DETERMINATION OF BLOOD MICROMINERAL AND FAT-SOLUBLE VITAMIN VALUES FOR WHITE-TAILED DEER

A Thesis

Presented to

The Faculty of the School of Agricultural Sciences

Sam Houston State University

In Partial Fulfillment

of the Requirements for the Degree of

Master of Science

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by

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May, 2021

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ABSTRACT

Greenwood, Megan P., *Determination of blood micromineral and fat-soluble vitamin values for white-tailed deer.* Master of Science (Agriculture), May, 2021, Sam Houston State University, Huntsville, Texas.

The current National Academies of Sciences, Engineering, and Medicine (NASEM) for micromineral and vitamin requirements for cervids are based on data collected from various small ruminant species. Lack of baseline requirements make diet formulation for high fenced, white-tailed deer (*Odocoileis virginianus*) herds particularly ambiguous. This study was to determine a baseline value for whole blood and serum micromineral and vitamin concentrations for white-tailed deer in an attempt to establish dietary requirements of microminerals and vitamins. Open does (n=223) were sampled using jugular venipuncture during fall breeding procedures. Captive-raised does housed at various high fenced ranches (n=3) throughout Texas were used, each with unique management strategies. Blood samples were analyzed for micromineral levels (Co, Cu, Fe, Mn, Mo, Se, and Zn) and fat-soluble metabolites (vitamin A, vitamin E, measured as α-tocopherol, and cholesterol). Age of the doe and ranch were used as main effects using the GLM procedure in SAS. Sampled averages were 6.31 ng/mL of Co, 1.04 µg/mL of Cu, 220.41 µg/mL of Fe, 4.43 ng/mL of Mn, 4.23 ng/mL of Mo, 172.48 ng/mL of Se, 0.54 µg/mL of Zn, 275.25 ng/mL of vitamin A, 1.80 µg/mL of vitamin E, and 79.61 of cholesterol. Ranch played an important role in micronutrient levels, with the exception of cholesterol (P=0.26). Micronutrient least squared means were also affected by age for Se, Zn, and vitamin E (P<.01). Pregnancy status was determined (n=93) via jugular venipuncture 30-37 d after breeding procedure. Females that became pregnant at initial breeding attempt had significantly higher serum Zn (P<.01) and vitamin E (P=0.03)

levels. Factors such as feed, forage, soil, genetics, and health management protocols could explain the variance in values. The establishment of circulating blood micronutrient levels will serve as a baseline for future white-tailed deer nutrient requirement research and feed formulation.

KEY WORDS: Microminerals, Trace minerals, Fat-soluble vitamins, White-tailed deer

ACKNOWLEDGEMENTS

I would like to thank Dr. Stanley Kelley, Dr. Phil Urso, Dr. Marcy Beverly, and Dr. Mark Anderson for their guidance over the past two years. Each of you has been influential in the success of this project and my time at Sam Houston State University. We thank the personnel of Texas Veterinary Medical Diagnostic Laboratory, especially Dr. Cat Barr, for coordinating the analysis of blood samples. This study was generously supported by Texas Deer Association along with Sam Houston State University. White-tailed breeding operations, along with their staffs, throughout the state of Texas allowed us to utilize their animals to make this project possible. Their support and hospitality are greatly appreciated.

Madison McCluskey, thank you for your patience and skill that allowed this project to run smoothly. I am grateful for the skills you have given me from drawing blood to tagging fawns and holding bottles. Your passion for animal husbandry is a constant inspiration; being your sidekick was a thrill. Kagen Burkett, you joined our team and hit the ground running. I have enjoyed having you alongside as we learned the ins-and-outs of the white-tailed deer industry. And lastly, Timber Thomson. Thank you for your friendship, your sampling assistance, and for always having my back.

Of course, a huge thank you to San Antonio Livestock Exposition for providing me with the scholarship that made this degree a possibility; without SALE's support I would not have been afforded the large breadth of experiences that being a Bearkat has given me.

PREFACE

"Advances are made by answering questions. Discoveries are made by questioning answers." – Bernard Haisch

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CHAPTER I

Introduction

White-tailed deer (*Odocoileus virginianus*) are a native Texas species that serve an important role in the ecosystem, economy, heritage, and more recently, agriculture sectors of Texas. Ranches dedicated to raising white-tailed deer have become a well-established portion of the agriculture sector. In the last decade, the scope of captive deer production has grown dramatically as producers continue to finetune their production methods to maximize profits. In the state of Texas alone, the white-tailed deer industry's overall economic impact exceeds $1.6 billion annually (Outlaw et al., 2017). Each year, the deer breeding industry alone is responsible for contributing $349.4 million to the Texas economy. There are approximately 1,006 permitted high-fenced deer ranches in the state that support countless jobs (Anderson, et al., 2007). It is estimated that $786.9 million is spent on ranch operating expenses, 30% of which is feed and hay costs (Outlaw et al., 2017). Just like other livestock species, feed costs are a huge portion of an operation's monthly expenses. Producers understand that high quality feed ingredients are necessary to unlock the genetic potential of their herd, but in order to maximize profits feed resources must be allocated properly. White-tailed deer ranches are founded with the goal of producing genetically superior does and large bucks with striking antlers to either be sold as breeders or be used for trophy hunts. Due to nutrition's impact on antler growth, supplemental feed and mineral programs are implemented with zeal, as this is perceived to be an unofficial portion of the Boone and Crockett antler equation. The Boone and Crockett equation is the industry standard for measuring antler growth, rewarding racks for number of points, spread, width, length of tines, and circumference.

However, there are many unknowns in regard to nutritional supplementation in deer as their base nutritional requirements are not fully understood. The deer industry still feeds animals using antiquated nutritional requirements based on other small ruminant species, such as sheep and goats, or field data which lacks scientific design. Very few large-scale nutrition focused research projects have been designed for white-tailed deer, in captivity or in the wild, leaving producers with little information when they build their feeding strategies. Furthermore, the research that has been completed is often discounted due to small sample sizes with a wide range of population variables.

Captive deer have drastically different behavioral patterns when compared to their wild relatives which may travel miles in search of specific browse plant species. Deer consume minute amounts of grass, preferring to select forbs and browse which are more nutrient dense (Wright, et al., 2002). Due to the limited ranging capability of captive herds, offering a complete supplemental ration becomes essential to meet nutritional needs that may be lacking given the minimum browse variety typical of captive deer enclosures. Additionally, deer in captivity experience added immune system stress due to increased disease exposure through closer animal interaction (Bartoskewitz, et al., 2007). Thus, research is needed to pinpoint the requirements of captive deer populations. However, it is inherently difficult to determine nutrient requirements for animals that are not contained in a dry lot setting and the methodology for feeding captive deer in this scenario has not been thoroughly developed as their livestock counterparts.

Forage and soil components, trace element interactions, genetic effect, physiological state, immune interaction, and rumen microflora are also influential variables that need to be accounted for in studies to come. There are few reports of blood

analyses from free range or captive deer populations. Those that do exist are markedly small. Few studies have been completed that explore vitamin and micromineral profiles, specifically. The establishment of circulating blood micronutrient levels from this and subsequent studies will serve as a baseline for future white-tailed deer nutrient requirement research and feed formulation.

Objective. Determine baseline values for whole blood and serum micromineral and vitamin concentrations for white-tailed deer in an attempt to establish dietary requirements of trace minerals, fat-soluble vitamins, and other metabolites.

CHAPTER II

Literature Review

White-Tailed Deer

White-tailed deer are one of the most popular big game species for wildlife enthusiasts, especially in the state of Texas. White-tailed deer are part of the Cervidae family, more commonly referred to as cervids. The males are unique in their ability to grow antlers, an outgrowth of the frontal bone, annually. This is the only completely regenerating organ found in mammals (Goss, 1984). Females are short day breeders that fawn in the spring with a high twinning rate. Mature bucks weigh between 58-113 kg while does range from 45-70 kg when feed resources are plentiful. White-tailed deer are classified as ruminants but differ from common livestock species as they are concentrate selectors. Concentrate selectors are unique as they prefer to browse for plants that are highly digestible, being high in starch, protein, and fats. Concentrate selectors spend very little time grazing and more time browsing. As a result, their diet is low in fiber and their ability to ferment cellulosic portions of cell walls is minimal (NRC, 2007).

Artificial insemination and embryo transfer are standard breeding practices employed on high-fenced white-tailed deer ranches in order to maximize the genetic influence of superior individuals. An early study by Jacobson, et al. (1989) found artificial insemination using semen with post-thaw motility greater than 70% resulted in 100% conception rates in captive white-tailed does bred on natural heat cycles. Insemination based on natural heat cycles poses a logistic and labor strain, thus pharmaceutical hormone synchronization prior to laparoscopic insemination is used. Laparoscopic insemination is a common practice when breeding small ruminants with

71.7% conception rates reported in merino ewes; however, no data percentages have been established for cervids (Hill, et al., 1998). Superstimulation using follicle-stimulating hormone (FSH) treatment is effective in small ruminants with the number of viable embryos harvested being influenced by genetics, nutrition, and technician (Armidiris and Cseh, 2012). Collected embryos are frozen for future use, transferred to a recipient female, or occasionally, a viable embryo is left in the donor doe.

