). These immunoglobulins form an important component of the immunological activity in colostrum. Receptor-mediated mechanisms transport the immunoglobulins out of the mammary epithelial cells and they are ejected from the mammary gland during suckling (Hurley & Theil, 2011). During the first 24 hours after birth, the gastrointestinal tract of the neonate is able to absorb intact immunoglobulins (Bush & Staley, 1980). Colostrum contains several isotypes of immunoglobulins; IgM, IgA, and IgG. Though

IgM appears during the initial contact of disease, and IgA prevents mucosal infections, IgG is the primary immunoglobulin found in colostrum (Hurley & Theil, 2011).

Passive Transfer

Without such a transfer of immunity from dam to offspring, the prevalence and severity of disease is greatly increased in neonatal ruminants. This is especially the case as glucocorticoids produced at parturition may suppress cellular immunity (Parkinson et al., 1982). It is important that neonates consume and absorb as much colostrum as possible as early as possible as there is a linear decrease in the intestinal absorption of IgG from 2 to 20 hours after birth for dairy calves (Matte et al., 1982). This means that there is a behavioral influence on the absorption of colostrum since the neonate must stand, approach the mother, search for the teat and nurse while the mother must accept these behaviors of the young (Price, 2008). Failure to ingest colostrum may also be due to physical malformalities that prevent the neonate from nursing. There may also be a failure to produce IgG or otherwise high quality colostrum. This may be due to premature birth, premature lactation, or leaking of colostrum from the teat (Tizard, 2013). The amount and composition of the colostrum and then milk is also of importance to the passive immunity of the fawn (Guidry, 1985). Nutritional level of the doe, especially during the third trimester can affect passive transfer success (Sams et al., 1996). The recommended amount of colostral IgG to prevent the failure of passive transfer in dairy calves is a total of 100 g in any amount of fluid. However, the greatest intestinal absorption if IgG occurs when the concentration of IgG in the colostrum is higher thus suggesting that a smaller fluid to IgG ratio is best. Deprivation of colostrum causes calves to be 50-75 times more likely to die within 21 days, especially in the first week of

life (Hammer et al., 2004). In research on pen-raised mule deer fawns, it was found that the morbidity rate was high and it was thought that this was due to low maternal care by the pen-raised does resulting in less colostrum consumption within 24 h post parturition (Parkinson et al., 1982). This work included wild-caught does and pen-raised does and showed that the fawns of wild-caught does had a lower mortality rate than the fawns of pen-raised does. Another explanation for this could be that the wild-caught does had a stronger immune system that allowed them to survive in the wild and this greater level of immunity was then passed to their fawns through colostrum. The issue of fawns of pen-raised does receiving fewer antibodies is compounded further by the increased ability of disease transmission and subsequent exposure across animals due to the greater density of animals in a confined space.

In calves, passive transfer is considered a failure when serum protein levels are less than 5.2 to 5.5 g/dL (Bielmann et al., 2010), when serum IgG is below 1.0 g/dL (Hammer et al., 2004; Weaver et al., 2000), and a Brix value of 8.5 or below (Hernandez et al.,2016). In the United States, it is estimated that 20 to 40% of calves experience failure of passive transfer (Bielmann, et al., 2010; Tyler et al., 1998; Hammer et al., 2004). This rate of failure of passive transfer in calves presents a significant issue. While Weaver et al. (2000) states that there is a limit to which a decrease failure of passive transfer (FPT) can be accomplished, there may be ways to reduce preventable animal deaths using on-farm methods. However, these studies related to neonate health have been conducted extensively in dairy cattle and those recommendations may be inadequate to use in the white-tailed deer industry. Specifically, in a study by Bah et al. (2015) on slaughterhouse blood, it was reported that New Zealand red deer differed in the

amount of IgG compared to sheep, swine, and cattle. The red deer blood differed ($P < 0.05$) in the concentration of plasma IgG from the sheep, swine, and cattle blood. The deer had a plasma IgG concentration of 10.3 ± 3.4 g/L while the sheep, swine, and cattle blood had 3.7 ± 3.4 g/L, 2.5 ± 0.5 g/L, and 20.3 ± 0.1 g/L of IgG respectively. This illustrates the difference in species and suggests that the dairy cattle standard cannot be borrowed by the deer industry. Previous research conducted in fawns of pen-raised white-tailed does is limited. Improved on-farm diagnostic technologies have not been utilized by white-tailed deer breeders and the corresponding benchmarks for FPT have not been determined for white-tailed deer as they have in cattle, horses, and sheep. Species specific benchmarks, in conjunction with improved on-farm methods to measure markers, would prove beneficial as a means to identify susceptible animals early enough to lower mortality and morbidity rates.

Determination of Passive Transfer

There is a widespread need for implementing useful tools and procedures for the assessment of colostrum quality and the success of passive transfer to improve fawn health and performance. Previous studies in other species have shown that body weights taken at birth are associated with health and survivability through weaning. In a study on survivability and immunity in piglets, researchers reported a difference in birth weight ($P < 0.5$) between those that survived to weaning (1.41 kg) and those that did not (1.08 kg, for piglets that died at <3 days of age, 1.26 kg, for piglets that died between 3 days of age and weaning; Devillers et al., 2011). However, in a study of over 2,000 goats by Singh et al. (2000), 27.90% of the kids with birth weights ≤ 2 kg and 34.0% of kids ≥ 4.1 kg at birth died within the first 15 days of life. The authors suggested that low birth weight

may be associated with susceptibility to low temperature and inability to nurse whereas high birth weight may have increased susceptibility to higher temperature (Singh et al., 2000; Ditchkoff et al, 2001). Elevated birth weights may also be associated with dystocia which can result in impaired breathing and reduced passive transfer due to cortisol related immunosuppression (Barrier et al., 2013). In either situation, the accompanying stress weakens the neonate's already compromised immune system (Tizard, 2013). In 60 goat kids, a difference ($P < 0.018$) was found in serum IgG concentration measured at 24 h after birth between those that survived to the end of the 84 h trial (15.18 ± 13.22 g/L) and those that did not (5.19 ± 11.20 g/L) (Arguello et al., 2004). Parkinson et al. (1982) conducted a trial discussed earlier with a small number of mule deer fawns (n = 28). They reported that the fawns that survived their first week had a greater ($P < 0.05$) serum IgG concentration (2.80 ± 0.81 g/dL) than fawns that died (0.72 ± 0.59 g/dL). These results illustrate that an average birthweight and higher absorption if IgG are necessary for the early survival of neonate animals.

In dairy cattle and horses, radial immunodiffusion (RID) is the benchmark test in serum IgG determination (Bielmann et al., 2010; Davis & Giguere, 2005; Hernandez et al., 2016), however, RID is time consuming, expensive, and not appropriate as an on-farm method of IgG determination. Fortunately, there are other direct ways as well as indirect ways to measure IgG concentration. These indirect methods include serum total protein (TP) and possibly serum Brix value. Brix is a measurement based on the amount of light that passes through a liquid. Outside animal science, it is used to measure the sugar content of wine, juices, and honey (Quigley et al., 2013). A Brix refractometer has been evaluated for its utility to assess colostrum quality in dairy cows, mares, ewes, and

sows (Bielmann et al., 2010; Chavatte et al., 1998; Harker, 1978; Weaver et al., 2000). A study by Bielmann et al (2010) examined the usefulness of an optical and digital Brix refractometer in the measurement of colostral IgG as compared to RID assessment. It was found that the optical and digital Brix measurements were highly positively correlated ($r = 0.98$). The optical instrument ($r = 0.71$) and the digital instrument ($r = 0.73$) were also highly positively correlated with the RID colostral IgG analysis. While not quite as highly correlated, the data still suggest that the refractometers are highly useful in measuring colostrum samples. In another colostrum Brix evaluation by Quigley et al. (2013), Brix was compared to RID and a turbidimetric immunoassay (TIA) which is a direct method of serum or plasma IgG concentration determination that is rapid and lower cost than RID. It was found that Brix was an acceptable estimate of colostral IgG and a more appropriate method than TIA colostral analysis.

Other direct methods of serum IgG concentration determination include zinc sulfate turbidity, glutaraldehyde coagulation, latex agglutination, turbidimetric immunoassays, and enzyme immunoassays. A study by Davis and Giguere (2005) has identified these methods as appropriate screening tests for FPT in foals, which is a serum IgG concentration of below 4.0 to 8.0 g/dL. However, it was suggested that foals suspected of FPT be tested again with another test to confirm. This suggests that the listed methods of IgG determination would not be quick or accurate methods of FPT detection. These researchers also included refractometers in their evaluation of FPT testing methods and reported refractometry to be a crude estimate of serum total protein concentration. However, according to Hernandez et al. (2016), refractometry is more easily standardized than the screening methods listed above, thus they are more useful in

evaluating FPT. This same study found that dairy calf Brix value and serum TP was highly positively correlated ($r = 0.91$); Brix value and TIA determined serum IgG were highly positively correlated ($r = 0.79$); and serum TP was highly positively correlated with TIA determined serum IgG ($r = 0.82$; Hernandez et al., 2016). Refractometers are therefore an effective on-farm tool for determining successful passive transfer.

CHAPTER III

Materials and Methods

IACUC Statement

All care, handling, and sampling of deer were approved by the Sam Houston State University Institutional Animal Care and Use Committee (Protocol number: 15-10-29-1027-3-01). This project fell under the USDA Pain/Distress Category Column C as it included no more than momentary distress outside of routine procedures and the limiting of distress during such routines procedures. Personnel were trained in handling deer and blood collection and supervised by the managing ranch (3-S Whitetails, Bedias, TX). Animals were returned to the herd after participating in the study.

Doe and Fawn Management

Eighty-eight white-tailed does (1.5 to 7.5 yr, 40-80 kg) from an established herd (3-S White Tails, Bedias, TX) were utilized to evaluate passive transfer in fawns. Does were mated utilizing laparoscopic insemination on 11 November 2015 with an expected due date calculated using the specific herd average gestation length of 196 days, 25 May 2016. Eight does were purchased in the fall as bred does and added to the herd. The composition of the parent genetics was predominately southern with some northern lines included. Does were maintained in five adjacent pens from breeding to weaning of their fawns and were fed diets that met or exceeded nutritional requirements. The diet consisted of ad libitum access to Sportsman's Choice Record Rack Deer Breeder Formula and approximately 113 g per doe per day of a mixed ration including Sportsman's Choice Record Rack Golden Deer Nuggets, Sportsman Choice Record Rack Deer Corn (Cargill, Minneapolis, MN), and AntlerMax Extreme Energy Supplement (Purina, St. Louis, MO).

Does were vaccinated on 15 April 2016 approximately 49 days prior to parturition (mean: 49 d, range: 32-102 d) with an EHD/BTV 9-way Combo Vaccine (Newport Laboratories, Worthington, MN) that contained Epizootic Hemorrhagic Disease virus serotypes 1, 2, and 6; Bluetongue virus 317; *Fusobacterium necrophorum*; *Clostridium perfringens* type A; *Pasteurella multocida*; *Escherichia coli*; *Arcaobacterium pyogenes* (new proposed name *Truperella pyogenes*); and *Bibersteinia trehalosi*. To accomplish this, does were restrained in a drop-floor chute designed for white-tailed deer for no longer than 5 minutes to limit stress. At the time of vaccination administration and at the time of breeding, a subset of 33 does were used to collect the following data: body weights were obtained and disposition scores from 1 to 5 (1 = docile and 5 = aggressive) were assigned by a single trained individual. Scores were assigned to evaluate deer behavior as an indicator of temperament and stress while restrained in the chute. Body condition scores (BCS), an assessment of body composition of fat and non-fat tissue obtained by palpating the ribs and spine (Herd & Sprott, 1996) by a single trained individual were assigned from 1 to 9 (1 = emaciated, 5 = average and 9 = obese). Blood samples (20 mL) were collected via jugular venipuncture into one non-additive vacutainer and one K_2EDTA vacutainer (Monoject, VWR, Radnor, PA) to determine base antibody quantities and a complete blood cell count. Body condition score, body weight, and blood samples were taken again on 9 May 2016 on the same subset of does 24 days post-vaccination to determine immune response to the EHD/BTV 9-way vaccine. Medications, feed, and other supplements used are listed in the appendices A and B.

A research team searched pens twice daily checking for newborn fawns and collecting blood samples from fawns that were 24 h old from 20 May 2016 to 10 July

2016. This procedure was repeated once daily until weaning on 3 October 2016. The majority of fawns remained in the pens with their dam and had access to their milk and the feed described earlier up until weaning. Fifty-one fawns were removed from their dams between 24 and 48 h of age and were raised as bottle fawns due to illness, lack of colostrum consumption, or if the fawn was less than 2.27 kg at birth. Fawns were kept in pairs in adjacent pens approximately 1 x 2 m in size. For the first two weeks, fawns were bottle-fed four times a day. From 2-4 wk of age, fawns were fed three times a day, and after 4 wk of age, fawns were fed twice a day. Beginning at 2 wk of age, fawns were offered pelleted feed. At 28 d, fawns were moved to larger adjacent pens approximately 2.5 x 9 m in size. Groups of four were housed in these pens where they had access to grass and were provided alfalfa hay in addition to the pelleted feed. Half of the fawns were fed Sportsman's Choice Record Rack Deer Breeder Formula and the other half were fed a proprietary blend called Fawn Starter. At approximately 84 d, fawns were weaned and again moved into larger pens approximately 20 x 20 m in size. This resulted in two groups of approximately 20 fawns until the end of another study over feed. Bottle-raised fawns were dewormed with ivermectin (Ivomec, Merial, Duluth, GA) at approximately 42 d of age. Fawns that remained on their dams were dewormed with ivermectin at approximately 60 d of age and weaned at approximately 120 d of age.

