THE IMPACT OF MANAGEMENT DECISIONS AND THEIR EFFECT ON REPRODUCTIVE PERFORMANCE OF BEEF CATTLE

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

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ABSTRACT

Two experiments were conducted to evaluate two management decisions made by beef cattle producers and their impacts on reproduction. In experiment 1, growth, attainment of puberty, and pregnancy rates were evaluated in crossbred heifers originating from two different breeding systems: 1) cows only exposed to natural service herd bulls (**NS**), or 2) cows exposed to ovulation synchronization and fixed-time AI followed by natural-service bulls (**TAI**, fixed-time artificial insemination). Artificial insemination did not influence growth rate during the development phase, attainment of puberty, or pregnancy rates in heifer progeny. In experiment 2, pregnancy attainment and calving distribution of beef females administered a control saline dose, killed virus, or modified-live pre-breeding vaccine per label recommendations were compared. No differences in pregnancy attainment were observed among the 3 time points measured, d 28, 56, and 90 as well as no differences seen among the calving distribution.

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DEDICATION

To my family, who always believed in me.

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LIST OF ABBREVIATIONS

µL.....microliter

ADG..... average daily gain

AI ..... artificial insemination

CIDR.....controlled internal drug release

d.....day

ES.....estrus synchronization

FSH ..... follicle stimulating hormone

GnRH .....gonadotropin releasing hormone

IM.....intramuscular

kg..... kilogram

KV..... killed virus

LH ..... luteinizing hormone

mg .....milligram

mL.....milliliter

MLV.....modified-live virus

$PGF_{2\alpha}$ .....prostaglandin F2 alpha

SE..... standard error

CHAPTER 1. INTRODUCTION AND REVIEW OF LITERATURE

Introduction

Reproductive performance and efficiency are vital components of any profitable cow-calf production system (Dziuk and Bellows, 1983; Payne et al. 2013). Producer profitability is driven by the proportion of breeding females that give birth and wean a calf every year. Less successful herds have a greater incidence of reduced reproductive performance when compared to herds with high calving rates. Poor reproduction within a herd results in decreased profit for the producer which can be caused by factors such as simple management flaws and/or catastrophic disease epidemic (Grooms, 2006). Thus producers may be able to enhance overall profitability by carefully selecting management strategies to implement in their operations. Heifer development and vaccination programs are among the strategies that a producer may implement.

Heifer selection and development can be vital management decisions made by beef producers. Choosing heifers that are the oldest and the heaviest may increase the likelihood of heifers becoming pubertal early in the in the breeding season (Greer et al., 1983). Artificial insemination is reproductive technology used to improve reproduction and genetics of livestock (Foote, 2002). The use of AI creates an opportunity for potential herd benefits including a concentration of the calving season and an increase in calf uniformity through increasing calf age and genetic potential (Lamb et al., 2006; Larson et al., 2006; Busch et al., 2007). Steichen et al. (2012) reported that use of AI also decreased the mean days to conception compared to females bred via natural service. Therefore use of AI could result in more calves born at the beginning of the calving season and, subsequently, more opportunity to select older genetically superior heifers to become replacement females. This may also increase the proportion of heifers that become pubertal early and become pregnant.

Vaccinations are tools that may improve overall herd health, productivity, and reproductive performance (APHIS, 2009). When properly administered, vaccinations can make a herd healthier by preventing disease and promoting herd immunity, which can alleviate potential negative impacts of disease on calf crops and overall profit. Vaccines are tools that have the ability to increase productivity by decreasing the risk of losses due to infertility, embryonic and fetal death, and abortions in females that without being vaccinated, may not carry a pregnancy to term (APHIS, 2009). Side effects such as immunosuppression, narrow spectrum of protection and possible return to virulence are also possible with the use of vaccines, are risks that must be considered (Griffin et al., 2002).

This literature review will discuss some of the management tools currently available for producers that may impact reproduction. Section 1 will review concepts related to heifer development and section 2 will review concepts related to pre-breeding vaccinations.

Section 1: Heifer Development

Puberty

Attainment of puberty involves the developmental process of endocrine and morphologic changes resulting in an individual able to reproduce (Senger, 2003). Puberty is a process that culminates with the first ovulation in conjunction with standing estrus (Perry and Cushman, 2013) and occurs when a heifer has the first opportunity to conceive in concurrence with the first normal luteal phase (Atkins et al., 2013). The timing of puberty in a female is the result of developmental events in congruence with environment, nutritional status, and age (Schillo et al., 1992). While the reproductive system is in place long before the onset of puberty, changes must occur in development and pulses of hormone activity before a female can reach reproductive maturity. The initiation of estrus cycles begins with gonadotropin releasing hormone (GnRH)

being released from the hypothalamus (Gasser, 2013) as a requirement for puberty. The secretion of GnRH stimulates the pulse and frequency of luteinizing hormone (LH) and follicle stimulating hormone (FSH) needed to signal the follicular development and estrodial secretion (Diskin and Kenny, 2014). Follicle stimulating hormone and LH are gonadotropins produced by the anterior pituitary and are produced throughout life. However, just before the onset of puberty, the concentrations of these hormones increase (Morgan et al., 1989). Follicle stimulating hormone is the promoter of follicular development, whereas luteinizing hormone causes the cascade of events leading to ovulation (Senger, 2003). At the time of FSH and LH rise, significant increases in uterine development and maturity are occurring as well as increases in length and size of follicles (Atkins et al., 2013). Maturation of reproductive organs and increases in the concentrations of required hormones are the basis for puberty.

Fetal programming is the concept that perturbations to the maternal system during critical developmental windows can have both short- and long-term consequences on offspring outcomes (Barker et al., 1993). Developmental programming affects can be seen with relation to heifer fertility and postweaning gain (Martin et al., 2007). Factors such as compromised maternal nutrition and/or breeding system of origin may influence growth, performance, attainment of puberty, and, fertility of heifer progeny. Genetic and environmental components (Patterson et al., 1999) such as nutrition (Schillo et al., 1992), as well as body weight, frame size, and breed (Freetly et al., 2011) are of major importance as to when a heifer will reach puberty (Fox et al., 1988).

Weight at first estrus is influenced by the plane of nutrition that an animal is subject to prior to reaching puberty (Greer et al., 1983). The greater the plane of nutrition, in both preweaning and postweaning, the earlier the start of estrus (Schillo et al., 1992). Heifers fed a

high corn supplement diet became pubertal earlier compared to heifers fed a low corn supplement diet (Buskirk et al., 1995). A greater proportion of heifers fed a high concentrate diet became pubertal earlier compared to a restricted forage diet (Cardoso et al., 2014). Although optimum growth rates change due to production system, frame score can be an indicator of heifer puberty. Females will reach puberty relative to their projected mature body weight and frame size (Fox et al., 1988). The larger the frame size, the larger the anticipated weight and more days that will be needed for that female to reach puberty. While mature size varies among breeds, post weaning growth is associated with management. *Bos Indicus* cattle may reach a greater proportion of skeletal and body maturity at puberty compared to *Bos Taurus* cattle, it may take those breeds longer to reach puberty (Freety et al., 2011). Age and absolute body weight are also not as precise a measurement of puberty as was the proportion of mature body weight reached (Freetly et al., 2011). Growth, frame size, and nutritional status all effect the pubertal status of females. Understanding the mechanisms by which management decision can effect a herd is vital to a successful operation. The manipulation of these factors could prove useful in making an operation more reproductively successful.

Replacement Heifer Selection

Selection of females, specifically heifers, can strongly affect the productiveness of a herd. Selecting heifers based on age may influence reproduction. In much of the literature, the calving season in divided into successive 21 d intervals according to when a calf is born which corresponds to estrus cycles of conception (Lestmeister et al., 1973; Funston et al., 2012; and Cushman et al., 2014). Heifer calves born in the first 21 d of the calving period had lighter birth weights than those heifers born later in the calving season (Funston et al., 2012). The same heifers also had greater weaning weights (Funston et al., 2012). A lighter birth weight, especially

for a young heifer could mean decreased incidence of dystocia or calving difficulty (Lee et al., 2002). Selection of heifers born in the first 21 d of the calving season may have lighter birth weights and may be beneficial if kept as a replacement. Heifers born in the first 21 d also had greater pre-breeding weights and a greater percentage of those heifers were cyclic at the beginning of the breeding season (70, 58, and 39% in the first period, second period, and third period of calving, respectively; Funston et al., 2012).