Minerals

Minerals, specifically microminerals or “trace minerals", are imperative to proper bodily functions of all living things. There are ten trace minerals known to be essential to ruminant animals: Chromium (Cr), Cobalt (Co), Copper (Cu), Iodine (I), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Nickle (Ni), Selenium (Se), and Zinc (Zn). These elements are present in the animal’s body tissues at very small amounts but work as components of hormones and enzymes with critical implications. Given that they are needed in such minute quantities, the healthy range between deficiency and toxicity of microminerals can be easily missed. Microminerals are difficult to study given the complex interactions between absorption of macrominerals and microminerals. Additionally, mineral levels in the blood are constantly fluctuating. Despite all of this, minerals serve as a cornerstone for feed formulation and herd health management. White-tailed deer herds that achieve the correct, delicate mineral formula are more likely to see decreased health issues. As a result, productivity may increase.

Cobalt. Cobalt can be found in blood serum and tissues, especially the liver. Cobalt functions as a component of vitamin B_{12} also known as cobalamin. The rumen’s microorganism population uses dietary Co to synthesize vitamin B_{12} which allows

ruminants to not be dependent on dietary vitamin B_{12} (NASEM, 2016). Vitamin B_{12} mainly functions in two animal tissue enzymes, methylmalonyl CoA and 5-methyltetrahydrofolate, which work to recycle methionine. It is through this biochemical pathway that Co is imperative to glucose production (Somers and Gawthorne, 1969). Vitamin B_{12} forms a nonlinear relationship between liver and blood serum levels as serum levels maximize while tissue levels may continue to climb (Grace and Wilson, 2002).

Although clinical evidence of Co deficiency in deer is rare, it has been documented in New Zealand (Grace and Wilson, 2002). Animals receiving a Co deficient diet will have low daily gains, decreased appetite, and overall unthriftiness. If the deficiency becomes severe, ruminants will exhibit signs of anemia coupled with impaired disease resistance (NASEM, 2016). Research using young, growing red deer observed that injecting Co did not improve growth rates as anticipated based on a similar study using sheep (Grace and Wilson, 2002). These results imply that deer populations are less susceptible to Co deficiency when compared to other small ruminants. In a separate study involving cattle, young, rapidly growing calves showed more favorable average daily gains and dry matter intake when fed 0.20 mg Co/kg, which is double the NRC's suggested feeding rate (Stangl, et al., 2000). Sheep have been tested for Co toxicity levels and tolerated being fed 100 times their daily requirement of Co without adverse symptoms (NASEM, 2016).

Deer milk has very high levels of vitamin B_{12} and passes readily from dam to fetus implying that gestating and lactating does have an increased Co requirement (Grace and Wilson, 2002). The micromineral Co should be regarded as essential in deer diets to

ensure proper synthesis of vitamin B_{12}. Toxicity is less of a concern given the ruminant's high threshold for Co. Legumes and other green forages grown in acidic soil typically have adequate Co levels. Cobalt levels tend to diminish when forage is dried for hay or the pH of soil increases (NASEM, 2016).

Copper. Copper metabolism and its interactions with other minerals is complex, making the study of Cu difficult. Many of the body's catalytic functions are reliant on Cu. Copper containing enzymes serve in melanin synthesis, growth, immune function, skeletal development and proper nervous system function. Despite Cu's role in bone development, studies comparing antler growth and Cu supplementation were inconclusive (Walker, et al., 1997). A large percentage of the Cu consumed daily is not absorbed, but instead passes to the large intestine where it is excreted as feces (O'Dell and Sunde, 1997). The Cu which is absorbed through the intestines eventually is stored in the liver with stores released into the blood when levels fall below normal (0.6 ppm in cattle); this makes liver biopsy the most reliable test of Cu status (O'Dell and Sunde, 1997; Herdt et al., 2000). Other groups have suggested Cu serum concentrations in red deer as 5-8 μmol/L for marginal status and greater than 8 μmol/L to reach adequate status (Grace and Wilson, 2002). Bartoskewitz, et al. (2007) reported serum Cu concentrations in white-tailed bucks to be 1.09 +/- 0.05 ppm despite a wide range in dietary Cu supplementation. Serum Cu levels do not fluctuate following meals or fasting, but levels do spike leading up to parturition (O'Dell and Sunde, 1997).

Marginal deficiency has been linked to decreased weight gain and a series of reproductive failures, including lengthened estrous cycles, anestrous, embryonic loss, and ovarian cysts. Deficiency in Cu has been linked to bone defects as Cu is integral in

connective tissue integrity (O'Dell and Sunde, 1997). Failure to form the proper collagen matrix leads to abnormal mineralization of bone followed by incidences of osteoporosis and fractures (O'Dell and Sunde, 1997). In red deer, symptoms of Cu deficiency such as ataxia and osteochondrosis have been documented in animals with blood serum levels below 3-4 μmol/L (Wilson and Grace, 2001). Native deer populations are historically deficient in Cu, based on tissue biopsy, during late winter and early spring when forages are dormant (Grace and Wilson, 2002). Nevertheless, in a small New Zealand study, liver samples from wild deer were compared to captive deer in the same region. Samples from the wild population had three times the concentration of Cu (Grace and Wilson, 2002). The availability of a diverse selection of browse may explain this phenomenon.

Copper is historically deficient in soil, therefore, making Cu supplementation a vital feed additive concern. However, Cu supplementation can become complex as its bioavailability is reliant on other minerals such as Ca, Fe, Mo, S, and Zn (Herdt et al., 2000). Copper and Zn fed in high concentrations (200-236 ppm Cu as copper sulfate and 1000-1135 ppm Zn as zinc oxide) to male white-tailed deer had mixed effects on deer performance. No dietary impacts were observed in antler or body size over the one-year trial (Bartoskewitz, et al., 2007). Treatment deer exhibited greater immune response during antibody challenges and showed less immune system hindrance when exposed to stress hormones (Bartoskewitz, et al., 2007). These results did not indicate signs of toxicity.

Iron. Iron is known to be an important part of oxygen transport through the blood as it is associated with hemoglobin. Greater than 50% of the body's Fe is found in blood (NASEM, 2016). Young ruminants have higher Fe requirements, 50 mg/kg in beef cattle,

since they are actively increasing blood volume (NASEM, 2016). Iron deficiency manifests itself as anemia and listlessness. Cereal grains and animal by-products used as protein sources are typically sufficient in providing dietary Fe. High levels of Fe in the diet significantly inhibits the absorption of Co, leading to lowered vitamin B_{12} and feed consumption (Reuber, et al., 1994). Soil, when red in color, is characteristically high in Fe content which is readily absorbed by forage and browse species (Dwevedi, et al., 2017).

Manganese. Manganese functions as a component and activator for many enzymes (Hurley and Keen, 1987). Skeletal development, reproduction, and growth all rely on Mn with reproduction demanding the most. Heifers fed 15.8 mg Mn/kg had decreased conception rates, delayed estrous cycling, and required more services per conception when compared to females fed 25 mg Mn/kg (Rojas, et al., 1965).

Little is known about Mn absorption. It is hypothesized that Ca, P, and Fe in high levels can interfere with the absorption of Mn. In areas with healthy soils, Mn should be sufficient in forages, however, corn-based diets are markedly low in Mn (NASEM, 2016).

Molybdenum. Molybdenum is a less understood trace mineral. It functions as a component in the enzymes xanthine oxidase, sulfite oxidase, and aldehyde oxidase (Mills and Davis, 1987). Free molybdate is transported through blood plasma and is stored as molybdoprotein bound to enzymes. Besides the notion that Mo may enhance ruminal microbial activity, its impact and dietary requirements have not been well established. Kessler (1991) determined a dietary Mo requirement of 0.1 mg/kg DM for goats. However, goats appear to be more susceptible to Mo deficiency than other species.

Differences in sulfur (S) metabolism in the small intestine may account for the Mo tolerability differences amongst species.

Goats receiving diets low in Mo had decreased feed intake, reproductive failure, and poor growth rates. Delayed puberty, reduction in pulsatile luteinizing hormone, and decreased conception rate has been observed in heifers receiving diets high in Mo while Cu status remained consistent across treatments (Phillippo, et al., 1987). Excessive dietary Mo will cause changes in coat color, scours, stiffness, and weight loss (NASEM, 2016). These side effects can be linked to Mo antagonistic effect on Cu absorption. It is well documented that Cu and S have an antagonistic relationship with Mo, as high levels of Mo will decrease Cu absorption and vice versa (NASEM, 2016). For example, Ca, P, Fe, S, and Mo in high amounts act as antagonists to the absorption of Cu, Mn, Se, and Zn from the gastrointestinal tract (Michael, et al., 2004).

Selenium. Selenium works to support and maintain immune system integrity, oxidative protection from free radicals, and maintain cell integrity (McMurray and Rice, 1982). Selenium is absorbed via the gut with little homeostatic regulation. Since it cannot be selectively metabolized from body stores, ruminant animals rely on constant absorption from the gastrointestinal tract. After absorption, Se is transferred to the liver where excess levels are converted into bile for excretion. Based on this interaction, serum and liver Se levels form a linear relationship (Grace and Wilson, 2002). In cattle, serum Se levels change to reflect an increase in dietary Se within 2 to 6 days (Herdt et al., 2000). Therefore, whole-blood and serum Se levels are both accurate ways to determine nutritional status, however, whole blood Se levels are preferred as they are more reflective of long-term dietary levels. Herdt (1995) sampled llamas from 29 herds

throughout the United States and predicted that serum Se levels greater than 160 ng/mL equated to adequate Se status in llamas.