Data Collection and Analysis

Data were collected on all of the 153 fawns born live between May 2016 and July 2016. Blood samples could only be obtained from 120 fawns. At birth, after the doe had dried the neonate, fawns were weighed using a portable hanging scale, body length was obtained from the point of shoulder to point of hip, hind cannon bone length was obtained

from the point of hock to point of pastern, and hind leg length was obtained from the point of the hock to the distal tip of the hoof measured with a soft measuring tape. These measurements were similar to those collected in other fawn research (Powell and DelGuidice, 2005; Parkinson et al. 1982). At 24 h postpartum, blood samples (6 mL) were obtained via jugular venipuncture from the fawns using a 23-gauge butterfly needle and extension kit (BD Worldwide, Franklin Lakes, NJ). Restraint of the fawns in both instances was limited to 15 minutes to reduce stress. Stress was also reduced as the fawns natural response to being approached up to two weeks of age is to lie low and motionless (Hiller, 1996). Blood samples were collected into 2 mL sterile vacutainer tubes, one containing 15% K_2EDTA and two non-additive tubes (Monoject, VWR, Radnor, PA). Immediately following collection, whole blood collected in the K_2EDTA tube was utilized in its unaltered state to determine Brix, total protein, and IgG concentrations with a portable refractometer (MISCO PA201, Solon, OH) and the remaining was used to perform a complete blood cell count (CBC) including the differentials using a CBC-cervid test at the Texas A&M Veterinary Medical Diagnostic Laboratory (TVMDL, College Station, TX). For the does, in addition to the CBC-cervid test, antibody titers to EHD serotype 1, 2, and 6 (virus neutralization) and Bluetongue (complement-enzyme linked immunosorbent assay) were quantified to assess effectiveness of the 9-Way vaccine in providing immunity. Whole blood measurement of IgG in the refractometer was discontinued part way through the project as the device was not able to evaluate IgG in whole blood. The two non-additive tubes collected on the fawns were centrifuged (ThermoFisher Scientific, Waltham, MA) at 2000 revolutions per minute for 10 minutes at 25ºC at which time serum was harvested, utilized in the

refractometer for determination of Brix, total protein, and IgG concentrations (Brix range 0-85 ºBrix, total protein range 0-14 g/dL, IgG range 2.2-25 g/L) with the remaining stored at -20°C in microcentrifuge tubes for later laboratory analysis of IgG at North Dakota State University (Fargo, ND). Concentrations of IgG in serum were measured by radial immunodiffusion using a commercially available kit to detect bovine IgG validated for use in cervids (Triple J Farms, Bellingham, WA). Procedures and tests were similar to those used in comparable studies (Sams et al., 1996; Donovan et al., 1998; Trindle et al., 1978; Drolet et al., 2013).

Morbidity and mortality rates along with health status were observed daily and growth measurements were observed and recorded biweekly until fawns reached six weeks of age. These measurements were collected from a subset of 46 bottle-raised fawns that survived until 6 weeks, however, all fawns had measurements taken at birth and all live fawns had weaning weights collected. Fawns with signs of illness such as reduced voluntary activity, reduced milk consumption, lethargy, incoordination, and weakness were examined and treated appropriately. The exam included taking a rectal temperature and measuring heart rate and respiration rate as well as noting any physical symptoms. Medications and other supplements used to treat fawns are listed in appendices A and B.

Doe data were analyzed using the CORR, MIXED, and FREQ procedures of SAS v. 9.4 (SAS Institute, Cary, NC) to determine BCS and weight correlations and differences as well as vaccine response in the does. Fawn data were analyzed using the CORR, MIXED, and LOGISTIC procedures of SAS to determine differences in Brix, total protein, and IgG concentration, blood cell counts, and growth measurements between fawns that survived to weaning and those that perished before weaning, and to

determine relationships between the refractometer readings and laboratory analysis of IgG concentration as well as a prediction of survival based on the aforementioned characteristics. Fawn was used as the experimental unit. Fixed effects were survival and environment prior to weaning.

CHAPTER IV

Results

Doe Data

The genetic composition of the herd was approximately two-thirds Texas lines with northern lines making up the other third. The mean BW of the subset of 33 does used to estimate vaccine response as shown in Table 1 increased ($P < 0.01$) from 59.79 kg on 15 April 2016 to 62.82 kg on 9 May 2016 while mean BCS did not change ($P = 0.36$). Greater BW and optimal BCS (5-7) is associated with increased health and increased reproduction (Herd & Sprott, 1996). The mean disposition score was 2.48 during the April collection but was not measured in May as the increased hormone levels in the does caused them to be much flightier.

Table 1

Mean body weight (kg), body condition score (1-9) and disposition score (1-5) collected on 15 April 2016 and 9 May 2016 from a subset of 33 does that were utilized to evaluate immune response to a 9-way vaccine

Item	N	April Mean	May Mean	*P*-value
Disposition Score[a]	33	2.48 ± 1.06	-	-
BCS	33	5.83 ± 0.79	5.74 ± 0.77	0.36
BW (kg)	33	59.79 ± 8.35	62.82 ± 8.37	<0.01

[a]Disposition score was not measured in May.

Table 2 shows that there was a significant response ($P < 0.02$) to EHD serotype 1, but that there was only a trend in response to bluetongue virus, EHD serotype 2 and EHD serotype 6 ($P = 0.08$, $P = 0.11$, $P = 0.11$, respectively). Bluetongue virus and EHD

serotype 2 are diseases that were most prevalent in the area in which this study was conducted. Therefore, more of the does had already been exposed naturally to these diseases resulting in a greater number of them that exhibit elevated antibody titers in April. It is unclear why the number of does that exhibited elevated antibody titers to EHD 2 decreased during the May collection. It is also unclear why a difference was not detected in EHD 6 titers between the test dates. This was possibly due to a small sample size or that a significant immune response could not be mounted within the 16 d between samples.

Table 2

Immune response to a 9-way vaccine administered to 33 mature does on 15 April 2016 as determined by differences in antibody titers on the day of administration and 16 days (May) later

Month	Item[a]	Count	*P*-value
April	BTV Titer Positive	27	0.08
April	BTV Titer Negative	5	
May	BTV Titer Positive	32	
May	BTV Titer Negative	1	
April	EHD1 Titer Positive	18	<0.02
April	EHD1 Titer Negative	14	
May	EHD1 Titer Positive	28	
May	EHD1 Titer Negative	5	
April	EHD2 Titer Positive	29	0.11
April	EHD2 Titer Negative	3	
May	EHD2 Titer Positive	25	
May	EHD2 Titer Negative	8	
April	EHD6 Titer Positive	15	0.11
April	EHD6 Titer Negative	17	
May	EHD6 Titer Positive	22	
May	EHD6 Titer Negative	11	

[a]BTV = blue tongue virus; EHD = epizootic hemorrhagic disease; number indicates virus serotype.

The final fawning rate was 1.77 fawns per doe. Many of the does gave birth to twins and a few had triplets, as anticipated. Offspring were determined using DNA analysis as per previous ranch policy. This was done not only for complete precision but out of necessity as many does allowed fawns that were not their own to nurse.

Fawn Data

During the trial, the morbidity rate was 75.8% and total mortality rate was 21.6% including unknown and trauma-related death. Mortality related to illness was 16.1% where 58.3% of those deaths occurred before 21 d of age. Age at death for all fawns ranged from 0-116 d. The fawning season began 17 May 2016 and continued until 26 July 2016 with two-thirds of the fawns born in May. There were several large storms in the early part of the fawning season while later in the season it remained relatively dry. There were 3 fawns that were still-born, 153 fawns born live, 51 total bottle-raised fawns, and a total of 33 deaths before weaning. Fawn deaths included 2 that disappeared during late June, 5 that were trauma related, and 3 that cause could not be determined, all of which were removed from analysis of fawns surviving until weaning. Means for measurements taken at birth such as birth weight (2.73 kg), cannon length (18.4 cm), leg length (23.1 cm), body length (28.1 cm), and serum IgG (2.82 g/dL) concentration as determined by RID are shown in Figures 1-3. Blood samples could only be obtained on 120 of the 153 fawns.

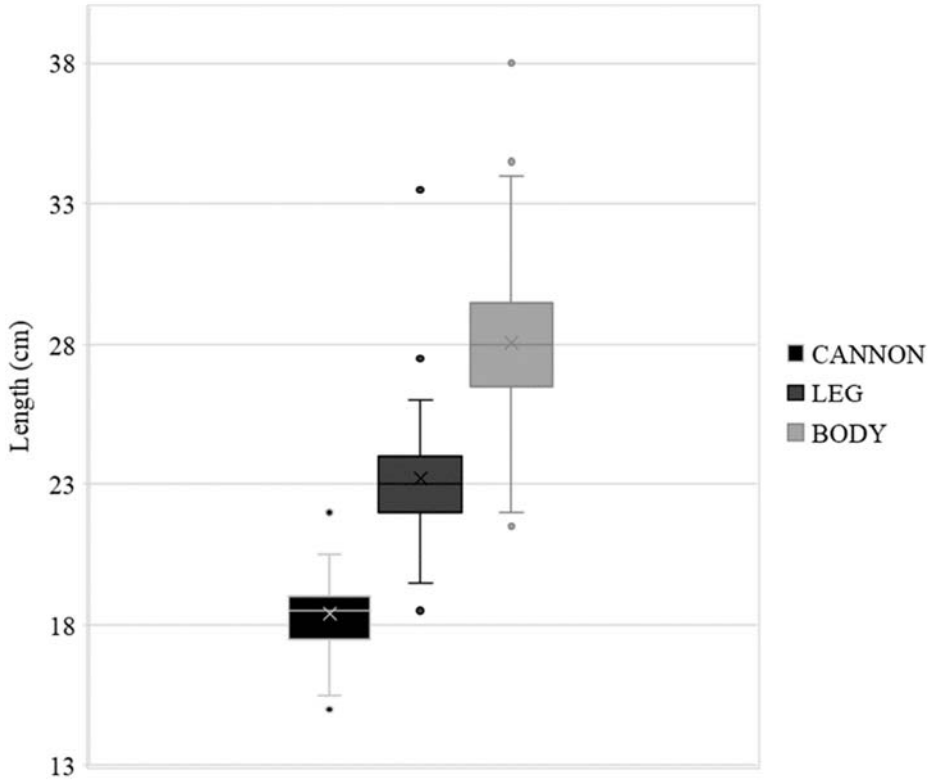

Figure 1. Mean cannon, leg, and body length (cm) at birth of all fawns.

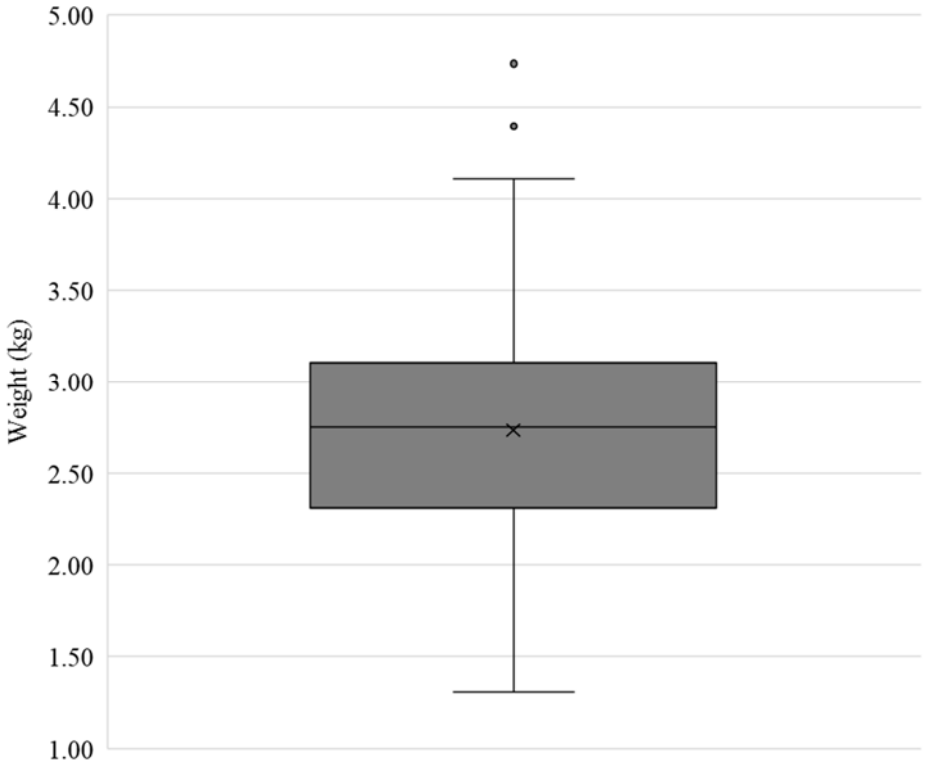

Figure 2. Mean birth weight (kg) for all fawns.

Figure 3. Mean serum IgG concentration (g/dL) as determined by radial immunodiffusion for 120 of the 153 fawns.

In regards to body measurements, shown in Table 3, fawns that survived had a greater ($P < 0.02$) cannon length (18.39 ± 0.10 vs 17.79 ± 0.23 cm) and body weight (2.74 ± 0.05 vs 2.33 ± 0.12 kg) at birth than fawns that died. The survivors also trended toward having longer ($P = 0.08$) bodies (28.06 ± 0.23 vs 27.00 ± 0.55 cm). Similarly, fawns that survived had greater ($P < 0.04$) serum concentration of IgG (2.87 ± 0.14 vs 2.15 ± 0.31 g/dL) as determined by RID than fawns that died. In regard to measurements determined using the hand-held digital refractometer, fawns that survived had greater ($P < 0.01$) serum Brix scores (8.93 ± 0.17 vs 7.55 ± 0.35 °Brix), greater ($P < 0.01$) serum total protein concentration (5.77 ± 0.13 vs 4.77 ± 0.28 g/dL), and trended towards greater ($P = 0.08$) serum IgG concentrations (9.51 ± 0.66 vs 6.80 ± 1.40 g/L) than fawns that

died. Plasma total protein determined as part of the CBC was not different ($P = 0.56$) between the two groups nor was the white blood cell count ($P = 0.20$). Additional information about the fawns can be found in appendices C & D.