Heifers that are able to be bred early in the breeding season also calve earlier and wean heavier calves compared with heifers that become bred later in the breeding season (Short and Bellows, 1971). With an earlier age at puberty, females can be bred with a higher chance of pregnancy due to more heifers being cyclic (Gutierrez et al., 2014). Heifers that have had at least 2 estrus cycles prior to the start of the breeding season are more likely to become pregnant than those heifers that are bred at pubertal estrus (Byerley et al., 1987). Increases in the number of fertile heifers at the start of the breeding season may lead to a greater proportion of heifers becoming pregnant early in the breeding season. A greater proportion of heifers born in the first and second 21 d calving period became pregnant compared to heifers born in the third 21 d period (Funston et al., 2012). The use of genetic selection for younger age at puberty could positively influence the pregnancy rates of females (Perry and Cushman, 2013). Heifers that reach puberty early in life may have greater potential of becoming pregnant early in the breeding season compared to heifers that have not reached puberty at the beginning of the breeding season.

Calving date, greatly influenced by date of conception, can influence the productiveness of a female as well as their subsequent progeny's performance. In addition to selecting heifers that become cyclic prior to the breeding season, heifers that calve early may have potential

advantages over those that calve late in the calving season. A greater proportion of heifers that calved in the first 21 d period of the calving season remained in the herd long enough to produce a fifth calf (Cushman et al., 2013). Females that calve in the first 21 d period of the calving season will also raise more kg of calf in their lifetime than those that calve in the second or third 21 d period of the calving season (Lesmeister et al., 1973). Antral follicle count, an indicator of fertility, was increased in heifers that calved in the first 21 d of the calving season (Cushman et al., 2014). Heifers with greater antral follicle counts were also more likely to become pregnant (Cushman et al., 2009). It is the selection of females that conceive early in the breeding season could allow for increase herd longevity (Perry and Cushman, 2013).

Calving Heifers

Bos Taurus heifers are expected to calve at 2 years of age in North America (Day and Nogueira, 2013). However females must have reached puberty prior to the breeding season for this to occur. A heifer must therefore become pubertal before 15 months of age if she is to calve at 2 years of age (Laster et al., 1972). Due to the increased calving difficulty risk with heifers, breeding 2-3 weeks ahead of the mature cow herd allows more time for young females to recover after their first birth (Larson, 2007). An uncomplicated calving should result in a recovery lasting roughly 30 d, including uterine involution (Diskin and Kenny, 2014). Recovery of uterine involution and the return of normal gonadotropin releasing hormone and luteinizing hormone frequencies dictate the time in which a female will return to estrus (Crowe et al., 2014). Just as in other species, the timing of a female to naturally become pubertal is variable.

Artificial insemination is a biotechnology used for reproductive improvement in many species, specifically livestock (Foote, 2002). Although available for over 40 years, adoption of AI in the U.S. beef industry is less than eight percent (NAHMS, 2009). Artificial insemination

and estrus synchronization (ES) and AI are tools used to enhance reproductive management. Estrus synchronization involves the manipulation of the estrus cycle for the purpose of bringing a large proportion of females into estrus at a predetermined time (Odde, 1990). Estrus synchronization has the potential to increase calf uniformity (Lamb et al., 2010). The use of artificial insemination also allows producers the ability to incorporate superior genetics into their herds without having to purchase a bull of similar quality (Lamb et al., 2010). The use of estrus synchronization (ES) and AI are mainly utilized by seedstock or purebred industry as opposed to the commercial industry that relies heavily on the use of natural service or bull breeding (Anderson et al., 2008). With increased management, labor, and time associated with implementing AI and ES combined with a large percentage of cattle being raised on a range type environment, producers may not see the economic value in such technology (Odde, 1990).

Heifer puberty is effected by nutrition (Cardoso et al., 2014), body weight and frame size (Fox et al., 1988), and breed (Freetly et al., 2011). Artificial insemination allows producers the opportunity to select for traits available in proven sires. Artificial insemination also decreased the mean days to conception compared to females bred via natural service (Steichen et al., 2012). Concentration of the calving season, possible with use of ES and AI, may allow for more calves to be born earlier in the calving season (Rodgers et al., 2012). In addition, heifers that conceive during a synchronized period wean calves that are older and heavier at weaning time, compared with heifers that do not conceive during the synchronized period (Steichen et al., 2014). Females born early in the calving season may be heavier at the time of breeding, be cyclic earlier and as a result, may become pregnant earlier in the breeding season. The objective of the current study was to evaluate the use of artificial insemination in dams and its subsequent effect of progeny heifer growth, attainment of puberty and pregnancy rates.

Section 2: Vaccination

Immune System Function

When microorganisms invade a host, immune responses occur in order to protect the host from harm (Schauber et al., 2008). Antigens, or substances like microorganisms, viruses, bacteria, and toxins are substances that evoke an immune response. There are 3 lines of defense of immune protection in the body, physical barriers, the innate immune system, and the acquired immune system. Physical barriers like skin, self-cleaning mucosal surfaces, and normal microbial flora are the primary deterrent of microorganisms and first line of defense in immune protection (Tizard, 2000). Skin allows for wound healing at a very quick rate when damaged, whereas the ability to cough and sneeze allows mucous to flow and rid the body of the pathogen. Also, each individual has an established microbial population associated with their skin and mucous membranes. The body is able to recognize the differences between the normal microbial flora, or self, and any bacterial or viral intruders that may be trying to do harm.

The next line of defense from foreign microbes in the body is the innate immune system, which can elicit an inflammatory response to invading potential pathogens. The innate immune system is a chemical and cellular defense that relies on the body's ability to differentiate between endogenous (normally occurring in the body) and exogenous (foreign organisms found in extracellular fluid or free in various tissues, i.e bacteria) chemical structures. When a microbial population colonizes a tissue, the body responds with increased blood flow (i.e. inflammation) and the movement of cells to the site of damage to begin the healing process (Tizard, 2000) as well as destruction of the microbial population (Benjamini et al., 2000). Neutrophils and macrophages are the cells that accumulate at the site of inflammation and function to attack and destroy antigen invaders. Neutrophils have the ability to bind, ingest, and digest foreign particles

through phagocytosis, yet have a very short lifespan (Tizard, 2000). Macrophages also function as phagocytes (Bhargava and Lee, 2012) and are attracted to the site of invasion by dying neutrophils. Macrophages are involved in tissue repair, removal of dead or dying tissue, and processing antigens for the acquired immune response (Tizard, 2000). Dendritic cells, like macrophages, function as antigen processors and are essential for initiating lymphocyte function and primary immune response (Akira et al., 2006). Dendritic cells collectively form a network within tissues and are found in all masses except brain, testes, and some parts of the eye.

The third and final line of defense in immune protection is acquired, or specific, immunity. Acquired immunity functions to produce antibody protection (proteins that bind exogenous or extracellular invaders; Law and Hangartner, 2008) as well as cell-mediated immunity (the activation of specific cells that can destroy exogenous material, create memory and protect from further damage; Tizard, 2000). Once an antigen has been taken up by macrophages or dendritic cells, it is processed and presented to the T cell for further processing (Ferenbach and Hughes, 2008). T cells are categorized as helper T cells, those that regulate immune responses (Tizard, 2000), and cytotoxic T cells, those that are made up of a population of lymphocytes that have the ability to destroy endogenous antigens (Entricam, 2002). The trapping of antigens and attraction of T cells by dendritic cells, the most efficient antigen processor, allows the presentation of the antigen for further processing as well as production of antibody by B-cells (Banchereau and Steinman, 1998). B cells are lymphocytes involved in antigen processing as well as the production of antibodies. These B cells are able to bind whole antigens and are able to make antibodies and are crucial for T cell function (Tizard, 2000). Acquired immunity also has the ability to retain the memory of a previous interactions with specific antigens (Tizard, 2000). The immune system is able recognize an antigen if it is later

confronted with it, allowing a fast, effective removal of the pathogen. With a complex immune system and specific layers of cells used as a protective barrier, the host is protected from various pathogens that threaten the survival of that individual (Entrican, 2002).