Grazing red deer supplemented with oral or injectable Se were compared to control deer that received no additional Se supplement. Supplemented deer, regardless of administration technique, had significantly higher blood Se levels (Grace, et al., 2000). Growth rates across groups remained the same with no response recorded in deer with blood Se levels greater than 140 nmol/L (Grace, et al., 2000). On the other hand, female black-tailed deer that received Se supplementation had higher preweaning fawn survival rates (0.83 fawns/doe versus 0.32 fawns/doe) (Flueck, 1994). Gabryszuk and Klewiec (2002) found that ewes who received Se injection during gestation reared lambs who were significantly heavier through the first 28 days of life compared to control ewes. Cattle that were treated with injectable Se before calving had fewer incidences of retained placentas (Michael, et al., 2004).

Selenium deficiency often leads to white muscle disease characterized by pale, damaged skeletal muscle identified during necropsy. White muscle disease has been reported in red deer with serum Se values ranging from 84-140 nmol/L (Wilson and Grace, 2001). Liver Se levels in diagnosed white muscle disease animals ranged from 73 - 440 nmol/kg DM (Grace and Wilson, 2002). Ewes with Se levels lower than their healthy counterparts within the same herd were more likely to be diagnosed with mastitis caused by staphylococcus aureus, coagulase-negative staphylococci, and *Mycoplasma agalactiae* (Giadinis, et al., 2011).

Texas has been established as a state with relatively low soil, rock, and groundwater Se levels (Cech, et al., 1984). Low soil Se levels translate to lower levels in

forage and browse. This increases the importance of Se in supplemental white-tailed deer diets.

Zinc. Zinc is well defined as a mineral imperative for growth and immune function. Deficiency is marked by reduced feed efficiency, impaired immune response, diarrhea, and skin lesions. Given that Zn is responsible for the production of protective keratins in the hoof, Zn is of particular importance in herds susceptible to hoof rot (Gressley, 2009). Plasma zinc values range from 0.8-1.2 mg Zn/L in sheep (Puls, 1994). Serum Zn concentrations in captive, white-tailed bucks have been reported as 0.47 +/- 0.05 ppm despite a drastic difference in dietary Zn levels (Bartoskewitz, et al., 2007). Zinc pools in liver, kidney, muscle, and spleen tissues. As these stores become well-supplied, absorption through the gastrointestinal tract diminishes (Herdt, et al., 2000). Zinc fluxes from tissue pools to blood serum constantly, with serum Zn levels only indicating deficiency once all stores have been depleted.

Blood Zn levels are expected to be lower in animals suffering from inflammatory diseases as Zn transfers from blood to tissue in the event of an inflammatory response. When animals are exposed to stress, Zn levels in blood serum are likely to diminish which further complicates the use of plasma Zn concentration as a diagnostic tool (O'Dell and Sunde, 1997). Lowered plasma Zn levels have been linked to increased prostaglandin F2α and first-term abortions in cattle and horses (Graham, et al., 1995). Additionally, females in gestation or lactation may exhibit lower blood Zn levels in comparison to open or dry females. Rats fed a Zn deficient diet prior to mating had disrupted oocyte chromatin methylation and development followed by a failure to conceive (O'Dell and Sunde, 1997), (Tian and Diaz, 2013). When rat females were

offered the Zn deficient diet beginning in the third trimester, pups out of restricted dams were born abnormally small with delayed skeletal maturation.

Injectable Minerals. Aside from a balanced trace mineral profile in the diet, many livestock producers utilize injectable trace minerals as a safeguard to protect against symptoms of deficiency. Injectable trace minerals are historically very expensive but boast a significant return on investment given their ability to increase conception rates while boosting immunocompetence. Injectable trace minerals administered in conjunction with standard vaccination procedures leads to higher antibody titer levels, an indicator of immune response (Roberts, et al., 2016). Reproductively, cattle and sheep that were given a trace mineral, subcutaneous injection prior to embryo transfer were one and a half times more likely to be pregnant at day 23 (Sales, et al., 2011). The added reproductive success seen in animals receiving trace mineral injections is often enough to justify adding it to an operation's herd health routine. However, operations that choose not to do so cite the fact that injectables have short-lived impact. Recent liver biopsy data from cattle receiving a trace mineral injection showed increased Cu and Se liver concentrations through day fifteen with decreases seen there after (Pogge, et al., 2012). Injectable trace mineral supplements are currently not labeled for cervid species and further trials would be required to confirm their efficacy in white-tailed deer. However, this could be an impactful management tool for deer producers in the future.

Fat-Soluble Vitamins and Metabolites

Dietary fat-soluble vitamin inclusions and healthy blood levels remain undefined in white-tailed deer. Due to the difficulty associated with obtaining a large number of samples, very few studies have been undertaken. 1,25 dihydroxy vitamin D and vitamin

K complex are both synthesized by rumen microbes and thus do not need to be supplemented in the diet (Ramsey, 1996). Vitamin D, needed for Ca metabolism by all animals, has been studied in white-tailed bucks. Van der Eems et al. (1988) collected biweekly blood serum samples over a twelve-month span. Antler mineralization phase correlated to higher 1,25 dihydroxy vitamin D in juvenile and aged buck blood samples. These findings are reasonable, given vitamin D's role in Ca absorption. Synthetic vitamin A and vitamin E additives are added to deer rations to satisfy vitamin needs despite a lack of research documenting exact nutritional requirements.

Vitamin A. Vitamin A, found in animal tissues as retinol and retinyl esters, is a commonly supplemented, important feed additive in the captive deer industry. Carotenoids, the most important to small ruminants being α-carotene, β-carotene, γ-carotene, and crytoxanthine, are found in plants and serve as the biological precursor to vitamin A. The NRC (2007) reports a vitamin A dietary requirement of 104.7 IU/kg for ruminants, with a 2-fold increase during late gestation and lactation. However, the efficiency of carotenoid conversion to vitamin A is still unknown in cervids and may impact requirements. Being a fat-soluble vitamin, absorption occurs along with intestinal lipid absorption through normal fat digestion. The liver is the primary storage site of vitamin A, containing 90% of the body's vitamin A. Blood plasma retinol levels averaged 187.5 µg/dL in mature ewes fed 6,000 µg retinol/kg of body weight (Donoghue, et al., 1979).

Vitamin A deficiency is characterized by decreased eyesight caused by xerophthalmia, weight loss, late-term abortion, retained placenta, and stillborn fetuses (NASEM, 2016). Giadinis, et al. (2011) found that dairy sheep herds with a high

incidence of mastitis had lower blood serum vitamin A compared to herds where mastitis is rare. Rams grazing dried forages during the breeding season had higher incidence of spermatozoa with abnormal heads and midpieces. Vitamin A supplementation began to decrease sperm abnormalities after six weeks (Abdulkareem, et al., 2005). Keirdorf and Keirdorf (1998) reported that retinoic acid, a derivative of vitamin A, injected into early antler tissue development resulted in accelerated antler growth in fallow bucks. Small ruminants with access to green forages and browse typically receive adequate vitamin A as plants are high in carotenoids. In situations where the diet is deficient in vitamin A, liver stores can mask signs of deficiency for 2-4 months. It is only at this point that blood serum retinol levels will drop to indicate a deficiency via blood test (Sommer and West, 1996). Ruminant species are generally less efficient in converting carotenoids to retinol when compared to nonruminants, with cattle degrading 67% of active vitamin A when on a concentrate diet (NASEM, 2016). Ruminants fed a high fiber diet had lower vitamin A degradation at only 20%, inferring that ruminal pH plays a role in vitamin A absorption (Weiss, et al., 1995).

Scientists have successfully synthesized vitamin A allowing it to be added to feed. However, carotenoids are quickly degraded by sunlight, oxygen, and high temperatures which makes storage difficult. Vitamin A degradation when exposed to daylight was significant, but artificial light had no detectable effect on stability (Allwood, 1982). Supplementation of alfalfa hay, typically seen in captive white-tailed deer operations, provides a significant amount of the deer's dietary vitamin A requirement.

Vitamin E. Vitamin E is simply a generic term for tocol and tocotrienol derivatives, which are found in lipid fractions of green plants (NRC, 2007). Most

tocopherol in forage is α-tocopherol which is also the isomer that appears at high levels in animal blood serum and tissue. Other isomers like β, γ, δ-tocopherol have low biological activity and appear in animal tissues at minute levels, leaving α-tocopherol as the isomer of concern. Growth, reproduction, disease resistance, and tissue integrity all rely on vitamin E. Vitamin E works as an antioxidative component to prevent peroxidative damage to cell membranes during immune responses, elevates production of the antibody immunoglobulin G (IgG), and increases stimulation of lymphocytes (Tengerdy, 1990). Although vitamin E does not cross placental tissue effectively, it is highly concentrated in colostrum assisting in jumpstarting the newborn animal's immune system (McDowell, et al. 1996). Three-year-old ewes who received injections of sodium selenite 0.1% and vitamin E 250 mg returned to estrus earlier and were more likely to become pregnant following first lambing (Gabryszuk and Klewiec, 2002). Vierk, et al. (1998) found that α-tocopherol supplementation in sheep helped to inhibit cellular collapse of corpora lutea tissue thus preventing involution and improving pregnancy rates.