Table 3

Means of body measurements obtained at birth and blood measurements obtained at 24 h after birth for fawns that died prior to weaning and fawns that survived to weaning

	Item	Died	Survived	*P*-value
Body Measurements[a]	Cannon Length (cm)	17.80 ± 0.23	18.39 ± 0.10	<0.02
	Leg Length (cm)	22.25 ± 0.53	23.07 ± 0.23	0.16
	Body Length (cm)	27.00 ± 0.55	28.06 ± 0.24	0.08
	Birth Weight (kg)	2.33 ± 0.12	2.74 ± 0.05	<0.01
Morbidity Estimate	Days Sick	4.00 ± 0.67	3.80 ± 0.29	0.78
Refractometer Readings	Serum Brix (%)	7.55 ± 0.35	8.93 ± 0.17	<0.01
	Serum TP (g/dL)	4.78 ± 0.28	5.78 ± 0.13	<0.01
	Serum IgG (g/L)	6.80 ± 1.40	9.51 ± 0.66	0.08
RID Assay[b]	Serum IgG (g/L)	2.15 ± 0.31	2.87 ± 0.14	0.04
CBC Results[b]	Plasma TP (mg/dL)	5.55 ± 4.79	8.05 ± 2.22	0.56
	WBC (K/μL)	2.32 ± 0.35	2.82 ± 0.16	0.20

[a]Cannon length taken from hind hock to ankle; Leg length taken from hind hock to toe tip; Body length taken from point of shoulder to point of hip.

[b]RID = radial immunodiffusion; CBC = complete blood count; TP = total protein; WBC = white blood cell count.

Total mortality rate for bottle-raised fawns was 17.6% and 23.5% for dam-raised fawns. Observed morbidity rate for bottle-raised fawns was 96.1% compared to 65.7% for dam-raised fawns. However, there was no difference ($P = 0.78$) between fawns that survived and those that died before weaning in the number of observed days of illness. The mortality rates for each group when considering only illness related deaths were 14.3%, 17.0%, and 16.1% for bottle-raised, dam-raised, and total population, respectively. As seen in Table 4, bottle-raised fawns had lighter ($P < 0.01$) birthweights (2.36 ± 0.11 vs 2.71 ± 0.08 kg), and shorter ($P < 0.02$) cannon bone length (17.78 ± 0.20 vs 18.41 ± 0.15 cm), but did not differ in body length ($P = 0.13$) or leg length ($P = 0.21$) from fawns raised by their dams. These differences can be accounted for due to the ranch's policy of bottle-raising fawns weighing less than 2.27 kg at birth and fawns appearing weak, sick or not to have nursed within 24 h after birth. There was a significant difference between bottle-raised fawns and those that remained at their dam's side in the number of days they were observed to be ill ($P < 0.01$). This is due to the fact that bottle-raised animals had much more frequent and much closer interaction with observers and therefore illnesses were identified with much greater accuracy and speed. Bottle-raised fawns had lower serum Brix values ($P < 0.05$), serum TP concentration ($P < 0.01$), and serum IgG concentration ($P < 0.04$) as determined by refractometer and had lower serum IgG concentration as determined by radial diffusion ($P < 0.03$), but the plasma total protein and white blood cell count did not differ ($P > 0.10$) as seen in Table 4.

Table 4

Means of body measurements obtained at birth and blood measurements obtained at 24 h after birth of bottle-raised fawns and fawns raised by their dams

	Item	Bottle-Raised	Dam-Raised	*P*-value
Body Measurements[a]	Cannon Length (cm)	17.78 ± 0.20	18.41 ± 0.15	<0.02
	Leg Length (cm)	22.30 ± 0.46	23.03 ± 0.35	0.21
	Body Length (cm)	27.08 ± 0.48	27.98 ± 0.36	0.13
	Birth Weight (kg)	2.36 ± 0.10	2.71 ± 0.08	<0.01
Morbidity Estimate	Days Sick	5.98 ± 0.58	1.82 ± 0.44	<.01
Refractometer Readings	Serum Brix (°Brix)	7.86 ± 0.32	8.63 ± 0.23	0.053
	Serum TP (g/dL)	4.85 ± 0.26	5.71 ± 0.18	<0.01
	Serum IgG (g/L)	6.5 ± 1.26	9.77 ± 0.90	0.04
RID Assay[b]	Serum IgG (g/dL)	2.13 ± 0.28	2.89 ± 0.19	0.03
CBC Results[b]	Plasma TP (mg/dL)	5.59 ± 4.34	8.00 ± 3.00	0.41
	WBC (K/μL)	2.45 ± 0.32	2.68 ± 0.23	0.55

[a]Cannon length taken from hind hock to ankle; Leg length taken from hind hock to toe tip; Body length taken from point of shoulder to point of hip.

[b]RID = radial immunodiffusion; CBC = complete blood count; TP = total protein; WBC = white blood cell count.

The refractometer measurements of Brix (r = 0.87), total protein (r = 0.92) and IgG (r = 0.91) concentrations using serum were highly correlated with IgG concentration quantified by RID as seen in Table 5. However, the refractometer measurement of IgG concentration underestimated the IgG concentration as determined by RID. Whole blood refractometer readings for Brix (r = 0.86) and total protein concentration (r = 0.85) were also highly correlated with IgG concentration quantified by RID, but whole blood IgG concentration as determined by refractometer was only moderately correlated (r = 0.31) as seen in Table 5. However, analysis of IgG concentration in whole blood using the refractometer produced erratic results suggesting that the machine was unable to read the

sample properly. Measurement of this value was discontinued during the project due to this error.

Table 5

Pearson correlation coefficients between whole blood Brix (BrixW), whole blood total protein (TPW), whole blood IgG (IgGW), serum Brix (BrixS), serum total protein (TPS), serum IgG (IgGS) as determined by refractometer, and IgG concentration as determined by radial immunodiffusion (RID), and plasma total protein (PTP) as determined by CBC

Item[a]	BrixW	TPW	IgGW	BrixS	TPS	IgGS	PTP	RID
BrixW	1	0.95	0.56	0.83	0.87	0.83	0.84	0.86
		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	116	112	29	116	116	116	106	116
TPW		1	0.60	0.81	0.84	0.86	0.86	0.85
			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		112	29	112	112	112	102	112
IgGW			1	0.32	0.32	0.35	0.42	0.31
				0.09	0.09	0.06	0.06	0.11
			29	29	29	29	21	29
BrixS				1	0.91	0.88	0.90	0.87
					<0.01	<0.01	<0.01	<0.01
				119	119	119	106	118
TPS					1	0.92	0.90	0.92
						<0.01	<0.01	<0.01
					119	119	106	118

(continued)

Item[a]	BrixW	TPW	IgGW	BrixS	TPS	IgGS	PTP	RID
IgGS						1	0.92	0.91
							<0.01	<0.01
						119	106	118
PTP							1	0.93
								<0.01
							106	106
RID								1
								118

[a]Rows from top to bottom: correlation coefficient, *p*-value, and sample size.

The serum IgG concentration benchmark for successful passive transfer appears to be 2.73 g/dL as seen in Table 6. This value was obtained by calculating one standard deviation below the mean serum IgG concentration as determined by RID for fawns that survived to weaning. The standards for the refractometer concentrations and plasma total protein were calculated by their regression equations as well as from one standard deviation below the mean values for fawns that survived to weaning since RID is not useful as an on-farm method of FPT detection. The corresponding refractometer serum measurements as seen in Table 6 are 8.67-8.76 °Brix, 5.57-5.65 g/dL for total protein concentration, 8.85-8.89 g/L for serum IgG concentration, and 5.83-6.09 mg/dL for plasma total protein concentration. The literature was unclear about how standards were precisely determined; however, further research can shed light on the topic. For Brix and total protein, both calculations resulted in similar values and thus we can be reasonably confident in their practicality. Although both values for plasma total protein were similar for our standard calculations, it may not be a useful standard as such since it was not significantly different between fawns that died before weaning and fawns that survived to weaning.

Table 6

Standardized benchmarks for plasma total protein, serum Brix, serum total protein, and serum IgG based on the calculated standard of 2.73 g/dL of serum IgG as determined by radial immunodiffusion (RID)

	CBC	Refractometer Readings			RID Assay
	Plasma Total Protein (mg/dL)	Serum Brix (°Brix)	Serum Total Protein (g/dL)	Serum IgG (g/L)	Serum IgG (g/dL)
Regression Determined Standard[a]	6.09	8.67	5.57	8.89	2.73
Standard Deviation Determined Standard[b]	5.83	8.76	5.65	8.85	2.73

[a]Standard determined from the regression equation between the measurement in question and the RID determined serum IgG concentration.

[b]Standard determined from one standard deviation below the mean for the fawns that survived to weaning.

Table 7 shows equation estimates from the LOGISTIC procedure in SAS. Serum IgG and serum Brix values obtained using the refractometer were the variables that were determined to be the most predictive of survival as opposed to birth date, sex, pen number, body measurements, and all other blood measurements. The variables chosen and the intercept will give the log of the probability of survival to weaning. To be entered into and to stay in the equation, variables had to have a *p*-value of less than 0.05. When refractometer determined serum IgG and RID determined serum IgG were removed from the SAS input to allow only variables from on-farm data collection methods to be used in the equation, serum Brix value remained a significant predictor; however, no other variables entered the equation. Removing all blood measurements from the input to allow only body measurements to enter the equation showed birth

weight to be the most predictive of survival. These two latter equations may be more practical in the prediction of fawn survival as IgG settings are no longer common on digital refractometers.

Table 7

Coefficients to estimate the probability of fawn survival as determined by the LOGISTIC procedure of SAS

Variables Included	Item	Estimate[a]	Standard Error	*P*-value
All Variables	Intercept	-9.74	3.72	<0.01
	Serum Brix	1.66	0.57	<0.01
	Serum IgG	-0.34	0.14	<0.02
Without Serum IgG	Intercept	-2.67	3.73	0.054
	Serum Brix	0.49	0.17	<0.01
Without Blood Measurements	Intercept	-2.1165	1.18	0.07
	Birth Weight	1.4786	0.47	<0.01

[a]Estimates will provide the log of the probability of survival

CHAPTER V

Discussion and Conclusion

Discussion

The results of this study indicate that body size may be related to survivability in white-tailed deer fawns. Smaller fawns had a higher probability of mortality than larger fawns. However, the largest fawns did not have a proportionally large advantage in growth rate over the average sized fawn. Previous research in pigs, goats, and calves reported lighter ($P < 0.05$) birth weights in animals that died during the respective observational trial than those that survived (Deviller et al., 2011; Singh et al., 2000; Linden et al., 2009). The fawns that survived had a greater body length, BW, serum total protein concentration, serum Brix value, and RID determined serum IgG concentration than those that died during the trial. In previous studies on goats and mule deer, neonates that survived had greater ($P < 0.05$) serum IgG concentration and thus higher levels of passive transfer than neonates that died (Arguello et al., 2004; Parkinson et al., 1982). Bottle-raised fawns have a better chance at surviving to weaning, suggesting that being under closer supervision increases early detection and treatment of illness in fawns. This also suggests that animals with higher quality genetics should be bottle-raised under close supervision to increase the chance that the fawn will survive to weaning.

The fawning rate of 1.77 fawns per doe was comparable to the rate reported in well-fed penned does of 1.74 by Verme (1965); however it was greater than the national average for both the 2005 and 2006 fawning seasons of 1.24 and 1.31, respectively (Anderson et al., 2007). There was no previous information on fawn-specific morbidity and mortality rates for pen-raised deer. Therefore, more research is necessary to

determine if the 75.8% morbidity, 21.6% overall mortality, and 16.1% illness-related mortality rates were within normal ranges. In addition, Texas deer are considered one subspecies and differ in body size and characteristics from their northern counterparts, therefore many studies involving northern pen-raised deer may not be wholly appropriate to apply to Texas pen-raised deer. This is especially the case in body size and mass (Hiller, 1996).

The 33 does used to collect blood samples were reasonably responsive to the vaccine as there were either trends or significantly greater titers during the second sample collection. However, EHD 2 titers decreased and the cause is unclear. Bluetongue virus and EHD 2 were common in the area (Bedias, TX) which meant that more of the does had previously been exposed to these viruses, thus reducing the potential impact of the vaccine. However, the does' immune systems may also have been overly taxed in being presented with nine different antigens and thus were not able to respond at a sufficient level to the EHD serotype 6. It may also be that a more significant response had occurred after the second blood sample could be collected. Tizard (2013) supports that the dam's vaccine-acquired immunity positively influences the neonate's immune system, thus validating the pre-fawning vaccination.

Since the TP standard was determined to be approximately 5.57 to 5.65 g/dL in this study, the 5.2 to 5.5 g/dL of TP standard of successful passive transferred may be borrowed from the dairy industry (Bielmann et al., 2010). This is also true for the Brix standard as we determined it to be approximately 8.67 to 8.76 ºBrix and the dairy cattle uses 8.5 ºBrix as their standard (Hernandez et al., 2016). Conversely, the serum IgG concentration standard developed in this study differs considerably from the standard

used in cattle (2.73 g/dL vs 1.0 g/dL; Hammer et al., 2004). In foals, failure of passive transfer is below 4.0 to 8.0 g/dL IgG concentration according to Davis and Giguere (2005); therefore, these discrepancies may suggest that IgG contributes a larger portion of serum total protein in white-tailed deer than in cattle but a smaller portion than in horses. Previous studies have shown that blood characteristics including IgG concentration differ ($P < 0.05$) between New Zealand red deer, cattle, sheep, and swine (Bah et al., 2016). This may not be an issue for on-farm determination of success of passive transfer as MISCO is discontinuing the IgG test on the refractometers as they have determined that this test is not as accurate in estimating IgG concentration as the Brix and total protein tests. These measurements are highly correlated with RID determined serum IgG concentration in calves (Quigley et al., 2013; Hernandez et al., 2016).

The prediction equation estimated using the LOGISTIC procedure of SAS containing all variables in the input showed that serum Brix value and serum IgG concentration determined by refractometer are significant ($P < 0.05$) in estimating the probability of fawn survival until weaning. This supports the digital refractometer as a useful tool in monitoring fawn health. Subsequent equations supported Brix as highly predictive and showed birth weight to be the most predictive body measurement. These predictive equations may also allow producers to more accurately predict the probability of fawn survival until weaning by using the estimates to find the log of the probability. Similarly, a study in free-ranging white-tailed deer by Ditchkoff et al. (2001) reported that low body mass/length^3 at birth to be predictive of fawn death before 21 days of age. Additionally, since the Brix value was identified as highly predictive of survival and highly correlated with RID-determined serum IgG concentration, the standard benchmark

for success of passive transfer in this method may be very useful in improving the health of neonate fawns. According to Hernandez et al. (2016) Brix value had previous optimal sensitivity (100%) and specificity (89%) to predict the failure of passive transfer.