Vaccinations

Vaccines are comprised of the antigenic material in which they are to protect against as well as other constituents such as preservatives, biological growth media, adjuvants and stabilizers (Eldred et al., 2006). Vaccines are given in order to induce an immune response, varying by type, to a pathogen for the purpose of protection against that specific pathogen (Halloran et al., 1997). Antigens within a vaccine are administered for the purpose of creating a response and a memory of the antigen to protect vaccinated individual at a later date (Pashine et al., 2005). Antibodies only bind to specific antigens that are able to stimulate their production and are then able to help destroy that antigen (Tizard, 2000). Vaccinations are often given multiple times, especially when vaccinating for the first time or for a new antigen or pathogen. The concept of boostering a vaccine, as a second injection is commonly referred to, is to increase the effectiveness of the protection being offered (Benjamini, 2000). The primary immunization allows for modest immune response. The second and third immunizations, booster vaccinations, allow for a secondary rapid rise in immune response and an improved ability to bind to the antigen and neutralize the pathogen. Antibody production is increased as well as immunological memory (West and Calandra, 1996). Once immunized, an individual should have the immunity to reduce the degree or duration of an infection or no longer be affected by the infectious pathogen. When a group or herd of animals is vaccinated against a specific pathogen, the widespread vaccination causes a reduction in transmission of the disease and indirectly becomes effective even for those animals that were not vaccinated (Halloran et al., 1997). The resistance

of a group as a result of reduced transmission due to high immunization is known as herd immunity (John and Samuel, 2000). Although transmission of a disease may be lowered, unvaccinated animals are still fully susceptible to infection if exposed (Fine et al., 2011).

Pathogens within a vaccine can be toxins, bacterial, viral or both viral and bacterial, and are classified by being either inactivated or modified-live. Inactivated or killed vaccines, as the name implies, contain only microorganisms, organisms, or organism by-products that are non-viable as a result of either heat or chemical treatment (Griffin et al., 2002; Eldred et al., 2006). Organisms in killed vaccines can no longer replicate and therefore pose no threat of becoming virulent. Inactivated vaccines function primarily to produce antibodies and do so with the use of adjuvants, or immunological agents that aid in immune response (Griffin et al., 2002). Modified-live vaccines contain live virus, in very small amounts, that has been altered and can no longer cause disease. Unlike inactivated vaccines, modified-live vaccines have the ability to produce a cell-mediated response as well as build antibodies (Frey, 2007).

The decision to use either inactivated or modified-live vaccines should be based on the specific needs of a particular herd, as there are advantages and disadvantages for both types of vaccination (Table 1.1.). Inactivated vaccines are safe, not immunosuppressive and with no threat of reversion to virulence (Kelling, 2004). Inactivated vaccines also elicit a humoral response. However, inactivated vaccines induce the production of specific antibodies and do not produce as strong or long lasting effects compared to modified-live vaccines (Kelling, 2004). Modified-live vaccinations provide a wider range of protection by the activation of all immune phases including humoral and cell-mediated response as well as producing a faster immune response to pathogens encountered (Detmer and Glenting, 2006; Griffin et al., 2002). However,

modified-live vaccines, while attenuated and selected for reduced virulence, have the ability to return to virulence if vaccination contains contaminated virus (Meeusen et al., 2007).

Table 1.1. Benefits and risks associated with inactivated (killed) or modified-live vaccines[1]

Inactivated		**Modified-live**	
Benefits	Risks	Benefits	Risks
• Safe	• Narrow spectrum of protection	• Wide range of protection	• Potential for return to virulence
• Not immunosuppressive	• Limited effects	• Humoral and cell-mediated immunity	• Causes reduced fertility when given at certain times
• No risk of reversion to virulence	• Not as long lasting immunity	• Quick immune response	• Shouldn't be given during pregnancy
• Safe in pregnant animals	• Requires more than 1 dose	• Labeled for use > 30 d before breeding	

[1]Adapted from Griffin, 2002, Kelling, 2004, Detmer and Glenting, 2006, and Meeusen et al., 2007.

Diseases Impacting Reproduction

An immune response, while possible in all tissues, employs the use of certain cells that are tissue specific and have the ability to act and respond in a specific manner. Epithelial cells that are found within the reproductive tract of females provide a physical barrier. Also, epithelial cells aid in the functions of the innate and acquired immune systems through the mucosal surface of the uterus, uterine horns, and vagina (Wira et al., 2005). When infections caused by a pathogen occur, the result is inflammation and a rise in temperature of the specified area. The immune response, which is needed for that individual, can also cause embryonic mortality (Vanroose et al., 2000). Protection from pathogens is done with vaccinations or by exposure to

an exogenous antigen and a buildup of antibodies. In vaccinations, antigens that have similar targets or affects, are combined to simplify the immunization process (Halsey, 2001). Diseases, or pathogens, such as bovine viral diarrhea virus (BVDV), infectious bovine rhinotracheitis (IBR), bovine respiratory syncytial virus (BRSV), parainfluenza virus 3 (PI3), and a host of *Leptospira* bacteria are among those often combined to protect against a wider array of antigens (Van Oirschot et al., 1999).

One of the most important diseases effecting cattle reproduction is BVDV (Grooms et al., 1998a). Bovine viral diarrhea virus is a single stranded RNA virus member of the *Pestivirus* genus and *Flaviviridae* family that affects the reproductive tracts of female cattle (Kelling, 2004). Bovine viral diarrhea virus has been identified and categorized into two strains, genotype 1 and 2, of which are both present in most modern day vaccines (Van Oirschot et al., 1999). Acute symptoms of BVD include, alteration of ovarian function and decreased fertility of nonpregnant females (Kelling, 2004), whereas more subjective signs of pregnant females are characterized by ovarian, placenta and fetal infections (Brownlie et al., 1998). Infection of fetal tissues at any time of gestation can result in abortion and embryonic and fetal loss; however, infection occurring during early fetal development (d 50-150 of gestation) generally leads to tolerance of the virus and a persistently infected calf upon birth. Infections occurring in late gestation (d 180 or greater), have a higher probability of surviving by way of immune response from the dam. Of all symptoms of BVDV, the persistently infected animal is among the most dangerous and costly. Persistently infected animals are sources of continuous infection that have the ability to shed virus to other cattle (Brock et al., 1998). Persistently infected animals are able to infect a gestating female, even if the female has been previously vaccinated against BVDV (Wittum et al., 2001). If cows vaccinated against BVDV come into contact with a BVDV

infected animal, that individual may contract the virus and show no clinical signs. However the virus could also be transmitted to a fetus via the dam and cause abortion, fetal malformations, or another PI calf (Frey et al., 2007). Sufficient control of BVDV within a herd can be done with the use of vaccination and the testing and culling of PI animals (Wittum et al., 2001).

Infectious bovine rhinotracheitis is caused by bovine herpesvirus-1 infection, a cell-derived envelope containing virally encoded membrane protein and member of the herpesvirus family (Muylkens et al., 2007). Symptoms of IBR include necrotizing oophoritis, inflammation of the corpus luteum and abortions (Givens, 2006). Fetal loss can occur as "abortion storms", or the mass fetal death within a herd. Abortions caused by IBR infection can occur within 24 hours after viral entry into blood leukocytes and placental tissues (Givens, 2006), however viral infection could remain as a latent infection (Anderson, 2007). Naïve heifers challenged with intravenous BHV-1 at 180 d of gestation had an 85.7% protection rate when vaccinated with an inactivated vaccine (Zimmerman et al., 2007). In contrast, 100% of unvaccinated heifers aborted after an IV BHV-1 challenge (Zimerman et al., 2007). Infection of BHV-1 may become latent once exposed due to the nature of a herpesvirus, however vaccination can aid in the control of outbreaks (Payne, 2013). Fetal and placental tissues expelled from females aborting as a result of IBR infections are also infected with the virus. Transmission of BHV-1 is possible if unvaccinated or naïve cattle come into contact with infected tissue. Infected fetal and placental tissues are characterized by dark red coloring due to hemoglobin imbibition as well as lesions on surrounding organs (Givens, 2006).