Literature regarding vitamin E requirements for cervids is limited with varied conclusions being reached. Blood plasma is a reliable way to measure vitamin E status with a high correlation between liver and plasma α-tocopherol levels according to some studies (McDowell, et al. 1996). Conversely, Charmley, et al. (1992) reported that blood lipid levels and physiological status may interfere with plasma's reliability as an indicator of vitamin E status. Ruminant animals with blood plasma α-tocopherol levels falling below 3.5 μmol/l are anticipated to exhibit symptoms of vitamin E deficiency, while white muscle disease lesions are associated with less than 1.5 μg of α-tocopherol/mL in blood serum (Dierenfeld, 1994); (NRC,2007). Symptoms include, but are not limited to,

tissue degeneration, muscular dystrophy, emaciation, impaired immune response, and decreased antioxidant capacity (NASEM, 2016; McDowell, et al. 1996). Dierenfeld and Jessup (1990) sampled free-ranging mule deer and reported mean α-tocopherol levels ranging from 0.8 to 4.2 µg/mL. It is important to distinguish total plasma tocopherol levels from α-tocopherol to ensure that values are not artificially elevated. Sheep receiving a diet devoid of vitamin E had blood serum levels fall below 1 µg/mL within four weeks of diet change as liver stores were depleted (Njeru, et al., 1994). In a study sampling mule deer from fourteen distinct herds, mean blood plasma concentrations for α-tocopherol varied dramatically by herd from 1.86 – 9.70 µmol/l (Dierenfeld, 1994). The broad range in vitamin E levels are likely due to habitat differences, although browse and forage samples were not analyzed.

Ruminants on green pasture typically receive adequate amounts of vitamin E. However, the concentration of α-tocopherol decreases as the plant matures, as hay cures, and storage duration increases. Concentrate feeds, like corn and distillers grains, are typically low in available vitamin E (NRC, 2007).

Cholesterol. Steroid hormones, such as progestogens, glucocorticoids, mineralocorticoids, androgens, and estrogens, serve as powerful signaling molecules to regulate bodily functions. Cholesterol is the precursor for all steroid hormones (Berg, et al., 2002). Blood serum cholesterol levels rise in ruminants as supplemental fat increases (Nestel, et al., 1978). Bile salts are derivatives of cholesterol and work to solubilize lipids, making lipids more efficiently absorbed in the small intestine. Intestinal biosynthesis of cholesterol and decreased excretion of bile acids are a direct effect of

increased fat in the diet. Cholesterol is also linked to calcium and phosphorus absorption as it serves as a precursor to vitamin D (Berg, et al., 2002).

Cholesterol has proven to be consistent in free-ranging white-tailed deer regardless of sex or age; however, there is significant variation in levels depending on season (Klinger, et al., 1986). Specifically, low cholesterol ranges were seen in the winter months when forage quality was known to be at its lowest point. However, considering the high level of fat fed to deer in captivity, 4-8% depending on formulation, serum cholesterol levels would likely vary from the wild population. Stage of gestation also plays an important role in the variability of serum cholesterol levels in cows (Herdt, et al., 2000). Gestating, non-lactating cattle reported serum cholesterol levels of 244.62 mg/dL, while open, lactating females were significantly lower at 95.73 mg/dL (Lennon and Mixner, 1957). In order to avoid variation, test groups must be segregated by gestation stage.

Physiological Factors

When it comes to minerals, species, growth, gestation, and lactation status are considered the primary cause of in herd variation of blood mineral levels. Within herd variation of mineral level ranges is dependent on the specific mineral. Minerals like Mg and Se often display a low coefficient of variation, around 7%, as blood serum levels are highly correlated with dietary adequacy (Herdt, et al., 2000). Blood samples collected on hunter-killed deer showed no significant differences when compared to ranges for non-drugged, live animals (Klinger, et al., 1986). Although mineral studies have been conducted on mule deer and red deer, there is reason to believe that these species vary in blood composition when compared to white-tailed deer. White and Cook (1974) analyzed

erythrocytes, hemoglobin, and albumin/globulin ratios in blood and saw differences in white-tailed deer when compared to other deer species. Additionally, they noted significant differences between newborn fawns and adult animals, but differences between sexes were minimal. This study did not analyze mineral or vitamin levels but serves as evidence that deer species and age groups do vary in their blood composition.

Age. In the wild, the life expectancy of does is approximately 6.5 yrs (Lopez, et al., 2003). Long bone growth is complete by 3 yrs of age in male and female white-tailed deer, with antler growth increasing annually from 1-6 yrs of age followed by a gradual decrease. Age of deer has not been correlated to a specific trend in blood mineral and vitamin levels. Similarly, in cattle, Said et al. (1964) found no trend in Ca and inorganic P levels based on cattle age. Blood macromineral elements of red deer blood samples did not show significant differences between age groups 3-8 months, 9-18 months, or older (Wilson and Pauli, 1983). However, newborn fawn blood samples differ from mature deer in its red blood cell counts (White and Cook, 1974). Gabryszuk and Klewiec (2002) sampled two and three-year-old ewes prior to the breeding season. Three-year-old females after first lambing had lower base Se and vitamin E blood serum levels when compared to two-year-old ewes. This may be due in part to the high concentration of both Se and vitamin E in colostrum and milk.

Inheritance. Lane et al, (1968) used Guernsey cattle to evaluate the effect of inheritance on mineral levels. Sire groups consisting of at least ten daughters were analyzed with mean ranges as follows: P, 5.8-6.6; Mg, 2.2-2.4; Ca, 7.1-7.6; Na, 268-286; and K, 45.2-61.2 mg/100 ml. Sire effects were deemed to be significant for P, Mg, Na, and K. Previous nutrition studies conducted on white-tailed bucks observed a wide range

in blood micromineral values for Cu and Zn among animals on identical diets and health protocols (Bartoskewitz, et al., 2007). This implies that another variable, such as genetics, may be at work. Further research is needed in ruminant species to determine a correlation between genetics and mineral metabolism.

Environmental Factors

There are few reports of blood analyses from free range deer populations. Those that exist are markedly small, given that deer had to be harvested before samples were taken. Flueck (1994) followed black-tailed does through migration for three years. They observed that the wild population exhibited symptoms of Se deficiency that was reversed by offering Se supplementation. These findings refute the assumption that wild ruminant populations are typically not susceptible to mineral deficiency because of adaptation over generations (Flueck, 1994). Michel, et al. (2017) captured wild does from various regions of Mississippi. The three sampled geographical areas varied in soil type, browse availability, and forage/browse nutrient quality. It was hypothesized that bucks born to wild dams in captivity would outperform their genetic peers due to the high plane of nutrition provided in captivity. Body and antler size increased 6% in captive born bucks over the average wild bucks from each region. However, the most significant impact came in the second generation when these same bucks were bred to captive raised does that had been on commercial feeds their entire lives. The resulting buck fawns sired by bucks out of wild dams were 18% heavier than the fawns by wild bucks of their respective regions with up to a 32% improvement in rack spread (Michel, et al., 2017). This study provides a glimpse at the power of epigenetics and fetal programming in native deer populations. Furthermore, it reiterates the power of nutrition to maximize

genetic expression. With semen and embryos from top white-tailed genetics selling at all-time highs, producers must be conscious of how feeding decisions impact the performance of their herd for generations and how it allows for expression of full genetic potential.

CHAPTER III

Materials and Methods

Ethical Statement. All care, handling, and sampling of deer was approved by the Sam Houston State University Institutional Animal Care and Use Committee (Protocol number: 19-12-04-1008-3-01) prior to the start of the experiment.

Data Collection. Captive raised, white-tailed does (n=223) ranging in age from 1 to 9 yr were sampled. Samples were obtained from a combination of three independently managed ranches in the state of Texas. Deer were immobilized using a sedative, 1.5 cc Medetomidine Ketamine-HCl, administered via intravenous injection or restrained manually in a chute in conjunction with artificial insemination, embryo collection, and embryo transfer procedures. One 6 mL blood sample was collected from each doe via jugular venipuncture into a royal blue-top tube containing an anticoagulant, ethylenediaminetetraacentic acid, for whole blood and serum analysis of microminerals. A second 6 mL blood sample was collected into lavender-top tubes, containing no anticoagulant for harvesting of serum used in vitamin analysis (Vacutainer; Becton, Dickinson and Co., Franklin Lakes, NJ). Following sample collection, 3 cc Atipamezole HCl was administered to each doe as sedative reversal. All animals were returned to the herd following sampling procedure. Samples were labeled using an animal identification number specific to this project to maintain anonymity. Birth dates were determined based on written records provided by each ranch. Age was calculated according to ranch recorded birth date and simplified to the nearest whole year.

Within 3 hrs of initial blood draw, blood was centrifuged for twenty minutes upon which serum was extracted from the lavender top tubes and moved to plastic transport tubes. Whole blood and serum samples were chilled in coolers and shielded from light. Within 24 hr of collection, all samples were delivered to Texas Veterinary Medical

Diagnostic Laboratory in College Station, TX for analysis of Co, Cu, Fe, Mg, Mo, Se, Zn, vitamin A, vitamin E, and cholesterol levels. Testing was performed according to Texas Veterinary Medical Diagnostic Laboratory standard operating procedures.

Pregnancy status (n=93) was determined via blood test by ranch staff 30-37 d after breeding procedure. Pregnancy-associated glycoproteins (PAGs) found in blood served as indication of fetal growth. Positive pregnancy status refers to does who became pregnant following artificial insemination or embryo transfer procedures that occurred the day of sampling. Open pregnancy status refers to does that did not successfully conceive.

Data Analysis. All data were analyzed using the General Linear Model procedure of SAS (SAS Institute Inc., Cary, NC, USA) to determine average values and interaction between ranch, animal age, and pregnancy status. Each animal served as an experimental unit.