Total protein in serum appears to be a sufficient on-farm indicator of passive transfer in white-tailed deer fawns as it is most highly correlated with RID determined IgG, but was not selected in the LOGISTIC equation as predictive of survivability. Conversely, in a passive immunity study in dairy heifers, serum TP was reported as one of the more common assessments of passive transfer status and was a significant predictor ($P < 0.01$) of mortality when neither serum Brix value nor serum IgG concentration was collected (Donovan et al., 1998). The plasma TP was not significantly different nor predictive ($P > 0.05$) between fawns that survived and fawns that died before weaning, which may suggest that clotting factors may be significantly different between the groups instead. The lack of significance in plasma TP also supports serum TP as the better option for determining the success or failure of passive transfer when given the choice. Additionally, plasma total protein as previously reported did not differ ($P > 0.05$) between red deer, sheep, pigs, and cattle (Bah et al., 2014).

We were optimistic that one of the tests using whole blood would be effective at estimating passive transfer so that this procedure would be simpler for the typical white-tailed deer breeder to perform on-farm. Brix and TP using whole blood revealed a valuable relationship to survivability and was highly correlated to serum IgG as determined by RID. However, direct IgG concentration measurement using whole blood was not useful as an indicator of passive transfer. Still, with the purchase of one piece of equipment, a refractometer to measure Brix value and serum TP, the typical deer breeder

can have another tool to help decrease fawn mortality rate in their herd. It is our hope that this research will prompt the increased use of on-farm passive transfer testing such that ranchers may use that information to bring in susceptible fawns sooner. These susceptible fawns would receive an earlier response to possible illness and thus would have an increased probability of survival.

Conclusion

Immunoglobulin gamma (IgG) is an antibody directly passed through doe colostrum to the fawn that is often used as a marker for the success or failure of passive transfer. Currently, the industry standard measurements for successful passive transfer are established for cattle and horses but no such standards exist for white-tailed deer. The objectives of this research were to establish successful passive transfer immunity industry standards and on-farm methods for evaluating health as well as to evaluate a handheld digital refractometer in the measurement of IgG in pen-raised white-tailed deer fawns. Fawns that survived had a greater cannon length and body weight at birth than fawns that died. In the current study, fawns that survived had greater serum concentrations of IgG than fawns that died and the refractometer reading of total protein was most closely correlated with results from the RID assay. In addition, serum Brix value as determined by the refractometer appears to be the best on-farm indicator of passive transfer and predictor of survivability in white-tailed deer fawns. These results indicate that a digital refractometer is an acceptable on-farm tool in evaluating passive transfer and predicting survivability of newborn white-tailed deer fawns. In addition, fawns that survived had a greater cannon length and birth weight than fawns that died. These results indicate that body size may also be related to survivability in white-tailed deer fawns; however,

additional research in white-tailed deer fawns is needed to establish more precise predictors of survivability.

CHAPTER VI

Recommendations

Future Directions for Research

This work was innovative in its approach to examine passive transfer rates in white-tailed deer fawns and establishing benchmarks for rates of passive transfer that can be measured with a rapid field test and be utilized by deer breeders, not only in Texas, but throughout the United States. With over 1,300 operations, the Texas deer breeding industry has established a presence across the state with the majority of operations located in rural areas (Frosch et al., 2008). The increase in operations has led to valued interest in the deer breeding industry which has become a vital component to rural economies. It is expected that rural communities across the country will also benefit from an improved deer industry. Identifying at-risk fawns prior to the onset of disease would be beneficial to reduce early life mortality rates which will have a significant impact on the cervid industry. Previous literature has very limited data on cervids which is especially limited in both the species aspect and the immunological aspect. This project has the potential to prompt the initiation of other projects of a similar nature which may attempt to answer questions related to cervid production or to modify and improve the current measurements and techniques. It is the hope of the authors that this project will improve the stability of the cervid industry and help shape the future to one of increased fawn health and survivability.

Possible studies that would help to increase pen-raised white-tailed deer health include aspects such as testing the IgG concentration present in the colostrum of the does. This could be done as an estimation with a subsample from each pen to reduce labor and

stress. Furthermore, an overall pen estimation would account for the observation that pen-raised white-tailed deer fawns are opportunistic in their nursing habits and the does allowed this behavior. Other aspects of interest would be the effect of doe disposition score and body condition score on fawn survivability as well as determining other markers of survivability either in the doe or in the fawn. Further study into the mortality of pen-raised whit-tailed deer fawns is also needed. The causes of fawn death may change as they approach weaning from predominately FPT related to predominately injury and trauma related. In addition to overall herd mortality, a Texas and national fawn mortality average is needed to further assess the health of an individual breeder's fawn crop. In accounting for the differences in size and mass of the different subspecies of white-tailed deer, a body mass/length index may be further developed as a predictor of survivability. Lastly, the research and development of a refractometer-like device that functions similar to a blood glucose meter for diabetic humans would be the next step in simplifying the FPT monitoring. Such a device would collect and measure a drop of blood from the fawns thus accelerating the entire process and further reducing the amount of supplies needed to conduct the test.

Future Directions for the Industry

It is the hope of the author that the pen-raised white-tailed deer industry will incorporate blood sampling for passive transfer evaluation into the normal fawn care schedule. A possible procedure which may be added to daily pen checks:

1. At 24 hours: take blood samples from fawns with labeled 2 mL vacutainer tubes and a 23-gauge butterfly needle extension set

2. Let the tubes sit for 2-4 hours to allow serum to separate without the use of a centrifuge while other chores are performed
3. Pipette the separated serum onto the digital refractometer sample plate
4. Run the total protein test and Brix test and IgG test if available
5. Record data with birth records and use it to make informed decisions on animal health

The inclusion of this procedure may greatly reduce neonate morbidity and mortality in pen-raised white-tailed deer without being overly time consuming. This will in turn boost the economic efficiency of the ever advancing white-tailed deer breeding industry and benefit rural communities across Texas and the United States.

REFERENCES

Anderson, D. P., B. J. Frosch, & J. L. Outlaw. 2007. Economic Impact of the United States Cervid Farming Industry. Texas A&M University, Agricultural and Food Policy Center, College Station, TX.

Arguello, A., N. Castro, J. Capote, J. Tyler, & N. Holloway. 2004. Effect of colostrum administration practices on serum IgG in goat kids. Livest. Prod. Sci. 90:235-239.

Bah, C., A. Bekhit, A. Carne, & M. McConnell. 2015. Composition and biological activities of slaughterhouse blood from red deer, sheep, pig and cattle. J. Sci. Food and Agric. 96:79-89.

Barrier, A. C., M. J. Haskell, S. Birch, A. Bagnall, D. J. Bell, J. Dickinson, A. I. Macrae, and C. M. Dwyer. 2013. The impact of dystocia on dairy calf health, welfare, performance and survival. Vet. Journal. 195:86-90.

Bielmann, V., J. Gilan, N. R. Perkins, A. L. Skidmore, S. Godden, & K. E. Leslie. 2010. An evaluation of Brix refractometry instruments for measurement of colostrum quality in dairy cattle. J. Dairy Sci. 93:3713-3721.

Borghesi, J., L. C. Mario, M. N. Rodrigues, P. O. Favaron, and M. A. Miglino. 2014. Immunoglobulin transport during gestation in domestic animals and humans – a review. J. Anim. Sci. 4:323-336.

Bush, L. J., & T. E. Staley. 1980. Absorption of colostral immunoglobulins in newborn calves. J. Dairy Sci. 63:672-680.

Chavatte, P., F. Clément, R. Cash, and J. F. Grongnet. 1998. Field determination of colostrum quality by using a novel, practical method. Am. Assoc. Equine Pract. Proc. 44:206–209.

Courtney, A., W. Epperson, T. Wittig, R. Pruitt, & D. Marshall. 2000. Defining failure of passive transfer in South Dakota beef calves. South Dakota Beef Report. p. 79-83.

Davis, R. & S. Giguere. 2005. Evaluation of five commercially available assays and measurements of serum total protein concentration via refractometry for the diagnosis of failure of passive transfer of immunity in foals. J. Am. Vet. Med. Assoc. 227:1640-1645.

Devillers, N., J. Le Dividich, & A. Prunier. 2011. Influence of colostrum intake on piglet survival and immunity. An Internatl. J. Anim. Biosci. 5:1605-1612.

Dewell, R., L. Hungerford, J. Keen, W. Laegreid, D. Griffin, G. Rupp, & D. Grotelueschen. 2006. Association of neonatal serum immunoglobulin G1 concentration with health and performance in beef calves. J. Am. Vet. Med. Assoc. 228:914-921.

Ditchkoff, S. S., M. G. Sams, R. L. Lochmiller, and D. M. Leslie, Jr. 2001. Utility of tumor necrosis factor-α and interlukin-6 as predictors of neonatal mortality in white-tailed deer. J Mammology. 82:239-245.

Donovan, G. A., L. Badinga, R. Collier, C. Wilcox, & R. Braun. 1986. Factors influencing passive transfer in dairy calves. J. Dairy Sci. 69:754-759.

Donovan, G. A., I. R. Dohoo, D. M. Montgomery, and F. L. Bennett. 1998. Associations between passive immunity and morbidity and mortality in dairy heifers in Florida, USA. Preventative Vet. Med. 34:31-46.

Drolet, B. S., L. M. Reister, T. D. Rigg, P. Nol, B. K. Podell, J. O. Mecham, K. C. VerCauteren, P. A. van Rijn, W. C. Wilson, and R. A. Bowen. 2013. Vet. Microbiology. 166:347-355

Dyck, G., & E. Swierstra. 1987. Causes of piglet death from birth to weaning. Can. J. Anim. Sci. 67:543-547.

Erhard, M., P. Amon, M. Younan, Z. Ali, & M. Stangassinger. 1999. Absorption and synthesis of immunoglobulins G in Newborn Calves. Reprod. in Dom. Anim. 34:173-175.

Frosch, B. J., D. P. Anderson, & J. L. Outlaw. 2008. Economic Impact of Deer Breeding Operations in Texas. Texas A&M University, Agricultural and Food Policy Center, College Station, TX.

Gardiner, T. 2000. Colostrum Biological Acivities: A Review. GlycoScience & Nutrition, 1:29.

Gonda, M. G. 2015. Understanding the Major Histocompatibility Complex and Immunoglobulin Genes. In H. Khatib (Ed.), Molecular and Quantitative Animal Genetics. Hoboken, NJ, USA: John Wiley & Sons, Inc.

Guidry, A. J. 1985. Mastitis and the Immune System of the Mammary Gland. In B. L. Larson (Ed.), Lactation. 1st ed. Ames, Iowa, USA: The Iowa State University Press. p. 229-262.

Hammer, C., H. Tyler, J. D. Quigley, Jr., & L. Ribeiro. 2004. Characterization of colostrum replacer containing IgG concentrate and growth factors. Animal Industry Report. AS 650, ASL R1906.

Harker, D. B. 1978. A simple estimation of the immunoglobulin content of ewe colostrum. Vet. Rec. 103:8–9.

Herd, D. B. & L. R. Sprott. 1998. Body Condition, Nutrition, and Reproduction of Beef

Cows. Texas Agricultural Extension Service, Texas A&M University, College Station, TX.

Hernandez, D., D. V. Nydam, S. M. Godden, L. S. Bristol, A. Kryzer, J. Ranum, & D. Schaefer. 2016. Brix refractometry in serum as a measure of failure of passive transfer compared to measured immunoglobulin G and total protein by refractometry in serum from dairy calves. Vet. J. 211:82-87.

Hiller, I. 1996. The White-Tailed Deer. Texas A&M Uni. Press. College Station, TX.

Hurley, W. L., & P. K. Theil. 2011. Perspectives on immunoglobulins in colostrum and milk. Nutrients. 3:442-474.

Linden, T., R. Bicalho, & D. Nydam. 2009. Calf birth weight and its association with calf and cow survivability, disease incidence, reproductive performance, and milk production. J. Dairy Sci. 92:2580-2588.

Matte, J., C. Girard, J. Seoane, & G. Brisson. 1982. Absorption of colostral immunoglobulin G in the newborn dairy calf. J Dairy Sci. 65:1765-1770.

Parkinson, D. E., R. P. Ellis & L. D. Lewis. 1982. Colostrum deficiency in mule deer fawns: Indentification, treatment, and influence on neonatal mortality. J. Wildlife Diseases. 18:17-28.

Pierce, B. A. 2012. Genetics: A Conceptual Approach. 4th ed. W. H. Freeman and Company. New York, NY.

Price, E. 2008. Principles & App. Dom. Anim. Behavior. CABI. Cambridge, MA.

Powell, M. C. & G. D. DelGuidice. 2005. Birth, morphologic, and blood characteristics of free-ranging white-tailed deer neonates. J. Wildlife Diseases. 41(Suppl 1):171-173.

Quigley, J. 2005. The role of oral immunoglobulins in systemic and intestinal immunity of neonatal calves. Managing and marketing quality Holstein steers. University of Minnesota Extension. Rochester, Minnesota.

Quigley, J. D., A. Lago, C. Chapman, P. Erickson, & J. Polo. 2013. Evaluation of the Brix refractometer to estimate immunoglobulin G concentration in bovine colostrum. J. Dairy Sci. 96:1148-1155.

Sams, M. G., R. L. Lochmiller, J. C. Qualls, J. D. Leslie, & M. E. Payton. 1996. Physiological correlates of neonatal mortality in an overpopulated herd of white-tailed deer. J. Mammology. 77:179-190.

Singh, L., P. Rout, R. Roy, & A. Mandal. 2000. Kid birth weights, pre-weaning survival, and growth to one year of age in Jamunapari Goats. Asian-Australasian J. Anim. Sci. 366-368.

Texas Admistrative Code. 2010. Texas Admistrative Code. Retrieved March 24, 2016, from http://texreg.sos.state.tx.us/public/

Texas Parks and Wildlife Department. 2015. Current Deer Breeder Facility Capacity Info. Austin, Texas: Available upon request of the Texas Parks and Wildlife Department. Retrieved October 7, 2015

Tizard, I. R. 2013. Veterinary Immunology. 9th ed. Saunders. St. Louis, MO.