Leptospires are spirochete bacteria that invade the kidneys and genital tract and cause a systemic disease called leptospirosis (Adler and de la Pena Moctezuma, 2010). Symptoms of leptospirosis are fever, renal failure, liver failure, and reproductive failure. Infection during

gestation can cause fetal death at any stage (Grooms, 2006), as well as stillbirths, fetal mummification, and weak offspring (Adler and de la Pena Moctezuma, 2010). Over 200 different Leptospira bacterium have been identified with carriers, or hosts, often being wildlife such as rodents and mice, however all land mammals are capable of being a carrier (Adler and de la Pena Moctezuma, 2010). Commonly, cattle vaccinations include leptospira canicola, grippotyphosa, hardjo-bovis, Pomona, and icterohaemorrhagiae. Serovar hardjo-bovis is the host adapted species in cattle and is transmitted via infected urine, placental fluids, or milk (Alt et al., 2001). Transmission occurs from direct or indirect contact with urine or infected tissues of cattle or hosts infected (Adler and de la Pena Moctezuma, 2010). Invasion by leptospires occurs through mucosal membranes and is then carried into the blood (Alt et al., 2001). Infection can circulate through the kidneys and cause shedding through the urine for months to years. Treatments with antibiotics can be effective, but cattle are easily protected from leptospirosis using vaccines that include multiple serovars (BonDurant, 2007).

Bovine respiratory syncytial virus and parainfluenza virus 3 are infectious diseases that do not directly affect the reproductive system but the respiratory system. BRSV is an enveloped, non-segmented, negative-stranded RNA virus that is a member of the pneumovirus genus and can affect both calves and adult cattle. Although generally diagnosed in the autumn and winter months, it is possible to see in spring as it is transmitted by direct contact between infected animals or by aerosol exposure (Valarcher and Taylor, 2007).

Impact of Vaccination on Reproductive Performance

Before evaluating differences in vaccines types, we must first know what happens when vaccines are not administered. Bovine viral diarrhea virus has a predilection to both oviduct epithelial cells and granulosa cells within the reproductive tissue of female cattle (Booth et al.,

1995). Fertility can be drastically impacted with the infection of oviduct epithelial and granulosa cells, as infection could carry over further into other reproductive tissues. Growth rate and size of dominant anovulatory and dominant ovulatory follicles decreased after acute infection with BVDV compared with the results seen prior to inoculation (Grooms et al., 1998b). When vaccines are given prior to breeding, a reduction in fetal loss due to infected tissues can be seen. Heifers vaccinated with an inactivated IBR vaccine, according to manufacturer recommendations, had fewer abortions than the nonvaccinated control heifers (Zimmerman et al., 2007). Similarly, cows vaccinated with IBR, BVDV, and leptospirosis had greater pregnancy rates and a greater proportion remained pregnant to artificial insemination compared to nonvaccinated control cows (Aono et al., 2013).

Although vaccinations are a tool to help protect reproductive health, potential virulence has caused concerns about the impacts of vaccination on reproductive performance in beef cattle. As a result of modified live vaccinations containing live virus, a potential risk is incurred with use, in the form of residual virulence (Tizard, 20000). Use of modified-live vaccines during estrus synchronization lowered the proportion of females becoming pregnant following the first estrus cycle compared to nonvaccinated females (Chaing et al., 1990). Similarly, heifers vaccinated with a modified live vaccine at the initiation of estrus synchronization had lower pregnancy rates than nonvaccinated heifers or heifers receiving an inactivated vaccine (Perry et al. 2013). In both cases, manufacturer recommendations were not followed.

As vaccinations are given to lower the risk of disease and economic loss, correct vaccination protocols and timing should be considered. Most vaccinations are designed to reach their peak immune response two to four weeks after administration, however variability does occur between kind of vaccines administered and previous immunity or vaccination (Daly,

2007). Any vaccination given not according to the manufacturer's recommendations or directions, including the timing of the vaccination, is considered off-label use. On-label use is a term used for management considerations that allow for complete accordance with the directions given to a specific product. Proper management should allow for the manufacturers recommendations to be followed when administering vaccinations of any kind (Kelling, 2004). Perry et al., (2013) found that administering modified-live vaccinations at the time of estrus synchronization lowered pregnancy rates 48 percent compared to those females given a killed virus 36 d before breeding and a booster killed vaccine at the time of estrus synchronization (8 d before breeding). Effects of vaccination type on reproductive performance, when administered according to manufacturer's recommendations is currently unknown. The current study was done to evaluate the effects of varying types of vaccination on reproduction when given according to label recommendations.

Literature Cited

Adler, B., and A. de la Pena Moctezuma. 2010. *Leprospira* and leptospirosis. Vet. Micro. 140:287-296.

Akira, S., S. Uematsu, and O. Takeuchi. 2006. Pathogen recognition and innate immunity. Cell. 124:783-801.

Alt, D. P., R. L. Zuerner, and C. A. Bolin. 2001. Evaluation of atibiotics for treatment of cattle infected with *Leptospira borgpetersenii* serovar hardjo. JAVMA. 219:636-639.

Anderson, J. D., Rhinehart, J. D., and Parish, J. A. 2008. Economic impact of artificial insemination vs. natural matimg for beef cattle herds. The Beef Site. ECT.

Anderson, M. L. 2007. Infectious causes of bovine abortion during mid- to late-gestation. Theriogenology. 68: 474-486.

Animal and Plant Health Inspection Service. 2009. Vaccination of cattle and calves on U. S. beef cow-calf operations. USDA Info sheet. Veterinary Services.

Aono, F. H., R. F. Cooke, A. A. Alfieri, and J. L. M. Vasconcelos. 2013. Effect of vaccination against reproductive diseases on reproductive performance of beef cows submitted to fixed-time AI in Brazilian cow-calf operations. Theriogenology. 79:242-248.

Atkins, J. A., K. G. Pohler, and M. F. Smith. 2013. Physiology and endocrinology of puberty in heifers. Vet. Clin. Food Anim 29:479-792.

Banchereau, J. and R. M. Steinman. 1998. Dendritic cells and the control of immunity. Nature. 392:245-252.

Barker, D. J. P., C. N. Martyn, C. Osmond, C. N. Hales, and C. H. D. Fall. 1993. Growth in utero and serum cholesterol concentration in adult life. BMJ. 307:1524-1527.

Benjamini, E., R. Coico, and G. Sunshine. 2000. Immunology: a short course, fourth edition. Wiley-Liss, Inc. New York, NY. p 18-29.

Bhargava, P., and C. Lee. 2012. Role and function of macrophages in the metabolic syndrome. Biochem. J. 442:253-262.

BonDurant, R. H. 2007. Selected diseases and conditions associated with bovine conceptus loss in the first trimester. Theriogenology. 68:461-471.

Booth, P. J., D. A. Stevens, M. E. Collins, and J. Brownlie. 1995. Detection of bovine viral diarrhea virus antigen and RNA in oviduct and granulosa cells of persistently infected cattle. J. Reprod. Fert. 105:17-24.

Brock, K. V., D. L. Grooms, J. Ridpath, and S. R. Bolin. 1998. Changes in levels of viremia in cattle persistently infected with bovine viral diarrhea virus. J. Vet. Diagn. Invest. 10:22-26.

Brownlie, J., L. B. Hooper, I. Thompson, and M. E. Collins. 1998. Maternal recognition of foetal infection with bovine virus diarrhea virus (BVDV)- the bovine pestivirus. Clin. Diagn Virol. 10:141-150.

Busch, D. C., D. J. Wilson, D. J. Schafer, N. R. Leitman, , J. K. Haden, M. R. Ellersieck, M. F. Smith, and D. J. Patterson. 2007. Comparison of progestin-based estrus synchronization protocols before fixed-time artificial insemination on pregnancy rate in beef heifers. J. Anim. Sci. 85:1933-1939.

Buskirk, D. D., D. B. Faulkner and F. A. Ireland. 1995. Increased postweaning gain of beef heifers enhances fertility and milk production. J. Anim. Sci. 73:937-946.

Byerley, D. J., R. B. Staigmiller, J. G. Berardinelli, and R. E. Short. 1987. Pregnancy rates of beef heifers bred either on pubertal or third estrus. J. Anim. Sci. 65:645-650.