Study Area

All three ranches were located in the inner coastal plains physiographic region. The inner coastal plains physiographic region is marked by elevations between 90-245 m featuring a series of parallel ridges and valleys. Exact location of ranches was omitted to maintain anonymity, but Ranch A was located in the Brazos Valley, Ranch B in the Piney Woods, while Ranch C fell in the South Texas Plains subregion. Soil quality varied by ranch from sandy, traditionally nutrient-poor soils to areas of deep, acidic loams and areas of high clay and Fe content. The average long-term minimum and maximum temperatures during the white-tailed doe breeding season, spanning November – December, were 6° C-21° C. The average daily precipitation in 2019 for all locations was lower than the long-term averages for the state of Texas.

All does were housed in a high-fenced setting, limited to white-tailed deer. This minimized interaction and competition with other species. Pen size and stocking density

varied by ranch with Ranch A and B does confined to pens ranging from 0.20–0.81 hectares. Browse was minimal to nonexistent at both ranches. Ranch A pens had warm season grasses in doe pens while Ranch B was devoid of forages; thus, limiting the diet to provided feedstuffs only. Females were given access to alfalfa hay, textured feed, and a free choice, gravity fed pellet. Textured feed (Table 1) was handfed daily at varying quantities based on the condition of the animal. Ranches A and B used the same alfalfa hay supplier; thus, their hay was expected to have similar nutrient values (Table 1). Quantities consumed were not measured but could be an area of interest in future studies. Ranch C maintained the lightest stocking density of 1.10 hectares per doe. Ranch C does had access to a free choice, gravity fed pellet and textured feed fed daily from fawning through breeding. Ranch C differed in that does did not receive alfalfa hay, but females had access to naturally occurring, native browse species.

Table 1

Proximate analysis and mineral breakdown of daily hand fed, feedstuffs[a] at individual ranches plus alfalfa hay[b]

	Ranch A	Ranch B	Ranch C	Alfalfa Hay
Crude Protein, %	17.90	17.40	21.90	19.90
Ca, %	2.62	2.60	1.89	1.51
P, %	0.82	1.05	0.88	0.27
K, %	1.22	1.34	1.34	1.88
Mg, ppm	0.47	0.54	0.32	0.62
Na, ppm	2,361.00	2,977.00	2,080.00	163.00
Cu, ppm	50.00	81.00	58.00	13.00
Fe, ppm	64.00	69.00	50.00	13.00
Mn, ppm	320.00	368.00	67.00	52.00
Zn, ppm	284.00	318.00	258.00	14.00

[a]Quantities fed varied by ranch. [b]Alfalfa hay fed at Ranches A and B only

CHAPTER IV

Results

Study Sampled Averages

Table 2 contains previously accepted healthy micromineral blood serum ranges of various cervid species and classes established by Puls (1994), henceforth referred to as reference data. This data was built using a compilation of small, antiquated studies utilizing a variety of cervid species from various environments under a broad range of nutritional conditions. These ranges are currently used by veterinarians and diagnostic labs when evaluating cervid blood samples to determine health status and make nutritional recommendations. In this current study, sampled means fell within previously accepted ranges for all established metabolites with the exception of Se, which was 22.48 ng/mL higher in the trial data set than the reference data range of 60-150 ng/mL. Sampled averages (n=223) were 6.31 ng/mL of Co, 1.04 µg/mL of Cu, 220.41 µg/mL of Fe, 4.43 ng/mL of Mn, 4.23 ng/mL of Mo, 172.48 ng/mL of Se, 0.54 µg/mL of Zn, 275.25 ng/mL of vitamin A, 1.80 µg/mL of vitamin E, and 79.61 of cholesterol in the current study.

Table 2

Reference data averages (Puls, 1994) compared to current study LS Means of serum micromineral and fat-soluble metabolites in sampled does

Analyte	Reference Data Average Ranges	Current LS Mean	SE
Co (ng/mL)	Unknown	6.31	0.194
Cu (µg/mL)	0.60-1.30	1.04	0.012
Fe (µg/mL)	152.00-277.00	220.41	12.134
Mn (ng/mL)	Unknown	4.43	0.449
Mo (ng/mL)	Unknown	4.23	0.141
Se (ng/mL)	60.00-150.00	172.48	1.383
Zn (µg/mL)	0.50-1.00	0.54	0.010
Vitamin A (ng/mL)	Unknown	275.25	15.421
Vitamin E (µg/mL)	Unknown	1.80	0.055
Cholesterol (mg/dL)	Unknown	79.61	1.920

Ranch

Ranch A provided 99 hd, Ranch B had 98 hd, and 26 hd were sampled at Ranch C (Figure 1). There were significant differences ($P < 0.01$) between ranch for all measured microminerals and fat-soluble vitamins as noted in Table 3. Cholesterol levels, however, ($P=0.26$) did not vary between ranches. Ranch C was statistically different from Ranches A and B for Cu, Fe, Mn, and vitamin A. However, Ranch A differed from Ranches B and C regarding Se and vitamin E. Zinc varied by ranch, with all locations being statistically different ($P < 0.01$).

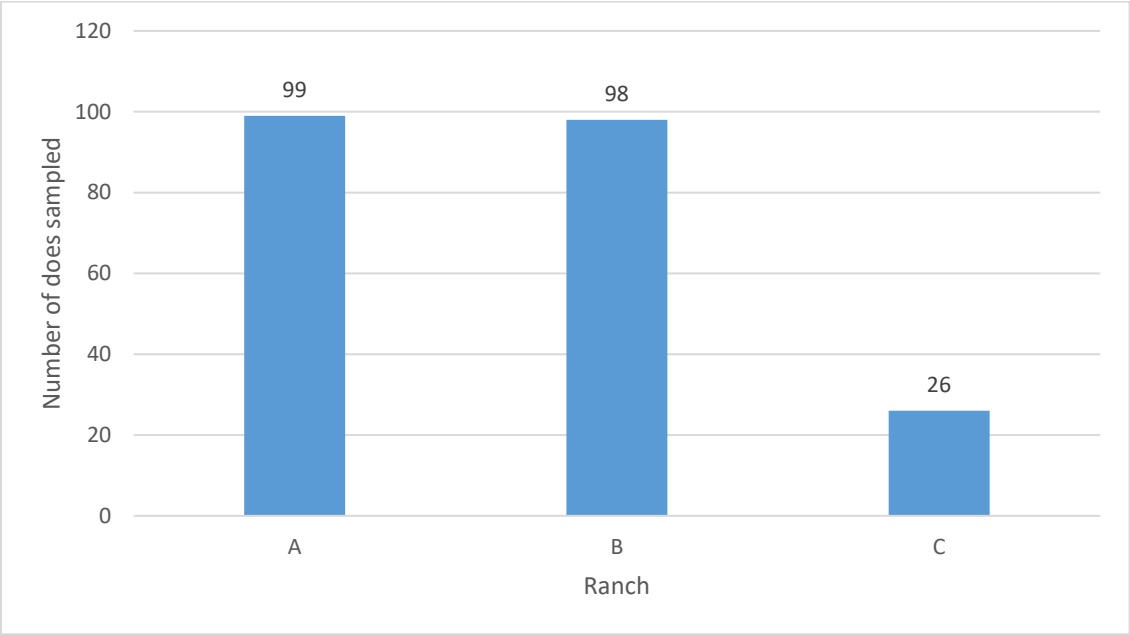

Figure 1

Total number of does sampled by ranch (n=223)

Table 3

LS Means of serum micromineral and fat-soluble metabolites in sampled does by ranch

Analyte	Ranch A	Ranch B	Ranch C	SE[d]	P-Value
Cu (µg/mL)	0.99[a]	1.02[a]	1.33[b]	0.044	<.01
Fe (µg/mL)	179.72[a]	197.84[a]	431.90[b]	38.116	<.01
Mn (ng/mL)	2.45[a]	3.87[a]	13.79[b]	1.319	<.01
Se (ng/mL)	160.51[a]	180.34[b]	185.93[b]	3.810	<.01
Zn (µg/mL)	0.52[b]	0.47[a]	0.74[c]	0.035	<.01
Vitamin A (ng/mL)	283.61[b]	293.13[b]	40.40[a]	57.283	<.01
Vitamin E (µg/mL)	2.24[b]	1.53[a]	1.60[a]	0.155	<.01
Cholesterol (mg/dL)	75.21	79.28	86.63	6.218	0.26

[abc]Means with different superscripts differ at $P < 0.05$. [d]Pooled Standard Error of the Mean

Age

The number of does sampled within each age group were not proportional (Figure 2). White-tailed deer life expectancy is 6.5 yrs, thus does aged 6-9 yrs were combined to form an "aged" category (Lopez, et al., 2003). Table 4 compared does in the study by age group. Age showed to play a significant role in Se, Zn, and vitamin E levels in white-tailed doe blood serum. As does aged, serum Zn levels decreased (Figure 3). No concrete

trend was established for Se (Figure 4) and vitamin E (Figure 5) as does aged. Copper, Fe, Mn, vitamin A, and cholesterol did not show to be affected by age.