Trindle, B. D., L. D. Lewis, & L. H. Lauerman. 1978. Evaluation of stress and its effects on the immune system of hand-reared mule deer fawns (*Odocoileus hemionus*). J. Wildlife Diseases. 14:523-537.

Tyler, J., D. Hancock, S. Wiksie, S. Holler, J. Gay, & C. Gay. 1998. Use of serum protein

concentration to predict mortality in mixed-source dairy replacement heifers. J. Vet. Internal Med. 12:79-83.

Verme, L. J. 1965. Reproduction studies in penned white-tailed deer. J. Wildlife Management. 29:74-79.

Weaver, D. M., J. W. Tyler, D. C. VanMetre, D. E. Hostetler, and G. M. Barrington. 2000. Passive transfer of colostral immunoglobulins in calves. J. Vet. Intern. Med. 14:569–577.

APPENDIX A: Deer Medical Information

Vaccine administrated to does 15 April 2016 and to fawns at 60 days

1. EHD/BTV 9-Way-Combo Product
    a. Newport Laboratories, Worthington, MN
    b. Provides immunity to:
        i. Epizootic Hemorrhagic Disease Virus serotypes 1 & 2
            1. Virus transmitted by biting flies
            2. Causes edema and lesions
        ii. Epizootic Hemorrhagic Disease Virus serotype 6
            1. Virus transmitted by biting flies
            2. Causes edema and lesions
        iii. Bluetongue Virus 317
            1. Virus transmitted by biting flies
            2. Causes edema and lesions
        iv. *Fusobacterium necrophorum* (Lumpy Jaw)
            1. Anaerobic, gram negative bacteria transmitted through wet soil
            2. Causes abscessation and necrosis
        v. *Clostridium perfringens* Type A
            1. Anaerobic bacteria transmitted through contaminated food and water from soil
            2. The Alpha toxin causes enteritis and enterotoxemia
        vi. *Pasteurella multocida*
            1. Gram negative bacteria transmitted through oral or respiratory
            2. Swelling of the head and neck and septic pnemonia
        vii. *Escherichia Coli*
            1. Bacteria transmitted from the soil and food and water contamination
            2. Causes diarrhea, urinary tract infections
        viii. *Arcanobacterium pyogenes* (New proposed name: *Truperella pyogenes*)
            1. Anaerobic, gram positive bacteria transmitted by direct contact with mucosa
            2. Causes abscessation, mastitis, and pnuemonia
        ix. *Bibersteinia trehalosi*
            1. Gram negative bacteria transmitted through saliva
            2. Causes pneumonia and septicemia

Antibodies (immunoglobulins), Probiotics, Energy & Protein Boosts

1. Fawn Boost
    a. Enable USA, Decatur, TX
        i. *E.Coli, Salmonella*, Clostridials A & D, Rotavirus, *Enterococcus faecium, Bacillus subtilis, Lactobacillus acidophilius, Bifidobacterium longum, and Bifidobacterium thermophilum Saccharomyces Cerevisae*

2. C & E Newborn Fawn Paste
    a. C & E Wildlife Products, Wellborn, TX
        i. *Enterococcus faecium, Lactobacillus acidophilius, Bifidobacterium thermophilum, and Bifidobacterium longum*

3. C & E Electromax Paste
    a. C & E Wildlife Products, Wellborn, TX
    b. Source of electrolytes (sodium, potassium, & chloride), probiotics, and digestive enzymes to dehydrated fawns and adult deer

4. C & E Jump Start
    a. C & E Wildlife Products, Wellborn, TX
    b. Help maximize immune response, and maintain optimal health coverage from pathogens.

5. C & E Energy Pack
    a. C & E Wildlife Products, Wellborn, TX
    b. A source of micro-encapsulated bacteria, enzymes and energy to assist fawns and adult deer when critical energy demands are high.

6. C & E D-Tox Paste
    a. C & E Wildlife Products, Wellborn, TX
    b. A paste that helps to neutralize destructive toxins produced by pathogenic bacteria and fungi.

7. Bovine Ecolizer
    a. Made by Novartis Animal Health US, Inc., in Larchwood, IA
    b. Clostridium Perfringens Type C Antitoxin-Escherchia Coli Antibody
    c. Oxytetracycline, phenol, and thimerosal

Antibiotics

1. Excede (ceftiofur crystalline free acid)
    a. Zoetis, Florham Park, NJ
        i. *Mannheimia haemolytica*
        ii. *Pasteurella multocida*
        iii. *Histophilus somni*
        iv. *Fusobacterium necrophorum*
        v. *Porphyromonas levii*

2. Baytril (enrofloxacin)
    a. Bayer Healthcare LLC, Animal Health Division, Shawnee Mission, Kansas
    b. Broad spectrum antibiotic labeled for use in Cattle and Swine

3. Oxytetracycline
    a. Oxytetracyline HCl soluble powder
    b. Broad spectrum antibiotic

4. Sulmet (sulfamethazine sodium) Drinking Water Solution 12.5%
    a. Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO
    b. Antibacterial for animal use only
        i. Bacterial Pneumonia and Bovine Respiratory Disease Complex (Shipping Fever Complex) *(Pasteurella* spp.); Colibacillosis (Bacterial Scours) *(Escherichia coli);* Necrotic Pododermatitis (Foot Rot) *(Fusobacterium necrophorum);* Calf Diphtheria *(Fusobacterium necrophorum);* Acute Metritis *(Streptococcus* spp.)

5. Zactran (gamithromycin)
    a. Merial, Duluth, GA
    b. Made to treat Bovine Respiratory Disease

6. Corid (amprolium)
    a. Merial Inc., Duluth, GA
    b. Treats coccidiosis (bloody scours), made for use in cattle

7. Micotil (tilmicosin)
    a. Elanco, Greenfield, IN
    b. Formulated for sheep and cattle. Fatal in swine and may be fatal in horses and goats
        i. Treats bovine respiratory disease (BRD) associated with *Mannheimia haemolytica, Pasteurella multocida and Histophilus somni*, and for the control of respiratory disease in cattle at high risk of developing BRD associated with *Mannheimia haemolytica.*
    c. Used as a last resort in the fawns as it is harsh on them

8. Zuprevo (Tildipirosin)
    a. Merck, Kenilworth, NJ
    b. Treats BRD caused by *Mannheimia haemolytica, Pasteurella multocida* and *Histophilus somni.*

9. L-S 50 Soluble Powder (lincomycin-spectinomycin)
    a. Zoetis, Florham Park, NJ
    b. Formulated for chickens as an aid in the control of:
        i. Airsacculitis caused by either *Mycoplasma synoviae* or *M. gallisepticum* (Chronic Respiratory Disease – CRD)
        ii. Complicated Chronic Respiratory Disease (CCRD) caused by *Escherichia coli* and *Mycoplasma gallisepticum*

10. Noromycin 300 LA (oxytetracycline)
    a. Norbrook, Overland Park, KS
        i. pneumonia and shipping fever complex associated with *Pasteurella* spp., and *Histophilus* spp.
        ii. infectious bovine keratoconjunctivitis (pink eye) caused by Moraxella bovis
        iii. foot-rot and diphtheria caused by *Fusobacterium necrophorum*
        iv. bacterial enteritis (scours) caused by *Escherichia coli*
        v. wooden tongue caused by *Actinobacillus lignieresii*
        vi. leptospirosis caused by *Leptospira pomona*
        vii. wound infections and acute metritis caused by strains of staphylococcal and streptococcal organisms sensitive to oxytetracycline.

11. Nuflor (Florfenicol)
    a. Merck, Kenilworth, NJ
    b. Formulated for bovine respiratory disease (BRD), associated with *Mannheimia (Pasteurella) haemolytica*, *Pasteurella multocida*, and *Histophilus somni*, and for the treatment of bovine interdigital phlegmon (foot rot, acute interdigital necrobacillosis, infectious pododermatitis) associated with *Fusobacterium necrophorum* and *Bacteroides melaninogenicus*. Also, it is indicated for the control of respiratory disease in cattle at high risk of developing BRD associated with *Mannheimia (Pasteurella) haemolytica*, *Pasteurella multocida*, and *Histophilus somni*.

Other medications

1. Vita-Jec B Complex Fortified
    a. Aspen Veterinary Resources, LTD, Liberty, MO
        i. Thiamine Hydrochloride (B1)
        ii. Niacinamide
        iii. Pyridoxine Hydrochloride (B6)
        iv. d-Panthenol
        v. Riboflavin (B2) (as Riboflavin 5'-Phosphate Sodium)
        vi. Cyanocobalamin (B12)
        vii. With Citric Acid and Benzyl Alcohol 1.5% v/v (preservative)

2. Dextrose
    a. Aspen Veterinary Resources, LTD, Greeley, CO
    b. Dextrorotatory form of glucose which is the predominant naturally occurring form.

3. Lactated Ringer
    a. Lactated Ringer's injection is a sterile, nonpyrogenic solution for fluid and electrolyte replenishment

4. Dexamethasone
    a. Butler Schein Animal Health Dublin, OH
    b. Dexamethasone Sodium Phosphate (DSP) is a salt of dexamethasone, a synthetic corticosteroid which possesses glucocorticoid activity
    c. Labeled for dogs and horses

Dewormers

1. Valbazen
    a. Zoetis, Florham Park, NJ
    b. Broad-Spectrum dewormer formulated for cattle, sheep and goats
    c. It is an anthelmintic effective in the removal and control of liver flukes, tapeworms, stomach worms (including 4th stage inhibited larvae of *Ostertagia ostertagi*), intestinal worms, and lungworms. Formulated as a suspension

2. Cydectin (Moxidectin antiparasitic)
    a. Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO
    b. active ingredient, moxidectin, offers a persistent kill of internal parasites at multiple stages, including the most economically damaging parasite, Ostertagia ostertagi (brown stomach worm)
    c. Controls external parasites including lice, grubs, and psoroptic mange mites
    d. No impact on beneficial dung beetle populations

3. Ivomec (ivermectin injection)
    a. Merial Inc., Duluth, GA
        i. Gastrointestinal roundworms (including inhibited *Ostertagia ostertag*i in cattle)
        ii. Lungworms
        iii. Grubs
        iv. Sucking lice
        v. Chorioptic
        vi. Sarcoptic mange mites

APPENDIX B: Deer Nutritional Information

Feeds and Supplements

1. Superior Fawn Milk Replacer
    a. Superior Milk Replacers, INC, Waterloo, IL
    b. Ingredients**:** Dried Whey Protein Concentrate, Dried Whey, Animal and Vegetable Fat (Preserved with BHA and BHT), Dried Whey Product, Lecithin, Dicalcium Phosphate, DL-Methionine, Calcium Carbonate, Copper Sulfate, L-Lysine, Vitamin A Supplement, Vitamin D3 Supplement, Vitamin E Supplement, Vitamin B12 Supplement, Folic Acid, Choline Chloride, Riboflavin Supplement, Niacin Supplement, Calcium Pantothenate, Thiamine Mononitrate, [Sodium Propionate, Potassium Sorbate, Calcium Propionate (Preservatives)], Ferrous Sulfate, Cobalt Sulfate, Zinc Sulfate, Manganese Sulfate, Magnesium Oxide, Ethylenediamine Dihydriodide, Sodium Silico Aluminate, Sodium Selenite, Artificial Flavor.

2. C & E Guardian Plus
    a. Manufactured by C & E Wildlife Products in Wellborn, TX
    b. Source of live, micro-encapsulated bacteria and dried egg solids

3. Alfalfa Hay
    a. Texas grown hay

4. Fawn Starter
    a. Cargill, Minneapolis, MN
    b. In test trials
    c. Contains probiotics Maintains a healthy digestive tract, appetite, & improved digestion

Protein	22.0% min	Salt	0.8% min
Lysine	1.0% min	Salt	1.2% max
Methionine	0.55% min	Sodium	0.3% min
Fat	5.0% min	Sodium	0.5 max
Fiber	11.0% max	Copper	50 ppm min
Calcium	1.0% min	Selenium	0.3 ppm min
Calcium	1.25% max	Vitamin A	10,000 IU/lb
Phosphorus	0.6% min	Vitamin E	20 IU/lb
Zinc	205 ppm min		

5. Record Rack Breeder Formula
    a. Sportsman's Choice, Cargill, Minneapolis, MN

Nutrient	**Min.**	**Max.**
Crude Protein	16.00%	-
Lysine	0.90%	-
Crude Fat	4.00%	-
Crude Fiber	-	20.00%
Calcium	1.60%	2.10%
Phosphorus	0.80%	-
Salt	0.50%	0.75%
Copper	50 ppm	-
Manganese	200 ppm	-
Selenium	0.3 ppm	-
Zinc	200 ppm	-
Vitamin A	10,000 IU/lb	-
Vitamin E	20 IU/lb	-

6. Golden Deer Nuggets
    a. Sportsman's Choice, Cargill, Minneapolis, MN

Nutrient	**Min.**	**Max.**
Crude Protein	13.0%	-
Lysine	0.5%	-
Crude Fat	12.0%	-
Crude Fiber	-	
Calcium	2.25%	2.75%
Phosphorus	1.0%	-
Salt	0.05%	0.25%
Copper	25 ppm	-
Zinc	100 ppm	-
Vitamin A	15,000 IU/lb	-
Vitamin E	20 IU/lb	-

7. Record Rack Super Premium Deer Corn
    a. Sportsman's Choice, Cargill, Minneapolis, MN

Nutrient	**Min.**	**Max.**
Crude Protein	6.75%	-
Crude Fat	3.00%	-
Crude Fiber	4.00%	-

8. AntlerMax Extreme Energy Supplement
    a. Purina Animal Nutrition LLC., Gray Summit, MO

Nutrient	**Min / Max**	**Amount**
Crude Protein	MIN	14%
Crude Fat	MIN	30%
Crude Fiber	MAX	7%
Calcium (Ca)	MIN	2.00%
Calcium (Ca)	MAX	2.50%
Phosphorus (P)	MIN	1.00%
Vitamin A	MIN	15000 IU/LB
Potassium (K)	MIN	1.00%
Salt (NaCl)	MIN	0.60%
Salt (NaCl)	MAX	1.00%
Ash	MAX	13.00%

Additional Analysis	Animal Protein Products Free, Ruminant Meat and Bone Meal Free

APPENDIX C: Additional Tables

Table 8

Correlation coefficients between doe body weight, body condition score, and disposition score

Item[a]	April		May	
	Body Condition Score	Body Weight	Body Condition Score	Body Weight
April				
Body Condition Score	1	0.41	0.74	0.47
		0.02	<.01	0.01
	33	32	33	33
Body Weight		1	0.35	0.98
			0.05	<.01
		32	32	32
May				
Body Condition Score			1	0.35
				0.04
			33	33
Body Weight				1
				33

[a]Rows from top to bottom: correlation coefficient, *p*-value, sample size.
[b]Disposition score was not measured in May.