Cardoso, R. C., B. R. C. Alves, L. D. Prezotto, J. F. Thorson, L. O. Tedeschi, D. H. Keisler, C. S. Park, M. Amstalden, and G. L. Williams. 2014. Use of stair-step compensatory gain

nutritional regimen to program the onset of puberty in beef heifers. J. Anim. Sci. jas.2014-7713; published ahead of print May 30, 2014, doi:10.2527/jas.2014-7713

Chiang, B. C., P. C. Smith, K. E. Nusbaum, and D. A. Stringfellow. 1990. The effect of infectious bovine rhinotracheitis vaccine on reproductive efficiency in cattle vaccinated during estrus. Theriogenology. 33:1113-1120.

Crowe, M. A., M. G. Diskin, and E. J. Williams. 2014. Parturition to resumption of ovarian cyclicity: comparative aspects of beef and dairy cows. Animal. 8:40-53.

Cushman, R. A., A. K. McNeel, and H. C. Freetly. 2014. The impacts of cow nutrient status during the second and third trimesters on age at puberty, antral follicle count, and fertility of daughters. Livestock. Sci. 162:252-258.

Cushman, R. A., L. K. Kill, R. N. Funston, E. M. Mousel, and G. A. Perry. 2013. Heifer calving date positively influences calf weaning weights through six parturitions. J. Anim. Sci. 91:4486-4491.

Cushman, R. A., M. F. Allen, L. A. Kuehn, W. M. Snelling, A. S. Cupp, and H. C. Freetly. 2009. Evaluation of antral follicle count and ovarian morphology in crossbred beef cows: investigation of influence of stage of the estrus cycle, age, and birth weight. J. Anim. Sci. 87:1971-1980.

Daly, R. 2007. Timing of reproductive vaccinations in beef cattle herds. Proceedings Applied Reproductive Strategies in Beef Cattle, Billings, MT. 2007:209-214.

Day, M. L., and G. P. Nogueira. 2013. Management of age at puberty in beef heifers to optimize efficiency of beef production. Anim. Front. 3:6-10.

Detmer, A. and J. Glenting. 2006. Live bacterial vaccines- a review and identification of potential hazards. Microbial Cell Factories. 23:1-12.

Diskin, M. G., and D. A. Kenny. 2014. Optimizing reproductive performance of beef cows and replacement heifers. Animal.8:27-39.

Dzuik, P. J. and R. A. Bellows. 1983. Management of reproduction of beef cattle, sheep and pigs. J. Anim. Sci. 57:355-379.

Eldred, B. E., A. J. Dean, T. M. McGuire, and A. L. Nash. 2006. Vaccine components and constituents: responding to consumer concerns. Med. J. Aust. 184:170-175.

Entrican, G. 2002. Immune regulation during pregnancy and host-pathogen interactions in infectious abortion. J. Comp. Path. 126:79-94.

Ferenback, D., and J. Hughes. 2008. Macrophages and dendritic cells: what is the difference?. Kidney Int. 74:5-7.

Fine, P., K. Eames, and D. L. Heymann. 2011. “Herd immunity”: a rough guide. Vaccines. 52:911-916.

Foote, R. H. 2002. The history of artificial insemination: selected notes and notables. J. Anim. Sci. 80:1-10.

Fox, D. G., C. J. Sniffen, and J. D. O’Connor. 1988. Adjusting nutrient requirements of beef cattle for animal and environmental variations. J. Anim. Sci. 66:1475-1495.

Freetly, H. C., L. A. Kuehn, and L. V. Cundiff. 2011. Growth curves of crossbred cows sired by Hereford, Angus, Belgian Blue, Brahman, Boran, and Tuli bulls, and the fraction of mature body weight and height at puberty. J. Anim. Sci. 89:2372-2379.

Frey, J. 2007. Biological safety concepts of genetically modified live bacterial vaccines. Vaccine. 25:5598-5605.

Funston, R. N., J. A. Mustgrave, T. L. Meyer, and D. M. Larson. 2012. Effect of calving distribution on beef cattle progeny performance. J. Anim. Sci. 90:5118-5121.

Gasser, C. L. 2013. Joint alpharma-beed species symposium: considerations on puberty in replacement heifers. J. Anim. Sci. 91:1336-1340.

Givens, M. D. 2006. A clinical, evidence-based approach to infectious causes of infertility in beef cattle. Theriogenology. 66:648-654.

Greer, R. C., R. W. Whitman, R. B. Staigmiller, and D. C. Anderson. 1983. Estimating the impact of management decisions on the occurrence of puberty in beef heifers. J. Anim. Sci. 56:30-39.

Griffin, D., S. Ensley, and G. Dewell. 2002. Understanding vaccines. University of Nebraska-Lincoln Extension Publication. G1445.

Grooms, D. L. 2006. Reproductive losses caused by bovine viral diarrhea virus and leptospirosis. Theriogenology. 66:624-628.

Grooms, D. L., K. V. Brock, and L. A. Wood. 1998a. Detection of bovine viral diarrhea virus in the ovaries of cattle acutely infected with bovine viral diarrhea virus. J. Vet. Diagn. Invest. 10:125-129.

Grooms, D. L., K. V. Brock, J. L. Pate, and M. L. Day. 1998b. Changes in ovarian follicles following acute infection with bovine viral diarrhea virus. Theriogenology. 49:595-605.

Gutierrez, K., R. Kasimanickam, A. Tibary, J. M. Gay, J. P. Kastelic, J. B. Hall, and W. D. Whittier. 2014. Effect of reproductive tract scoring on reproductive efficiency in beef heifers bred by timed insemination and natural service versus only natural service. Theriogenology 81:918-924.

Halloran, M. E., C. J. Struchiner, and I. M. Longini, Jr. 1997. Study designs for evaluating different efficacy and effectiveness aspects of vaccines. Am. J. Epidemiol. 146:789-803.

Halsey, N. A. 2001. Safety of combination vaccines: perception versus reality. Pediatr. Infect. Dis. J. 20:S40-44.

John, T. J., and R. Samuel. 2000. Herd immunity and herd effect: new insights and definitions. European J. Epidemiology. 16:601-606.

Kelling, C. L. 2004. Evolution of bovine viral diarrhea virus vaccine. Vet. Clin. Food Anim. 20:115-129.

Lamb, G. C., C. R. Dahlen, J. E. Larson, G. Marquezini, and J. S. Stevenson. 2010. Control of the estrous cycle to improve fertility for fixed-time artificial insemination in beef cattle: a review. J. Anim. Sci. 88: E181-E192.

Lamb, G. C., J. E. Larson, T. W. Geary, J. S. Stevenson, S. K. Johnson, M. L. Day, R. P. Ansotegui, D. J. Kesler, , J. M. DeJarnetteand, and D. G. Landblom. 2006. Synchronization of estrus and artificial insemination in replacement beef heifers using gonadotropin-releasing hormone, prostaglandin $F_{2\alpha}$, and progesterone. J. Anim. Sci. 84:3000-3009.

Larson, J. E., G. C. Lamb, J. S. Stevensson, S. K. Johnson, M. L. Day, T. W. Geary, D. J. Kesler, J. M. DeJarnette, F. N. Schrick, A. DiCostanzo, and J. D. Arseneau. 2006. Synchronization of estrus in suckled beef cows for detected estrus and artificial insemination and times artificial insemination using gonadotropin-releasing hormone, prostaglandin $F_{2\alpha}$, and progesterone. J. Anim Sci. 84: 332-342.

Larson, R. L. 2007. Heifer development: reproduction and nutrition. Vet. Clin. Food Anim. 23:53-68.

Laster, D. B., H. A. Glimp, and K. E. Gregory. 1972. Age and weight at puberty and conception in different breeds and breed-crosses of beef heifers. J. Anim. Sci. 34:1031-1036.

Law, M., and L. Hangartner. 2008. Antibodies against viruses: passive and active immunization. Curr. Opin. Immunol. 20:486-492.

Lee, D., I. Misztal, J. K. Bertrand, and R. Rekaya. 2002. National evaluation of calving ease, gestation length, and birth weight by linear and threshold model methodologies. A. Appl. Genet. 43:209-216.

Lesmeister, J. L., P. J. Burfening, and R. L. Blackwell. 1973. Date of first calving in beef cows and subsequent calf production. J. Anim. Sci. 36:1-6.