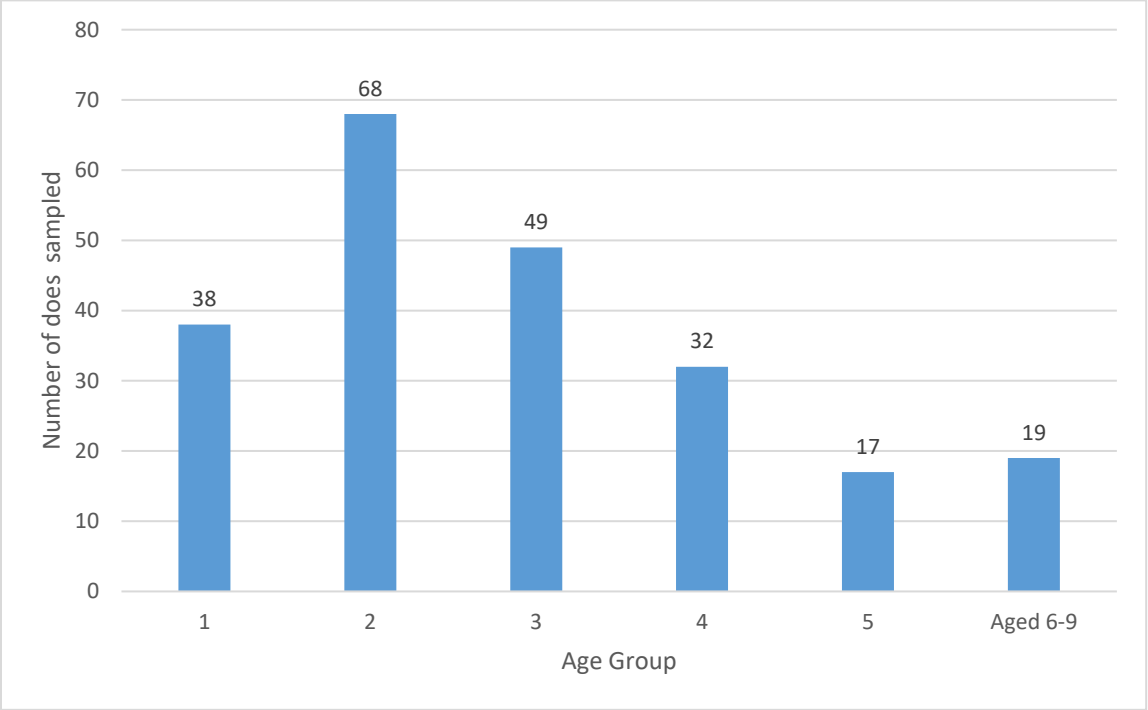

Figure 2

Total number of does sampled by age (n=223)

Table 4

LS Means of serum micromineral and fat-soluble metabolites in sampled does by age group

Analyte	1	2	3	4	5	6-9	SE[d]	*P*-Value
Cu (µg/mL)	1.07	1.13	1.15	1.08	1.12	1.13	0.053	0.32
Fe (µg/mL)	290.55	298.05	236.61	284.46	271.17	238.07	43.307	0.41
Mn (ng/mL)	7.22	6.38	7.23	7.23	6.20	5.96	1.495	0.93
Se (ng/mL)	163.39[a]	179.20[b]	177.80[b]	181.23[b]	176.36[b]	175.63[b]	4.331	<.01
Zn (µg/mL)	0.61[b]	0.63[b]	0.60[b]	0.58[ab]	0.51[a]	0.51[a]	0.030	<.01
Vitamin A (ng/mL)	165.82	224.48	270.83	201.72	175.24	196.18	56.030	0.40
Vitamin E (µg/mL)	2.12[c]	1.69[abc]	1.88[bc]	1.49[abc]	1.84[bc]	1.72[abc]	0.184	<.01
Cholesterol (mg/dL)	87.24	79.44	86.31	75.13	76.40	77.72	7.420	0.35

[abc]Means with different superscripts differ at $P < 0.05$. [d]Pooled Standard Error of the Mean

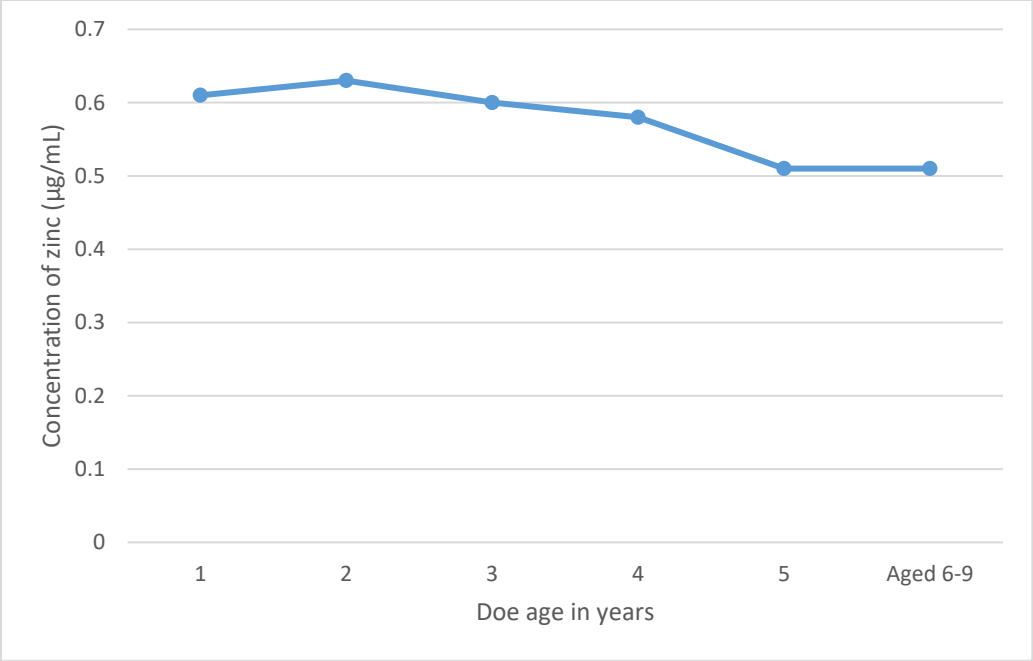

Figure 3

Zinc LS means by doe age group

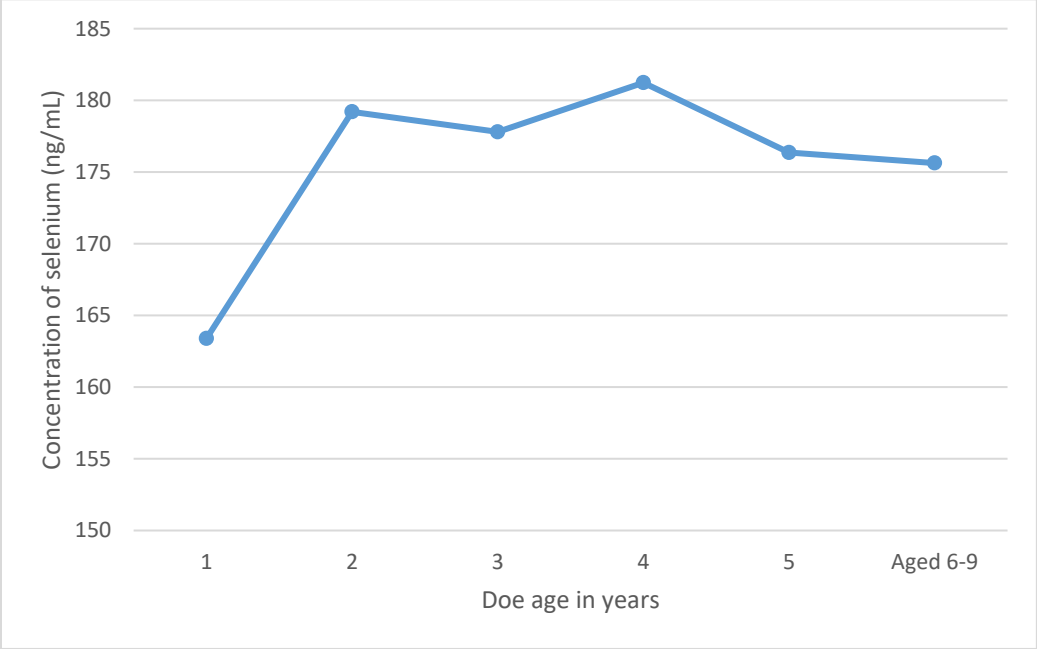

Figure 4

Selenium LS means by doe age group

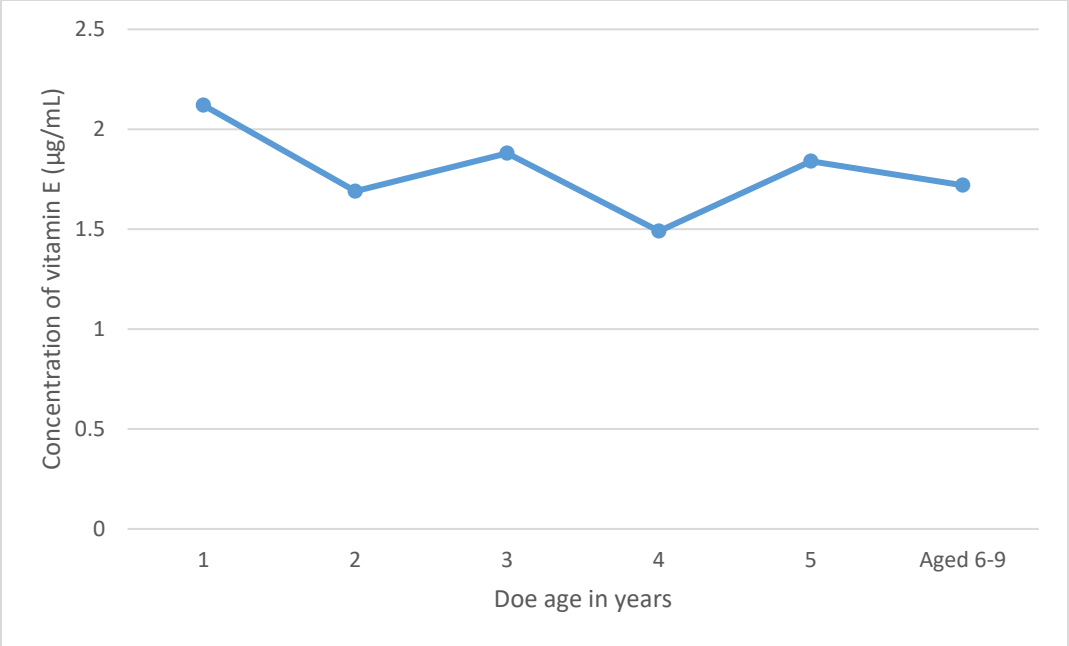

Figure 5

Vitamin E LS means by doe age group

Interactions

Interactions between main effects of ranch and age were detected for Co and Mo. Ranch C was lower than Ranches A and B for Co, but no trend was established across all ages and ranches (Figure 6). Molybdenum tended to increase with age at Ranches A and B (Figure 7).