Table 9

Descriptive data of fawns that died prior to weaning or survived to weaning

	Died	Survived	Total
AI[a]	27	83	110
Natural Service	6	37	43
Total	33	120	153
Female	12	48	60
Male	21	72	93
Total	33	120	153
Pen 9	1	1	2
Pen 11	7	20	27
Pen 13	7	19	26
Pen 15	4	27	31
Pen 17	6	27	33
Pen 19	8	26	34
Total	33	120	153
Not sick	8	29	37
Observed sick at least once	25	91	116
Total	33	120	153
Rate	75.8%	75.8%	75.8%

[a]AI = laparoscopic artificial insemination sired.

Table 10

Descriptive data of bottle-raised and dam-raised fawns

Item	Bottle-Raised	Dam-Raised	Total
AI	37	82	119
Natural Service	14	20	34
Total	51	102	153
Female	30	30	60
Male	21	72	93
Total	51	102	153
Pen 9	1	1	2
Pen 11	14	13	27
Pen 13	7	19	26
Pen 15	10	21	31
Pen 17	9	24	33
Pen 19	9	25	34
Total	51	102	153
Died	9	24	33
Survived	42	78	120
Total	51	102	153
Rate	17.6%	23.5%	21.5%
Not sick	2	35	37
Observed sick at least once	49	67	116
Total	51	102	153
Rate	96.1%	65.7%	75.8%
Died Due to Illness	Bottle-Raised	Dam-Raised	Total
Died	7	16	23
Survived	42	78	120
Total	49	94	143
Rate	14.3%	17.0%	16.1%

[a]AI = laparoscopic artificial insemination sired.

Table 11

CBC results of blood collected from fawns at 24 h of age

Item	Died	Survived	*P*-value	Bottle-raised	Dam-raised	*P*-value
WBC (K/µL)	2.29 ± 0.35	2.82 ± 0.16	0.17	2.45 ± 0.32	2.65 ± 0.22	0.61
RBC (M/µL)	7.92 ± 0.46	8.32 ± 0.21	0.44	8.07 ± 0.42	8.17 ± 0.29	0.85
HGB (g/dL)	7.35 ± 0.72	8.12 ± 0.33	0.33	7.68 ± 0.65	7.80 ± 0.45	0.88
HCT (%)	23.31 ± 1.31	25.09 ± 0.61	0.22	24.51 ± 1.19	23.88 ± 0.82	0.66
MCV (fL)	29.11 ± 4.96	32.71 ± 2.30	0.51	29.88 ± 4.49	31.94 ± 3.11	0.71
MCH (pg)	9.26 ± 7.99	12.69 ± 3.70	0.70	9.41 ± 7.24	12.54 ± 5.01	0.72
MCHC (g/dL)	31.88 ± 0.34	31.31 ± 0.16	0.12	31.67 ± 0.30	31.52 ± 0.21	0.69
PLT (K/µL)	590 ± 58	537 ± 27	0.41	563 ± 51	564 ± 37	0.99
PTP (mg/mL)	5.55 ± 4.79	8.05 ± 2.22	0.56	5.59 ± 4.34	8.00 ± 3.00	0.41
FIB (mg/dL)	244 ± 48	288 ± 22	0.40	245 ± 44	287 ± 30	0.43

[a]WBC = white blood cell; RBC = red blood cell; HGB = hemoglobin; HCT = hematocrit; MCV = mean corpuscular volume; MCH = mean corpuscular hemoglobin; MCHC = mean corpuscular hemoglobin concentration; PLT = Platelets; PTP = plasma total protein; FIB = fibrinogen.

APPENDIX D: Additional Figures

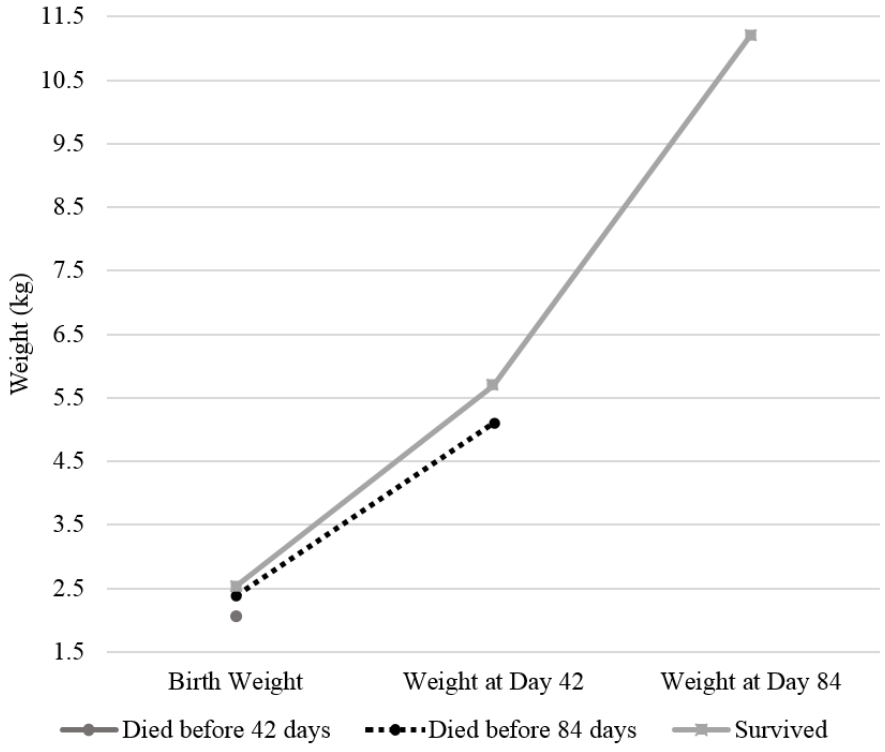

Figure 4. Bottle-raised fawn weight at birth (d 0) as well at d 42 and 84, which are the middle and end of the experiment for these fawns. The light gray line represents fawns that survived until weaning, the black dotted line represents fawns that died before 84 days, and the medium gray dot represents fawns that died before 42 days. There was no difference within day between groups ($P > 0.10$).

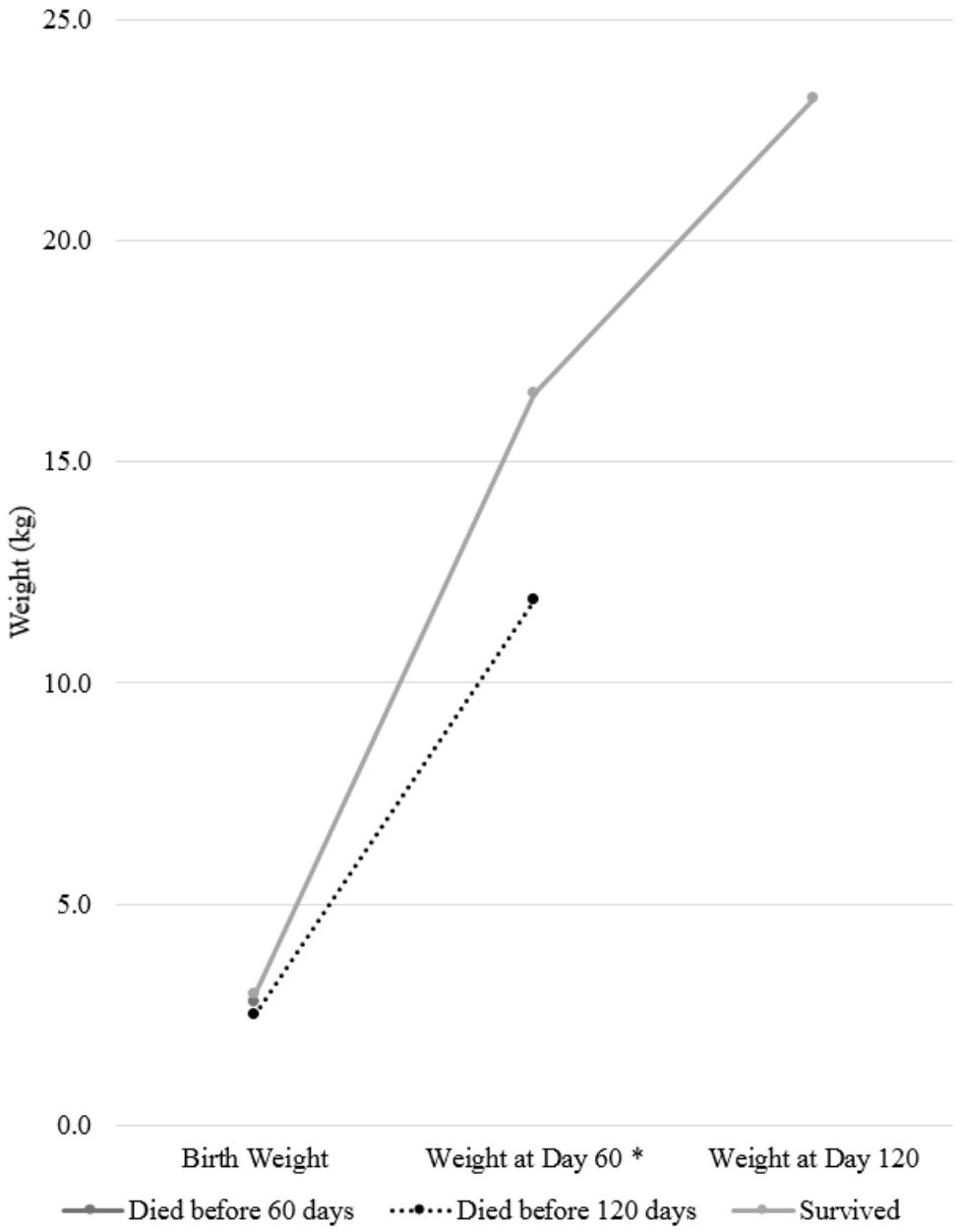

Figure 5. Dam-raised fawns weight at birth (d 0) as well at d 60 and 120, which are the middle and end of the experiment for these fawns. The light gray line represents fawns that survived until weaning, the black dotted line represents fawns that died before 120 days, and the medium gray dot represents fawns that died before 60 days. *There was a difference within day between groups ($P < 0.01$) at day 60.

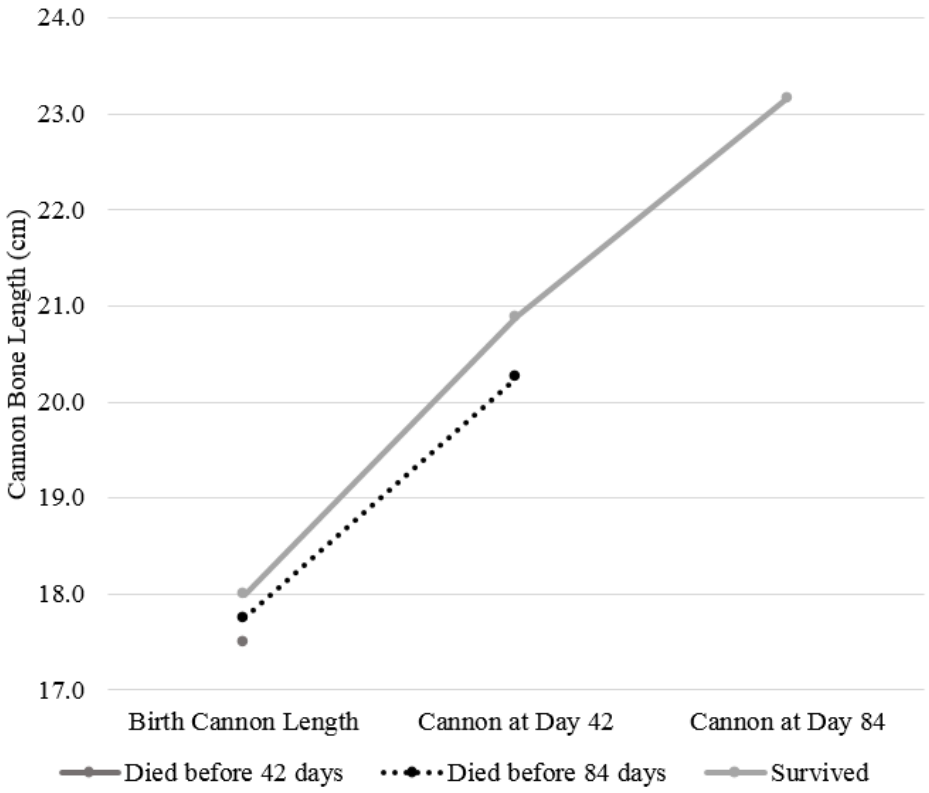

Figure 6. Bottle-raised fawns' cannon length (cm) at birth (d 0), d 42 and d 84. The light gray line represents fawns that survived until weaning, the black dotted line represents fawns that died before 84 d, and the medium gray dot represents fawns that died before 42 days. There was no difference within day between groups ($P > 0.10$).