Martin, J. L., K. A. Vonnahme, D. C. Adams, G. P. Lardy, and R. N. Funston. 2007. Effects of dam nutrition on growth and reproductive performance of heifer calves. J. Anim. Sci. 85:841-847.

Meeusen, E. N. T., J. Walker, A. Peters, P. Pastoret, and G. Jungersen. 2007. Current status of veterinary vaccines. Clin. Micro. Rev. 20:489-510.

Morgan, C., J. F. Quirke, and J. F. Roche. 1989. Puberty in heifers: a review. Anim. Repro. Sci. 18:167-182.

Muylkens, B., J. Thiry, P. Kirten, F. Schynts, and R. Thiry. 2007. Bovine herpesvirus 1 infection and infectious bovine rhinotracheitis. Vet. Res. 38:181-209.

National Animal Health Monitoring Service (NAHMS). 2009. Beef 2007-08 Part II: Reference of beef cow-calf management practices in the United States. 2007-08. Pages 18-27. Natl. Anim. Health Monit. Ser., Fort Collins, CO.

Odde, K. G. 1990. A review of synchronization of estrus in postpartum cattle. J. Anim. Sci. 68: 817-830.

Pashine, A., N. M. Valiante, and J. B. Ulmer. 2005. Targeting the innate immune response with improved vaccine adjuvants. Nature. Med. Supp. 11:563-568.

Patterson, D. J., S. L. Wood, and R. F. Randle. 1999. Procedures that support reproductive management of replacement beef heifers. J. Anim. Sci. 77:1-15.

Payne, C. A., B. Vander Ley, and S. E. Poock. 2013. Setting the stage for long-term reproductive health. Vet. Clin. Food Anim. 29:555-565.

Perry, G. A., A. D. Zimmerman, R. F. Daly, R. E. Buterbaugh, J. Rhoades, D. Scholz, A. Harmon, and C. C. L. Chase. 2013. The effects of vaccination on serum hormone concentrations and conception rates in synchronized naïve beef heifers. Theriogenology. 79:200-205.

Perry, G. A., and R. A. Cushman.2013. Effect of age at puberty/conception date on cow longevity. Vet. Clin. Food Anim. 29:579-590.

Rodgers, J. C., S. L. Bird, J. E. Larson, N. Dilorenzo, C. R. Dahlen, A. Diconstanzo, and G. C. Lamb. 2012. An economic evaluation of estrus synchronization and timed artificial insemination in suckled beef cows. J. Anim. Sci. 90:4055-4062.

Schauber, J. and R. L. Gallo. 2008. Antimicrobial peptides and the skin immune defense system. J. Allergy Clin. Immunol. 122:261-266.

Schillo, K. K., J. B. Hall, and S. M. Hileman. 1992. Effect of nutrition and season on the onset of puberty in the beef heifer. J. Anim. Sci. 70:3994-4005.

Senger, P. L. 2003. Pathways to pregnancy and parturition, second revised edition. Current Conceptions, Inc., Pullman, WA. p. 360.

Short, R. E., and R. A. Bellows. 1971. Relationships among weight gains, age at puberty and reproductive performance in heifers. J. Anim. Sci. 32:127-131.

Steichen, P. L., S. I. Klein, Q. P. Larson, K. M. Bischoff, V. G. R. Mercadante, G. C. Lamb, C. S. Schauer, B. W. Neville, and C. R. Dahlen. 2014. Effects of artificial insemination and natural service breeding systems on calving characteristics and weaning weights of resulting progeny. ASAS Joint Annual Meeting, Kansas City, MO. (Abstr).

Steichen, P. L., S. L. Klein, Q. P. Larson, K. M. Bischoff, V. G. R. Mercadante, G. C. Lamb, C. S. Schauer, B. W. Neville, and C. R. Dahlen. 2012. Effects of natural service and artificial insemination breeding systems on pregnancy rates and days to conception. Proceedings: ASAS Western Section. 63:66-69.

Tizard, I. R. 2000. Veterinary immunology: an introduction, sixth edition. W. B. Saunders Company, Philadelphia, PA. p. 1-8, 58-68, 235-252.

Valarcher, J., and G. Taylor. 2007. Bovine respiratory syncytial virus infection. Vet. Res. 38:153-180.

Van Oirschot, J. T., C. J. M. Bruschke, and P. A. Van Rijn. 1999. Vaccination of cattle against bovine viral diarrhea. Vet. Microbiol. 64:169-183.

Vanroose, G., A. de Kruif, and A. Van Soom. 2000. Embryonic mortality and embryo-pathogen interactions. Anim. Reprod. Sci. 60-61:131-143.

West, D. J., and G. B. Calandra. 1996. Vaccine induced immunologic memory for hepatitis B surface antigen: implication for policy on booster vaccination. Vaccine. 14:1019-1027.

Wira C. R., K. S. Grant-Tschudy, and M. A. Crane-Godreau. 2005. Epithelial cells in the female reproductive tract: a central role as sentinels of immune protection. AJRI. 53:65-76.

Wittum, T. E., D. M. Grotelueschen, K. V. Brock, W. G. Kvasnicka, J. G. Floyd, C. L. Kelling, and K. G. Odde. 2001. Persistent bovine viral diarrhea virus infection in US beef herds. Prevent. Vet. Med. 49:83-94.

Zimmerman, A. D., R. E. Buterbaugh, J. M. Herbert, J. M. Hass, N. E. Frank, L. G. Luempert, III, and C. C. L. Chase. 2007. Efficacy of bovine herpesvirus-1 inactived vaccine against abortion and stillbirth in pregnant heifers. JAVMA. 231:1386-1389.

CHAPTER 2. EFFECTS OF BREEDING SYSTEM OF ORIGIN (NATURAL SERVICE OR ARTIFICIAL INSEMINATION) ON GROWTH, ATTAINMENT OF PUBERTY, AND PREGNANCY RATES IN CROSSBRED BEEF HEIFERS

Abstract

The objective of this study was to compare growth, attainment of puberty, and pregnancy rates in beef heifers originating from two different breeding systems. One hundred and ninety crossbred Angus heifers were born to dams that were exposed to 1 of 2 treatments: 1) natural service (**NS**, cows were only exposed to herd bulls for the duration of the breeding season), or 2) fixed-time artificial insemination (**TAI**, cows exposed to ovulation synchronization and AI followed by natural-service bulls). Body weights of heifers were taken on d 0, the initiation of the study (weaning) and 189, pasture turnout) with a mean age of 209 ± 1.2 d at the initiation of the trial (d 0). Blood samples were collected at d 0, 10, 112, 122, 219, and 229 and concentrations of progesterone were used to determine the proportion of females that had attained puberty during the development period. On d 229 synchronization of ovulation was initiated (7-d CO-Synch + CIDR) and all heifers were inseminated with a single TAI at 54 h after CIDR removal. Clean-up bulls were placed in breeding pastures 10 d after AI and remained with heifers until 56 d after AI. Pregnancy rates were determined via transrectal ultrasonography on d 28 and 90 after AI. Body weight at initiation of the experiment was greater ($P = 0.01$) for heifers in the TAI treatment (239.9 ± 2.8 kg) compared with heifers in the NS treatment (229.6 ± 2.8 kg). No differences ($P \geq 0.14$) between treatments were observed in weights of heifers taken at the time of pasture turnout (d 189; 345.1 ± 3.4 and 338.0 ± 3.4 kg for TAI and NS, respectively),

or ADG (0.56 ± 0.01 and 0.58 ± 0.01 kg/d for AI and NS, respectively). At the initiation of the experiment a greater proportion of the NS heifers (11.6%) tended ($P = 0.06$) to be cyclic compared with TAI heifers (4.2%). However, no differences ($P \geq 0.40$) were observed between treatments in the proportion of heifers cyclic at the interim evaluation (d 112 and d 122, 27.5% cyclic) or at the initiation of the breeding season (d 219 and 229, 85.5% cyclic). No differences ($P \geq 0.81$) were present between treatments in either pregnancy rates to AI (d 28 relative to AI) 32.9% or season-ending (d 90 relative to AI) pregnancy rates 91.1%. In addition, no differences were seen in the distribution of calving (0-21 d: $P = 0.49$, 22-42 d: $P = 0.30$, >42 d: $P = 0.29$ and No Calf [heifers that did not calve]: $P = 0.68$).Breeding system of origin did not influence growth rate during the development phase, attainment of puberty, or pregnancy rates in crossbred beef heifers.