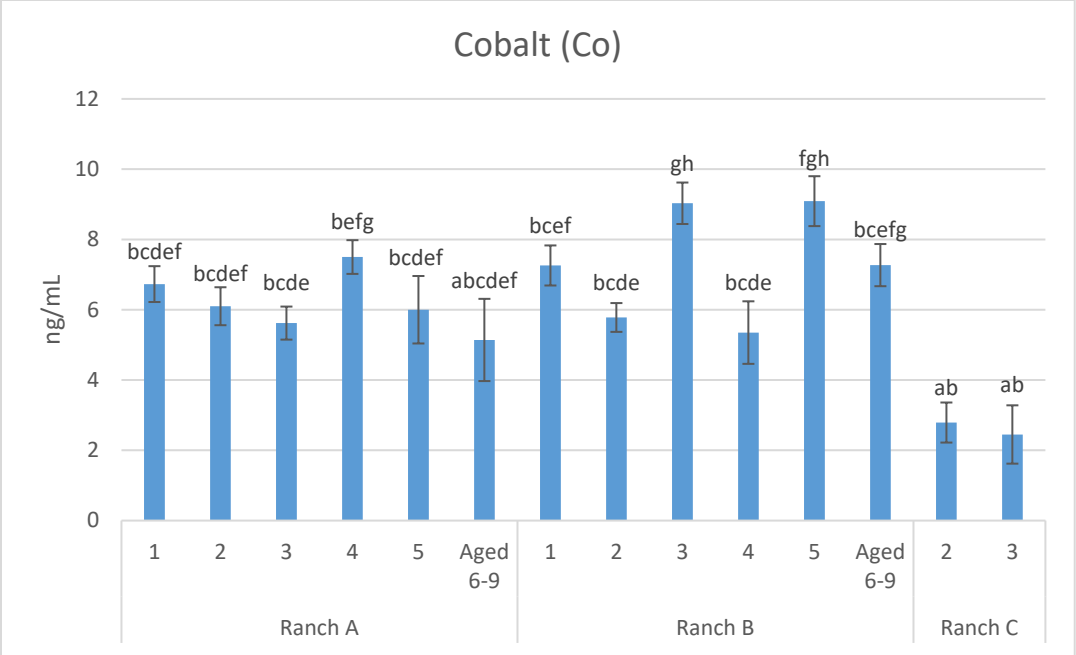

Figure 6

Interaction between main effects of age and ranch for Co

[abcdefgh]Means with different superscripts differ at $P < 0.05$

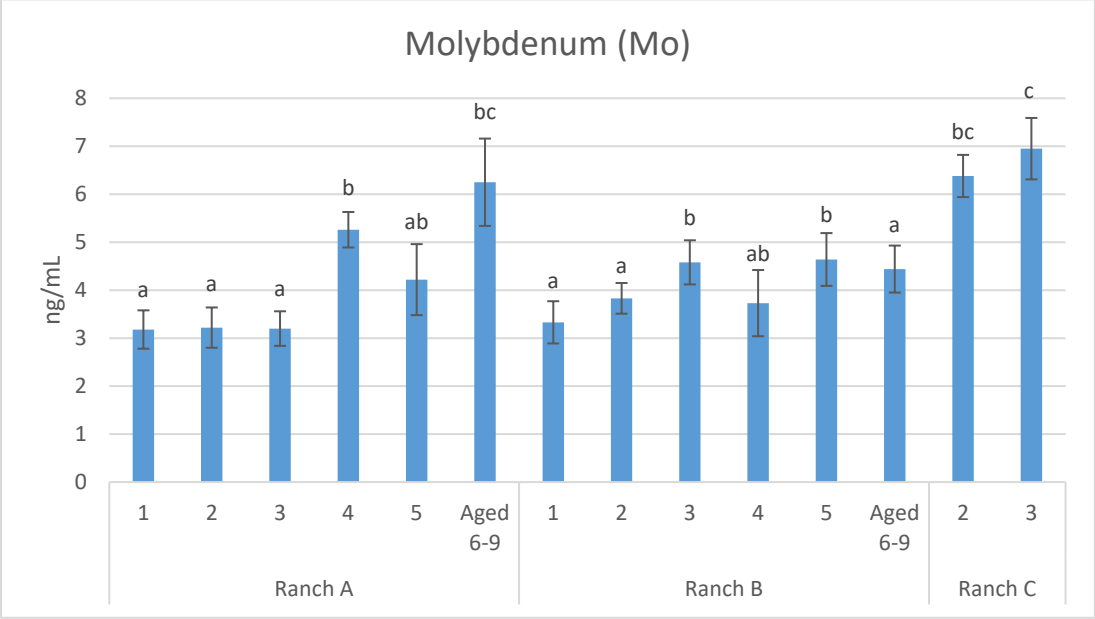

Figure 7

Interaction between main effects of age and ranch for Mo

[abc]Means with different superscripts differ at $P < 0.05$

Correlation

No strong correlations were established across sampled analytes (Table 5). However, Fe and Zn had a weak correlation, 0.44. Similarly, Vitamin E and cholesterol also displayed a weak correlation, 0.44.

Pregnancy Status

Sampled LS means for does reported to be open following breeding procedures were statistically the same ($P > 0.05$) as bred females for all analytes with the exception of Zn and Vitamin E (Table 6). Open females had lower circulating Zn levels than bred does ($P < 0.01$). Vitamin E was also lower ($P = 0.03$) in females that did not successfully conceive on the first attempt.

Table 5

Pearson Correlation Coefficients for serum micromineral and fat-soluble metabolites in sampled does

	Co	Cu	Fe	Mn	Mo	Se	Zn	Vit A	Vit E	Cholesterol
Co (ng/mL)		-0.29	-0.16	-0.21	-0.06	-0.01	-0.17	0.15	0.27	0.21
Cu (µg/mL)	-0.29		0.14	0.36	0.25	0.31	0.19	-0.17	-0.10	0.18
Fe (µg/mL)	-0.16	0.14		0.08	0.21	0.19	0.44[a]	-0.03	-0.08	0.01
Mn (ng/mL)	-0.21	0.36	0.08		0.21	0.23	0.17	-0.16	-0.03	0.18
Mo (ng/mL)	-0.06	0.25	0.21	0.21		0.37	0.21	-0.10	-0.16	0.25
Se (ng/mL)	-0.01	0.31	0.19	0.23	0.37		0.17	-0.06	-0.39	0.21
Zn (µg/mL)	-0.17	0.19	0.44[a]	0.17	0.21	0.17		-0.04	-0.01	0.20
Vitamin A (ng/mL)	0.15	-0.17	-0.03	-0.16	-0.10	-0.06	-0.04		-0.03	-0.11
Vitamin E (µg/mL)	0.27	-0.10	-0.08	-0.03	-0.16	-0.39	-0.01	-0.03		0.44[a]
Cholesterol (mg/dL)	0.21	0.18	0.01	0.18	0.25	0.21	0.20	-0.11	0.44[a]	

[a]Denotes weak correlation

Table 6

Pregnancy status of does determined by blood test 30-37 d following breeding procedure that occurred in conjunction with sampling for micromineral and fat-soluble analyte analysis

Analyte	Open[a] LS Mean	Bred[b] LS Mean	SE[c]	*P* - Value
Co (ng/mL)	6.24	7.20	0.456	0.10
Cu (µg/mL)	0.99	1.00	0.031	0.95
Fe (µg/mL)	179.34	194.87	12.398	0.34
Mn (ng/mL)	4.31	4.02	0.384	0.56
Mo (ng/mL)	3.09	3.21	0.232	0.68
Se (ng/mL)	170.07	167.34	3.587	0.56
Zn (µg/mL)	0.42[x]	0.48[y]	0.025	<.01
Vitamin A (ng/mL)	270.56	271.38	15.387	0.97
Vitamin E (µg/mL)	1.78[a]	2.19[b]	0.151	0.03
Cholesterol (mg/dL)	77.09	80.38	4.803	0.61

[a]Open refers to does who did not became pregnant following artificial insemination or embryo transfer procedures that occurred the day of mineral sampling. [b]Bred refers to does who became pregnant following artificial insemination or embryo transfer procedures that occurred the day of mineral sampling. [c]Pooled Standard Error of the Mean. [xy]Means with different superscripts differ at $P < 0.05$

CHAPTER V

Discussion

Study Sampled Averages

Study averages validate the assumption that white-tailed does fall within previously accepted ranges as established by the reference data. Sampled Se levels were higher than the previous data, but no outward expression of Se toxicity symptoms were observed. Herdt (1995) predicted that llamas with serum Se levels > 160 ng/mL, regardless of region raised, were adequate in their Se status which aligns with study sampled averages. Texas does not fall in a region known for high soil Se concentrations (Cech, et al., 1984). This may imply that Se supplementation in captive operations exceeds cervid requirements or that white-tailed deer may tolerate higher serum Se levels than previously implied by reference data.