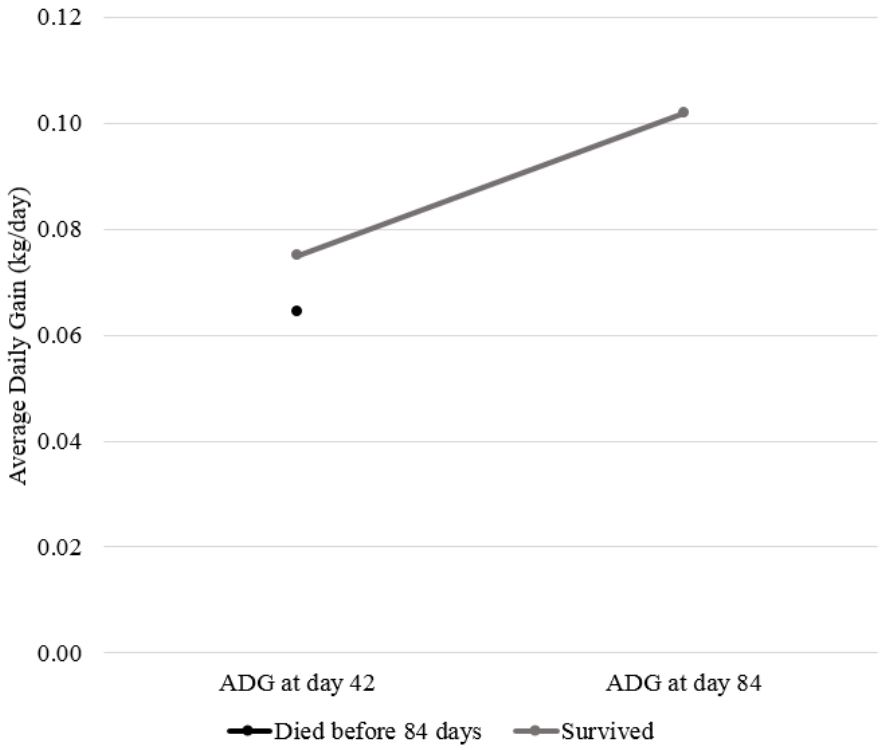

Figure 7. Average daily gain (ADG) of bottle-raised fawns. The medium gray line represents the fawns that survived until weaning and the black dot represents the fawns that died before 84 d. There was no difference within day between groups ($P > 0.10$).

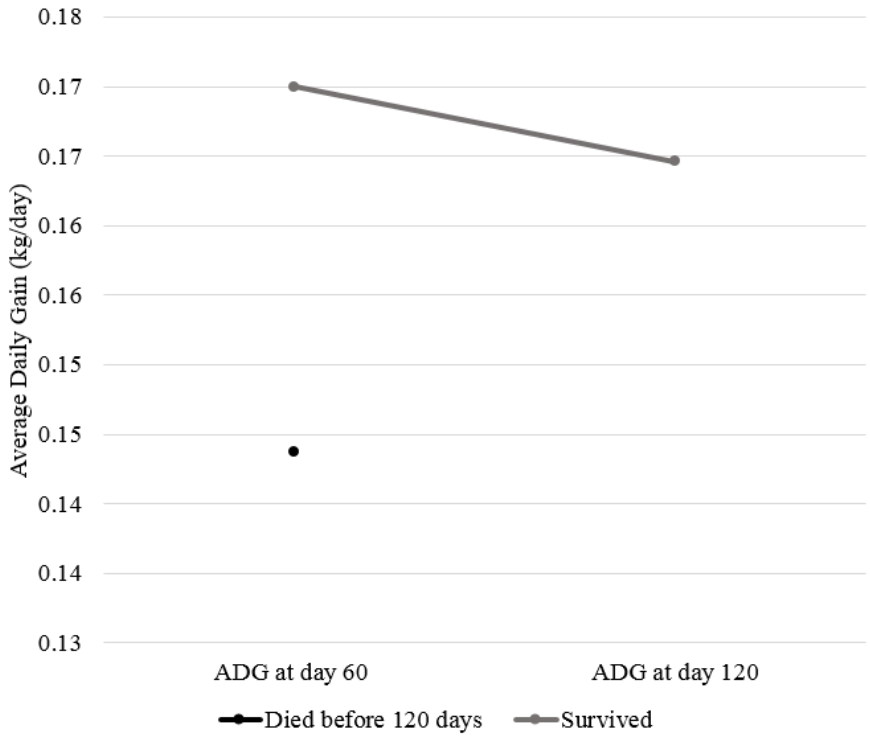

Figure 8. Average daily gain (ADG) of dam-raised fawns. The medium gray line represents the fawns that survived until weaning and the black dot represents the fawns that died before 120 d. There was a trend within groups ($P = 0.06$) and a significant difference across days ($P < 0.01$).

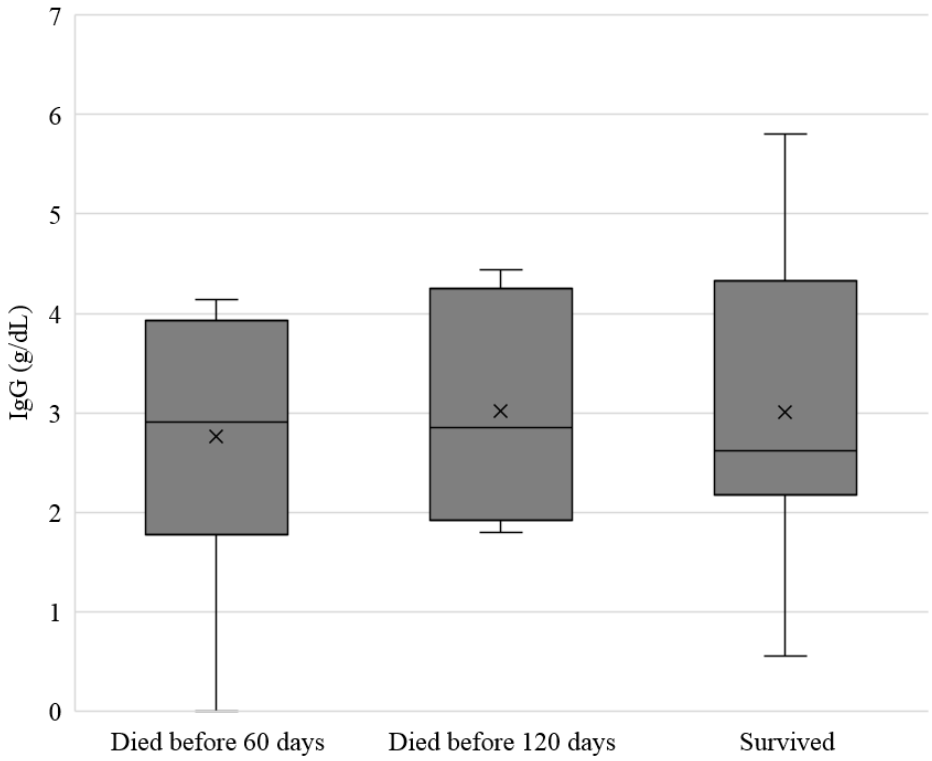

Figure 9. Radial immunodiffusion (RID) determined serum IgG concentration obtained at 24 h after birth of dam-raised fawns with comparison between fawns that died before d 60, fawns that died before d 120 and fawns that survived until weaning. There was no difference between groups ($P > 0.50$).

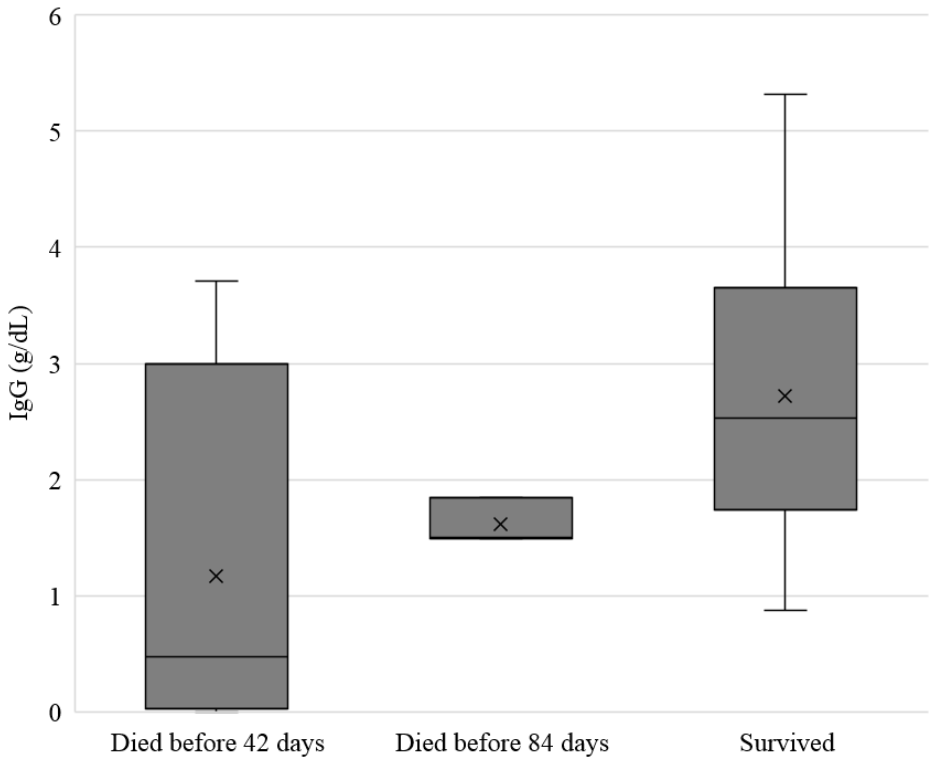

Figure 10. Radial immunodiffusion (RID) determined serum IgG concentration obtained at 24 h after birth of bottle-raised fawns with comparison between fawns that died before d 42, fawns that died before d 84 and fawns that survived until weaning. There was no difference within groups ($P > 0.10$).

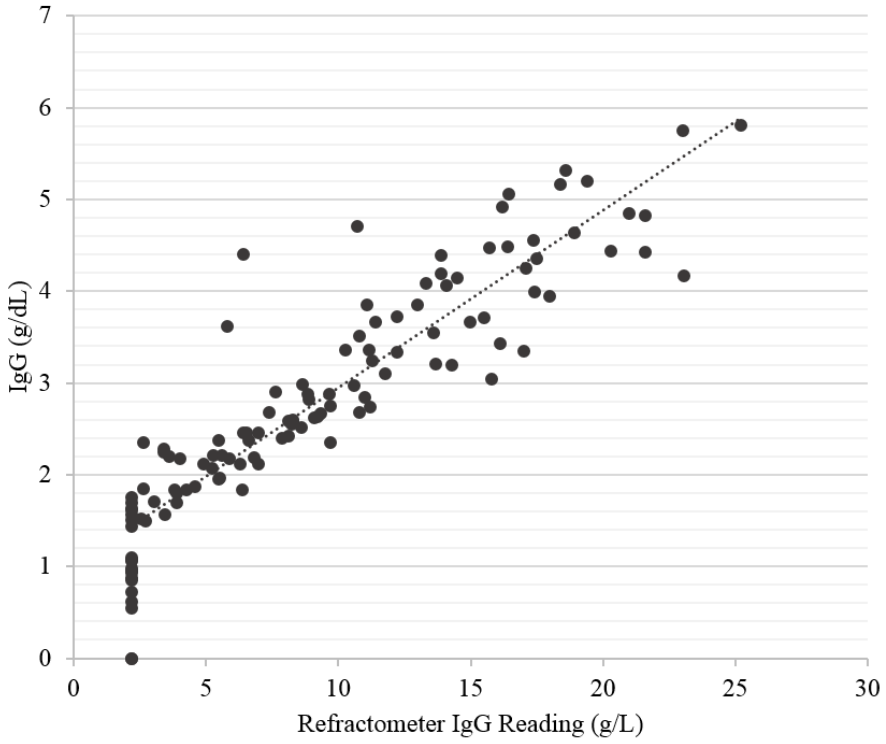

Figure 11. Regression between refractometer serum IgG concentration reading and radial immunodiffusion (RID) determined serum IgG concentration. The equation is $y = 0.1932x + 1.0131$, $r^2 = 0.83$ and $r = 0.91$.

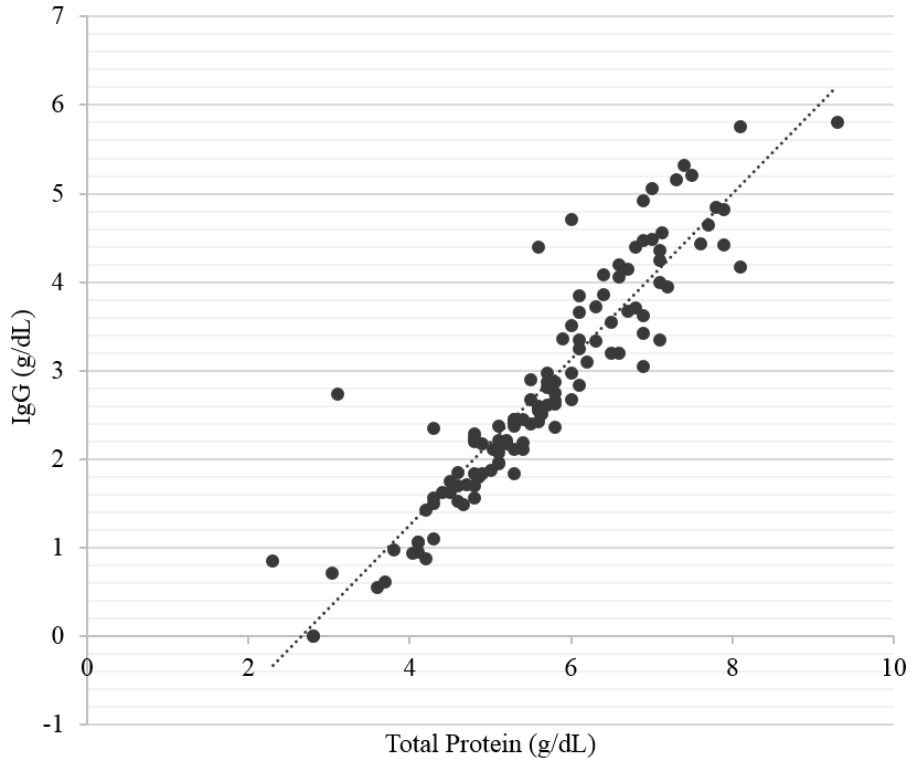

Figure 12. Regression between refractometer serum total protein concentration and radial immunodiffusion (RID) determined serum IgG concentration. The equation is y = 0.9351x - 2.4826, $r^2 = 0.85$ and r = 0.92.