Introduction

A major factor in the determination of the herd lifespan of a female is the onset of puberty and the ability of that female to become pregnant every year. Calving date can influence the productiveness of a female as well as their subsequent progeny's performance. Heifer calves born in the first 21 d of the calving period have lower birth weights than those heifers born later in the calving season while also having higher weaning weights (Funston et al., 2012). Older and heavier heifers may become pubertal earlier than those born later in the calving season as females generally reach puberty at a time relative to their projected mature body weight and frame size (Fox et al., 1988). Those females that reach puberty 45 d before the start of any breeding program will be beneficial to the herd, as they will have several estrus cycles prior to insemination, and may conceive early in the breeding season (Hall, 2013).

The use of estrus synchronization would allow for the selection of heifers that become pregnant early in the breeding season (Gutierrez et al., 2014). Those heifers that become pregnant early in the breeding season and calve in the first 21 d of the calving season remain in the herd for a greater amount of time when compared to those that calve later (Cushman et al., 2013).

Our previous research has highlighted the fact that incorporating AI into a management scheme resulted in older, heavier calves at weaning compared with a breeding systems that relied solely on natural service breeding (Steichen et al., 2014). Fetal programming is the concept that perturbations to the maternal system during critical developmental windows can have both short- and long-term consequences on offspring outcomes (Barker et al., 1993). Factors such as compromised maternal nutrition and/or breeding system of origin may influence growth, performance, attainment of puberty, and, fertility of heifer progeny. Maternal stimuli including exposure of dams to artificial insemination and natural service breeding systems may alter heifer progeny age and body weight at weaning with concomitant changes in fertility and pregnancy rates. The objective of the current study was to evaluate post-weaning growth, attainment of puberty, and pregnancy rates of heifer progeny originating from either AI or natural service breeding systems.

Materials and Methods

All cattle were managed according to the Federation of Animal Science Guide for the Care and Use of Agricultural Animals in Agriculture Research and Teaching (FASS, 1999). All procedures were reviewed and approved by the Institutional Animal Care and Use Committee of North Dakota State University.

One hundred-ninety Angus based crossbred virgin heifers were managed at the Central Grasslands Research Extension Center, located approximately 14 km NW of Streeter, ND. Heifers were born to dams randomly assigned to one of 2 treatments (Steichen et al., 2014); 1) exposed to herd bulls for duration of breeding season (natural service; **Control**, n = 95) and 2) exposed to ovulation synchronization and fixed-time AI followed by natural service bulls for the duration of the breeding season (Timed AI; **TAI**, n = 95).

At the start of the experiment (heifer weaning), females were weaned (d 0), housed in a drylot for a 189 d wintering period (d 0-189), fed common diets that met or exceed NRC (1996) recommendations, and then turned out to pasture for summer grazing (d 189), breeding (d 239) and ultrasound pregnancy examinations (d 266 and d 320). Body weights were collected on two consecutive days prior to the AM feeding at the start (d -1 and 0) and end of the feeding period (d 188 and 189) which also coincided with pasture turnout. Blood samples were collected via jugular venipuncture or tail venipuncture in 10-mL Vacutainer tubes (BD Worldwide, Franklin Lakes, NJ) on d 0 and 10 (beginning), d 112 and 122 (middle), and d 219 and 229 (end) of the developmental period. Blood samples were analyzed for concentrations of progesterone via a radioimmunoassay (Coat-A-Count, Siemens Medical Solutions Diagnostics, Los Angeles, CA) to determine the proportion of cyclic females before the onset of breeding. The radioimmunoassay kit was validated using 100 μl for bovine serum (Kirby et al., 1997). Assay tubes for the standard curve contained 0.01, 0.025, 0.05, 0.2, 0.5, 1, 2, and 4 ng of progesterone per tube. Assay sensitivity was based on 100 μl sample in 0.1 ng/mL. Heifers were defined as cyclic at each point of the development period when either or both samples in the 10 d interval had concentrations of progesterone ≥ 1 ng/mL (Perry et al., 1991).

Before ovulation synchronization and breeding, 40 heifers were culled from the herd to achieve herd management objectives, resulting in 145 heifers remaining to be bred (Control; n = 66 and AI; n = 79). One hundred and forty-five heifers were exposed to ovulation synchronization (7-d CO-Synch + CIDR; Lamb et al., 2006), consisting of insertion of a controlled internal drug releasing insert (CIDR, 1.38 g Progesterone, Zoetis, Inc., Florham, NJ, USA) and 100 μg Gonadotrophin Releasing Hormone (GnRH) i.m. (2 mL Factrel, Zoetis, Inc.), followed in 7 d by CIDR removal and 25 mg $PGF_{2\alpha}$ i.m. (5 mL Lutalyse, Zoetis, Inc.), followed in 54 ± 2 h by 100 μg GnRH i.m. and fixed-time AI (d 239 AI). Clean-up bulls, were placed in breeding pastures 10 d after AI and remained with cows and heifers for 46 d (d 295).

Transrectal ultrasonography (5-MHz linear array transducer, Aloka 500V, Corometrics, Wallingford, CT) was used to determine presence of a viable fetus (via detection of fetal heartbeat) on d 28 and 90 relative to AI. Scans on d 28 were used to determine the proportion of females that became pregnant to AI, while scans on d 90 were used to determine season ending pregnancy rates.

All heifers were housed in a drylot for a 189 d wintering period (d 0-189), then turned out to native pasture for summer grazing (d 189). While in the drylot, heifers were fed a ration once daily that met or exceeded their NRC (1996) requirements. The diet consisting of approximately 2 kg of corn/hd/ daily and a mixture of corn silage and grass hay (Steichen, 2013). Native pastures were a northern mixed grass prairie consisting of Kentucky bluegrass (*Poa pratensis* L.), western snowberry (*Symphoricarpos occidentalis* Hook.), blue gamma (*Bouteloua gracilis* [H. B. K] Lag. Ex Griffiths), needle and thread [*Hesperostipa comate* (Trin. + Rupr.) Barkworth], and sun sedge (*Carex inops* spp. *Heliophila* L. H Bailey; Hirschfeld et al., 1996)). Heifers were followed through to parturition where birth date was recorded.

The GLM procedure of SAS (SAS Inst. Inc., Cary, NC) was used to analyze all continuous data (age, weight, average daily gain, and days to conception). The GENMOD procedure of SAS was used to analyze the binomial data (cyclic status, pregnancy rate, and calving distribution). A statistical model for date of birth of the calving season included effects of treatment (NS or TAI) and 21 d age increments of the calving season (0-21, 21-42, or > 42). Each model included the effect of treatment, natural service or artificial insemination. Significance was declared at $P \leq 0.05$.

Results

At the initiation of the study (weaning), heifers born of dams exposed to artificial insemination were older ($P = 0.004$) and heavier ($P = 0.01$) than the heifers born to dams exposed to natural service (Table 2.1.). Heifer body weights on d 189 were similar ($P = 0.14$) between treatments. Total gain and average daily gain (ADG) from d 0 to d 189 were also similar between treatments ($P \geq 0.23$).

Table 2.1. Effect of artificial insemination versus natural service on growth of beef heifers

	Treatment[1]			
Item	AI	NS	SE	*P* - value
No. heifers	95	95	-	-
Age, d[2]	212.9[a]	206.0[b]	1.67	< 0.01
Initial body weight, kg	239.9[a]	229.6[b]	2.83	0.01
Final body weight, kg	345.7	338.6	3.40	0.14
Gain, kg	105.8	100.0	1.86	0.23
ADG, kg	0.6	0.6	0.01	0.23

[1]Treatments: AI = Artificial insemination (dams of heifers exposed to ovulation synchronization and AI followed by natural service bulls), NS = Natural service. (dams of heifers only exposed to herd bulls for the duration of the breeding season).
[2]Age = the age of heifers at the initiation of the experiment (weaning).
[a,b]Means within rows with uncommon superscripts differ ($P \leq 0.05$).