Ranch

Ranch location, management practices, and feeding programs show to play an important role in circulating micromineral blood serum levels of white-tailed does. Copper, Fe, Mn, and Zn levels were significantly higher at Ranch C. Further research of intake and mineral bioavailability of feedstuffs, soil, and water are needed to pinpoint the cause of these differences.

Ranch C had a large standard error for Fe attributed to females with exceptionally high levels. Although soil samples were not collected, Ranch C had red tinged soil, characteristic of high Fe content, on the property (Dwevedi, et al., 2017). This coupled with the available browse might explain the significantly higher serum Fe levels found in these does. Iron has an inhibitory effect on Co absorption, linking the low Co and high Fe levels observed at Ranch C (Reuber, et al., 1994). Nevertheless, Co and Fe did not show

a strong correlation when all does were considered (Table 6). This indicates that Ranches A and B did not reach Fe levels high enough to have an antagonist effect on Co.

Ranches A and B, which had higher serum vitamin A levels, both supplemented with alfalfa hay while Ranch C does consumed browse which is characteristically lower in vitamin A content during the winter breeding season (Somner and West, 1996). Weiss, et al. (1995) reported that cattle fed high concentrate diets, similar to captive white-tailed does, had retinol disappearance of 80% due to lower ruminal pH. Additionally, vitamin A is highly sensitive to light and temperature making sampling difficult (Allwood, 1982). These factors could explain the varying levels of vitamin A between ranches.

Age

Samples were not collected from does of all ages, 1-9 yrs, from all three ranches; this resulted in missing blocks of data. The lack of differences between age groups for Cu, Fe, Mn, vitamin A, and cholesterol may indicate that values can be applied to white-tailed does aged 1-9 yr. However, the significant differences between ages for Se, Zn, and vitamin E may indicate that diagnostic averages should be broken down by age as an all-inclusive value may not accurately represent white-tailed deer as they age. Gabryszuk and Klewiec (2002) reported a decrease in serum Se and vitamin E from 2 yr old to 3 yr old ewes. This trend was not observed in study sampled averages as maiden does were lower ($P < 0.01$) in serum Se and higher in serum vitamin E ($P < 0.01$) when compared to older age groups.

Interactions

Cobalt and Mo levels are dependent on the age of the doe as well as the location. No concrete pattern was established across ranch and age groups for Co or Mo. Further research with a more pointed focus is required to determine the impacts of locations, management, and age on Co and Mo.

Pregnancy Status

Females that failed to conceive on the day of sampling had lower circulating levels of plasma Zn compared to bred does. Tian and Diaz (2013) reported that Zn deficient diets fed 3-5 days prior to breeding are linked to a failure to develop a healthy oocyte and successfully conceive in other mammals. Additionally, Graham, et al. (1995) linked low circulating Zn to higher prostoglandin F2 levels and subsequent reproductive failure in cattle. It should be noted that serum study averages for both open and bred females would be considered marginally Zn deficient when compared to the reference data.

Vitamin E was 0.41 µg/mL lower in open does in comparison to bred females. Vitamin E is necessary for the proper development of corpora lutea tissue resulting in higher pregnancy rates for vitamin E supplemented ewes (Vierk, et al., 1998). Thus, vitamin E may serve as an area of greater concern in white-tailed deer supplementation going forward. Despite the importance of micronutrients in proper reproduction, statistical differences for the remaining micronutrients were not observed between open and bred females. This serves as an indication that established values are a representative base-line of healthy, reproductively sound does.

Future Research

Further research should evaluate the interaction between blood micromineral levels and levels present in the liver to further validate these two sampling methods as a diagnosis of mineral status. Pen studies using white-tailed deer, coupled with blood serum averages established in this study, would allow for a more accurate understanding of precise mineral supplementation requirements for captive raised white-tailed deer. Additionally, samples representing fawns, bucks, bred females, and lactating females would allow the data to be extrapolated to more classes of white-tailed deer.

CHAPTER VI

Management Implications

Cervid management is growing in scope and intensity. It is paramount that animals are managed as safely and effectively as possible. The reported levels will contribute to the definition of micromineral and vitamin blood serum averages. Going forward, these values can serve as a stepping off point for more pointed nutritional trials. Long term, these blood micromineral and fat-soluble metabolite ranges can be used as a diagnostic tool for captive and free roaming white-tailed deer populations and in an effort to establish micronutrient requirements in white-tailed deer.

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VITA

Megan Phyllis Greenwood

EDUCATION

Sam Houston State University, Huntsville, Texas
Masters of Science in Agriculture Science- Thesis
Start Date: August 2019
Expected Completion Date: May 2021
Advisor: Dr. Stanley Kelley

Texas A&M University, College Station, Texas
Bachelors of Science in Animal Science
Magna Cum Laude
Start Date: August 2014
Completion Date: December 2017

CERTIFICATIONS

Professional Animal Scientist, American Registry of Professional Animal Scientists
- Recognized through examination and continued education to be proficient in beef cattle

Artificial Insemination/Pregnancy Test, Bovine Elite
- Certified to be proficient in artificial insemination, pregnancy test, and estrus synchronization

Beef Quality Assurance Certified Producer, Oklahoma Beef Council
- Completed course detailing proper animal handling and husbandry as it relates to beef production

Dairy Production and Management, Penn State University
- Certified in dairy genetics, nutrition, farm economics, and industry sustainability

EXPERIENCE

3-S Texas Outdoors, Bedias, Texas
April 2020 - August 2020
- Worked alongside pen manager during fawning season
- Administered health treatments to does and fawns as needed
- Introduced students to cervid production by creating hands-on learning opportunities in WMGT 3350
- Pulled blood samples for pregnancy testing from 100+ does

Graduate Teaching Assistant, Huntsville, Texas
August 2019 - Current
- Instruct students on the basics in nutrition, handling, and production methods for the major livestock species as well as food science
- Assess the learning of students through assignments, research papers, and tests
- Facilitate field trips to the agricultural operations of Gibbs Ranch and the Goree and Eastham prison units
- Assist in instructing meat science lab and techniques in slaughter and fabrication of multiple species

- Work closely with faculty members and facility management to ensure an effective learning environment
- Record student assignment progress and attendance for multiple courses
- Assist with research projects in the equine science and wildlife departments

Livestock Judging Team, Huntsville, Texas
August 2019 - Current
Coach

- Lead judging team in bi-weekly practices and advanced concepts of livestock evaluation
- Plan travel to major shows, ranches, and competitions working with industry leaders
- Officiate youth livestock judging contests throughout the state
- Plan and coordinate The Bearkat Classic, a junior livestock show, as a fundraising event
- Improve individual team member performance through tailored learning experiences

Westway Feed Products, Tomball, Texas
January 2018 - May 2019
Quality Assurance Specialist

- Formulated using BestMix program to formulate feed for 28 liquid feed plants in the United States
- Remained up to date on ingredient availability and price fluctuations to ensure least-cost formulation
- Collaborated with sales, operations, and purchasing to meet a variety of customer needs
- Produced and desseminated the “Formulations Newsletter” quarterly
- Conducted quality audits at all Westway locations

Noble Research Institute, Ardmore, Oklahoma
May 2017 - August 2017
Scholar in Agriculture

- Researched and interpreted data to produce scholarly article for publication
- Presented research to consultant team for dissemination
- Interpreted and applied scholarly articles as they relate to production practices in Southern Oklahoma
- Met with cattle producers to offer consultation regarding their varied production goals
- Expanded professional network by working alongside consultants and scholars with different specialties ranging from soil health to economics

Undergraduate Research Experience, College Station, Texas
January 2017 – December 2017
Texas A&M University - Research Leader

- Designed experimental parameters for 12-head experiment
- Coordinated undergraduate research experience by building an immersive educational experience
- Calculated digestibility differences to determine statistical significance of results

ABBA Australian Exchange Program, Queensland, Australia
September 2015 – November 2015
Exchange Student

- Worked with various families on working stud operations throughout Queensland
- Treated and handled cattle, sheep, and horse herds

MEETINGS/ CONFERENCES ATTENDED

Feedlot Bootcamp, Plains Nutrition Council, August 2020
Antler Fest, Texas Deer Association, February 2020 *Presented*
Liquid Feed Symposium, American Feed Industry Association, September 2018
Beef Cattle Short Course, Texas A&M University, August 2017, 2018
OCA Convention & Tradeshow, Oklahoma Cattlemen's Association, July 2017
Cattle Industry Convention, National Cattlemen's Beef Association, February 2016

PROFESSIONAL ORGANIZATIONS

SHSU Stock Horse Team	2020-Current
International Brangus Breeders Association - Membership & Education Committee member	2014-Current
American Society of Animal Science	2017-Current
International Red Brangus Breeders Association - Board of Directors - Scholarship Committee member	2013-Current
Texas A&M Horse Judging Team	2014-2016
Texas Aggie Cattlewoman	2014-2017
Texas A&M Horseman's Association	2014-2017

HONORS

Senior Merit Award, COALS	2017
Foundation Scholarship, TSCRA	2016
Departmental Scholarship, TAMU ANSC	2015-2017
Memorial Scholarship, IRBBA	2014-2016