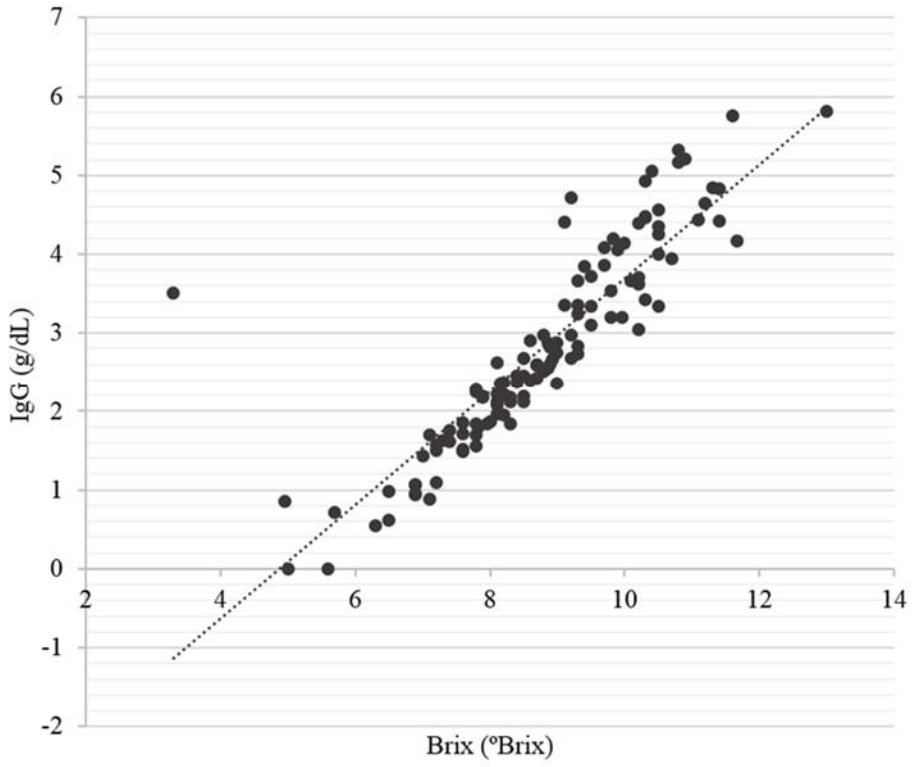

Figure 13. Regression between refractometer serum Brix value and radial immunodiffusion (RID) determined serum IgG concentration. The equation is y = 0.7207x - 3.5154, $r^2 = 0.76$ and r = 0.87.

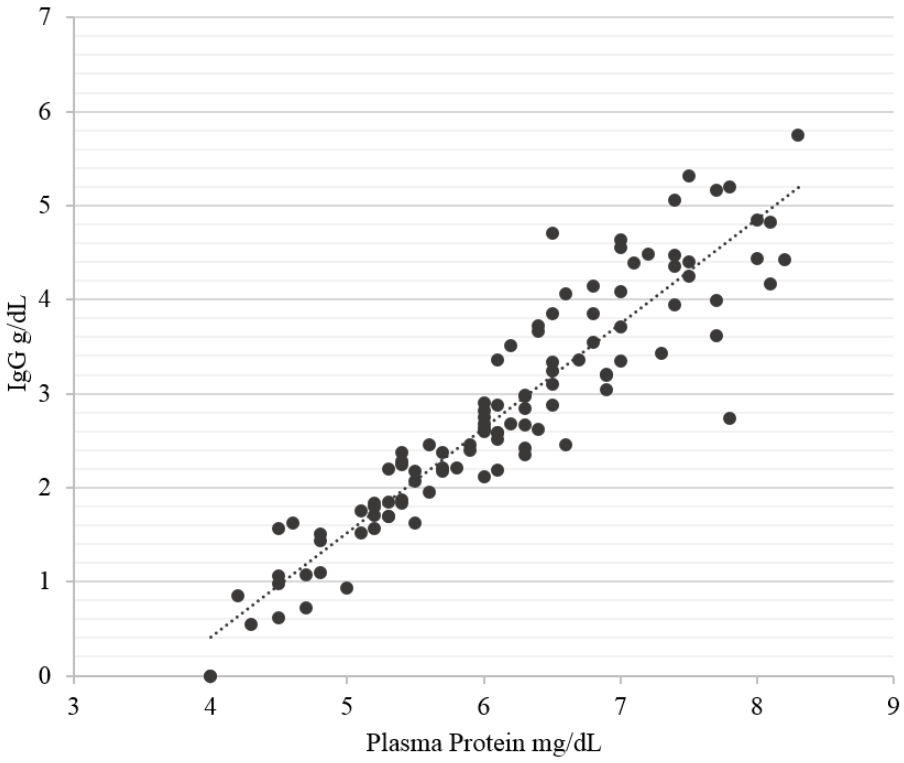

Figure 14. Regression between complete blood cell count test (CBC) determined plasma total protein concentration and radial immunodiffusion (RID) determined serum IgG concentration. The equation is $y = 1.1103x - 4.0263$, $r^2 = 0.86$ and $r = 0.93$.

APPENDIX E: IACUC Page

Sam Houston State University

A Member of the Texas State University

Institutional Animal Care and Use Committee

Committee Members

Regular Members	Alternate Members
Marcy Beverly, Ph.D.	Mark Anderson, Ph.D.
James Harper, Ph.D.	Adam Schmidt, Ph.D.
Jessica Leatherwood, Ph.D.	Joni Seeling, Ph.D.
Autumn Smith-Herron, Ph. D.	Jeff Wozniak, Ph.D.
T.C. Sim, Ph.D.	Michael Moore, D.V.M.
Gerald Etheredge, D.V.M.	
Vernette Porter, Community Member	

Date: December 2, 2015

To: Lizzie Evers [Faculty Supervisor: Dr. Jessica Leatherwood]
ASET
Box 2088
Campus

From: Dr. Marcy Beverly, IACUC Chair

Re: **Form G – Amendment**
ID # 15-10-29-1027-3-01
Project Title: *Evaluation of passive transfer immunity in white-tailed deer*

Species: *White-tailed Deer: Does and Fawns*

Start: December 2, 2015 **End:** October 29, 2018

Your **Initial IACUC Review** submission was reviewed and approved under **Designated Member Review** (DMR) procedures on **December 2, 2015** with the following result:

Approved – DMR

Annual Review Form Deadline: N/A—not required for Amendment submissions

VITA

Elizabeth Erin Evers

EDUCATION

Master of Science (May 2017) in Agricultural Science at Sam Houston State University, June 2015 – present. Thesis title: Evaluation of Passive Transfer Immunity and its Relationship to growth and performance in White-tailed Deer Fawns.

Bachelor of Science (May 2015) in Agricultural Science, Biology Minor, Truman State University, Kirksville, MO.

ACADEMIC EMPLOYMENT

Graduate Teaching Assistant, Department of Agricultural Sciences and Engineering Technology, Sam Houston State University, August 2016-present. Responsibilities include: Preparation and presentation of undergraduate courses, grading, and tutoring.

Graduate Research Assistant, Department of Agricultural Sciences and Engineering Technology, Sam Houston State University, June 2015-present. Responsibilities include: Preparation, conduction, and dissemination of research and outreach events for the Alternative Agriculture and Food Systems grant and research in white-tailed deer nutrition, reproductive physiology, behavior, and immunity as well as nutritional research in swine, caprine, and equine.

PROFESSIONAL CERTIFICATIONS

Cervid Chronic Wasting Disease Test Sample Collection Certified

PUBLICATIONS

Evers, E.E., K.J. Stutts, J.L. Leatherwood, M.J. Anderson, C.J. Hammer & C.R. Stewart. (2017, May). *Evaluation of Passive Transfer Immunity and Predicting Survivability in Newborn White-tailed Deer Fawns*. (Unpublished master's thesis). Sam Houston State University, Huntsville, TX.

Hudson, S.*, M. Loveless*, **E.E. Evers**, K.J. Stutts, J.L. Leatherwood, M.J. Anderson, & C.J. Hammer. (2017, April). *Evaluation of Passive Transfer Immunity in White-tailed Deer*. Poster Session at the Undergraduate Research Symposium. Sam Houston State University, Huntsville, TX.

Evers, E.E.*, K.J. Stutts, J.L. Leatherwood, C.R. Stewart, C.J. Hammer & M.J. Anderson. (2017, April). *Evaluation of Passive Transfer Immunity and Predicting Survivability in Newborn White-tailed Deer Fawns*. Poster Session at the Agriculture

Consortium of Texas Student Research Symposium. Sam Houston State University, Huntsville, TX.

Evers, E.E. *, M.J. Anderson, & T.R. Pannkuk. (2016, August). *Consumers of Texas Alternative Agriculture: A Brief Study of Preferences and Beliefs*. Poster Session at the conference of the American Society of Horticultural Science, Atlanta, GA.

Evers, E.E. *, M.J. Anderson, & T.R. Pannkuk. (2016, August). *Producers of Texas Alternative Agriculture: A Brief Study of Beliefs*. Poster Session at the conference of the American Society of Horticultural Science, Atlanta, GA.

Evers, E.E. *, M.J. Anderson, & T.R. Pannkuk. (2016, August). *Texas Alternative Agriculture: A Brief Comparison of the Beliefs of Consumers and Producers.* Poster Session at the conference of the American Society of Horticultural Science, Atlanta, GA.

Evers, E.E. * & G.R. Wehner. (2014, April). *Facial Whorl Position as a Predictor of Docility, Mothering Ability and Calf Performance.* Oral Presentation at the Truman State University Undergraduate Research Symposium, Kirksville, MO.

PROFESSIONAL EXPERIENCES

SAM HOUSTON STATE UNIVERSITY, Huntsville, TX Aug 2016 – Present
Graduate Teaching Assistant – Teaching two sections of ANSC 1119 – Animal Science laboratory course (Fall 2016) and all four sections of PLSC 1107 – Plant and Soil Science laboratory course (Spring 2017)

- Instructing students on the basics in nutrition, handling, and production methods for the major livestock breeds as well as food science and safety
- Assessing the learning of students through assignments, research papers, and tests and facilitating field trips to the agricultural operations of the Ellis, Goree, and Eastham prison units
- Instructing students on the basics in plant structures, sexual and asexual plant propagation, the effects of media, light and growth regulators on plant growth, woody plants, biological competitors, plant identification, career topics and sustainability
- Assessing the learning of students through assignments, discussion questions, lab reports, and facilitating speakers and field trips to the Walker County Extension office
- Performing all other duties of a Graduate Assistant as needed

SAM HOUSTON STATE UNIVERSITY, Huntsville, TX June 2015 – Dec 2016
Graduate Research Assistant – Conducting research and outreach events for the Alternative Agriculture and Food Systems grant

- Designing surveys for agricultural consumers and producers and the associated analysis of beliefs and identifying agricultural issues to address through outreach events and courses at Sam as well as for presentation at agricultural conferences

- Organizing outreach events exploring specialty topics and survey results for agricultural producers and consumers, including designing fliers and collaborating with faculty, producers, and the Texas Department of Agriculture
- Assisting in the research and data collection of white-tailed deer nutrition, reproductive physiology, behavior, and immunity studies as well as nutritional research in swine, caprine, and equine
- Performing all other duties of a graduate assistant as needed including, but not limited to teaching labs, grading assignments, and facilitating field trips

TRUMAN STATE UNIVERSITY, Kirksville, MO May 2013 – Aug 2014
Farm Hand – Raised fruits and vegetables for the campus food system, Sodexo, through the Farm to School Program and for sale at the Market on the Mall

- Seeded, transplanted, weeded, harvested, washed, prepared, and delivered fruits and vegetables
- Kept the farm running smoothly by performing chores such as herding cattle and cleaning stalls and equipment

TRUMAN STATE UNIVERSITY, Kirksville, MO Aug 2012 – May 2014
Undergraduate Researcher – Conducted research on the correlations of hair whorl location with docility and mothering ability in TSU's herds of 30 Gelbvieh cattle under the guidance of Dr. Wehner

- Defined research topic, developed methodology, conducted literature review, and collected data on cow-calf pairs from the fall and spring herds
- Received a Grant-in-aid of Scholarship and Research and presented at the Student Research Conference in March 2014

HICKORY HOLLOW FARM, Callao, MO May 2013 – Dec 2013
Student Researcher – Assisted Dr. Seipel with a SARE Grant testing lamb weight gain on oat grass and teff grass as well as performing other farm chores

- Dewormed, vaccinated, tagged or ear notched, and castrated sheep, swine, and cattle
- Moved and fixed polywire fences, built corral, cut brush, sprayed herbicide, and recorded data
- Operated farm equipment such as ATV, large tractor, and skid loader
- Co-presented research findings at the Missouri Livestock Symposium in December 2013

SIGMA ALPHA (Professional Agricultural Sorority), Truman State University, Kirksville, MO 2011 – 2015
Corn Maze Co-Chair – Fall 2013 & 2014

- Organized our chapter's largest fundraiser, the Haunted Corn Maze, and raised over $3,500 in four days in 2013 and over $4,000 in 2014
- Managed 45 members, coordinated donations of seed corn and fertilizer, and completed a can food drive the first night of Corn Maze each year

OTHER ACTIVITIES, Truman State University, Kirksville, MO 2011-2015
Pre-Veterinary Club (President 14-15), Delta Tau Alpha Honors Agriculture Fraternity (Vice President 14-15), Up-Chuckles Comedy Club (Secretary, 2014), Beef Cattle Show Team, Collegiate Farm Bureau, Equestrian Team, and Sharp Shooters

HONORS AND AWARDS

Nominated for Ag Workers Graduate Student Leadership and Service Award (2017), Sam Houston State University, Huntsville, TX.

Nominated for Graduate Student Excellence in Research Award (2017), Sam Houston State University, Huntsville, TX.

Nominated for Texas Deer Association Research Award Grant (2017), Sam Houston State University, Huntsville, TX.

Agriculture Consortium of Texas Student Research Symposium 2nd Place in the Graduate Poster Competition (2017), Sam Houston State University, Huntsville, TX.

College of Science and Engineering Technology Special Graduate Scholarship (2017), Sam Houston State University, Huntsville, TX.

Deer Breeders Corporation Scholarship (2016), Sam Houston State University, Huntsville, TX.

College of Science and Engineering Technology Special Graduate Scholarship (2016), Sam Houston State University, Huntsville, TX.

Outstanding Student in Agriculture (2015), Truman State University, Kirksville, MO.

Departmental Honors (2015), Truman State University, Kirksville, MO.

PROFESSIONAL MEMBERSHIP

American Society of Animal Science

OTHER COMPETENCIES

SAS Statistical Package (SAS Institute, Cary, NJ)