A greater proportion of heifers in the natural service treatment tended ($P = 0.06$) to be cyclic at the beginning of the developmental period (d 0-10), compared with heifers in the AI treatment (Figure 2.1.). Concentrations of progesterone were used to determine cyclic status of heifers at time of weaning, roughly 1 year of age, and finally at the time of CIDR insertion prior to breeding. If females had not yet become cyclic at this point in their life cycle, successful breeding and pregnancy may not be reached (Byerley et al., 1987). However, no differences ($P \geq 0.40$) were observed among treatments in the proportion of cyclic heifers at the midpoint of the development phase and the initiation of the breeding season. Although no differences were noted in heifer cyclicity , it is important to note the high number of heifers that were cyclic prior to the start of the breeding season (i.e. 86 percent cyclic).

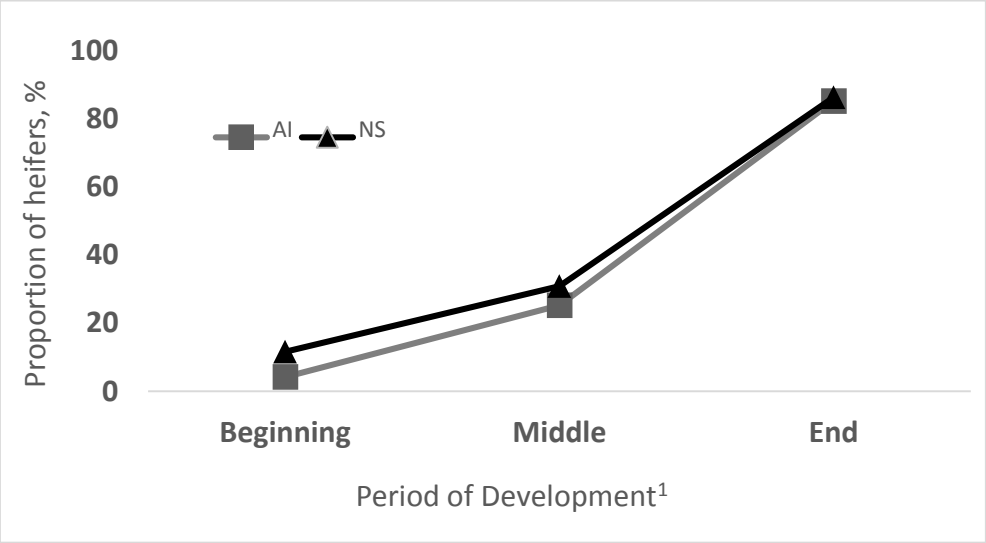

Figure 2.1. Effect of artificial insemination versus natural service on the attainment of puberty
Treatments: AI = Artificial insemination (dams of heifers exposed to ovulation synchronization and AI followed by natural service bulls), NS = Natural service (dams of heifers only exposed to herd bulls for the duration of the breeding season).
[1]Cyclic status at beginning, middle, and end represent the period of development in which blood samples were taken.

No differences between treatments in pregnancy rate ($P \geq 0.71$) were observed. In addition, days to conception were similar ($P = 0.71$) for heifers born to dams exposed to AI or natural service (Table 2.2.). Also, no differences in the distribution of calves born in 21 d calving intervals ($P \geq 0.11$) were observed (Figure 2.2.).

Table 2.2. Effect of artificial insemination versus natural service on pregnancy status of beef heifers

	Treatment[1]		
Item	AI n = 95	NS n = 95	*P* - value
Pregnancy[2], %			
AI	32.9 (26/79)	34.9 (23/66)	0.81
Season ending	91.1 (72/79)	90.9 (60/66)	0.96
Days to conception	28.18 ± 3.06	26.52 ± 3.32	0.71

[1]Treatments: AI = Artificial insemination (dams of heifers exposed to ovulation synchronization and AI followed by natural service bulls), NS = Natural service (dams of heifers only exposed to herd bulls for the duration of the breeding season).

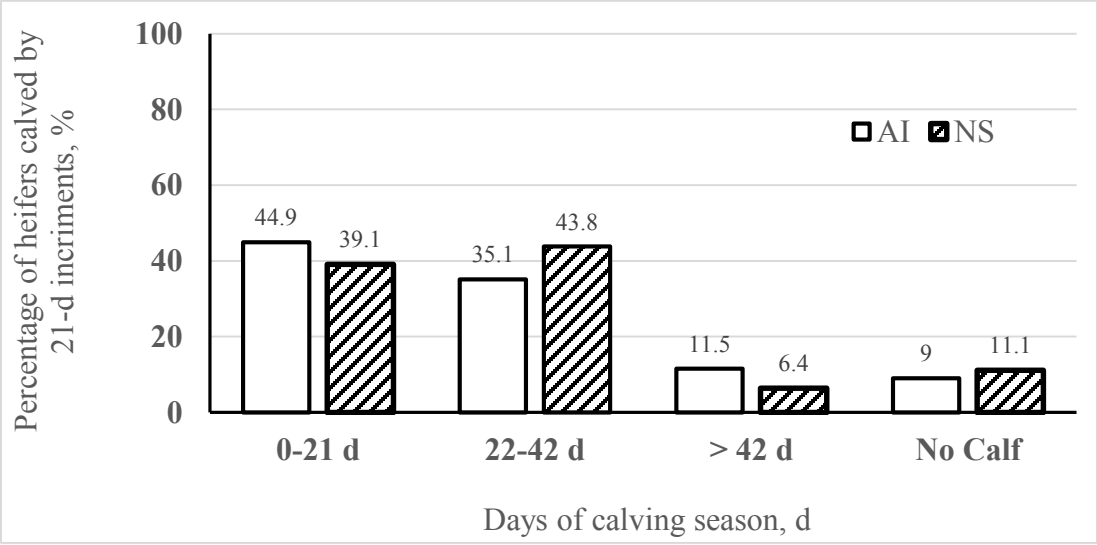

Figure 2.2. The percentage of heifers calved by 21-d increments of the calving season Treatments: AI = Artificial insemination (dams of heifers exposed to ovulation synchronization and AI followed by natural service bulls), NS = Natural service (dams of heifers only exposed to herd bulls for the duration of the breeding season).

Discussion

Heifers born to dams exposed to artificial insemination were older and heavier compared to heifers born to dams exposed to natural service. Use of ES and AI allowed for the mass breeding of females on a single day (d 239). Additional benefits of estrus synchronization and AI when compared to natural service include the number of calves conceived and born early. In agreement with the present study, a greater proportion of mature females bred via AI, calved in earlier in the calving season than cows exposed to only natural service (Rodgers et al., 2012), allowing AI born calves to be older. Calves that are conceived early will be born earlier in the calving season and will be older and heavier at weaning (Sprott, 1999). Weaning weights were greater per cow exposed than those cows bred by natural service (Rodgers et al., 2012). Weaning weights were also greater for heifers that were calved in the first 21 d period of the breeding season (Funston, et al., 2012). Although not seen in the current study, ADG was affected by calving period in previous work. Heifers that calved early in the calving season had less rapid ADG than heifers that calved later (Lestmeister et al., 1973). Preferential treatment may be given to those animals, specifically heifers, which calve early to apply more intense management (Lestmeister et al., 1973).

Heifers born to natural service bred dams tended to become cyclic earlier compared to heifers born to artificially inseminated dams. When grouped by calving period, age at puberty was similar for heifers born in the first, second, and third calving periods (Cushman et al., 2014). Also, antral follicle counts, an indicator of fertility, of calves born in the first 21 d calving period were different compared with heifers born in the second and third calving periods (Cushman et al., 2014). In contrast, heifer caves born in the first 21 d period of the calving season became cyclic earlier than those heifers born in the third 21 d period of the calving season. Differences

between studies may be attributed to the difference in age. In the current study, heifers born to dams exposed to AI were 6 d older than heifers born to dams exposed n to natural service. Age difference among the three 21 d calving periods differed by more than our study (Funston et al., 2012). However, age may not be as precise a measurement of puberty (Freetly et al., 2011). Although heifers born from AI bred cows were not any more likely to be pubertal early compared to natural service bred cows, it is important to note that high proportion of females in both treatments were cyclic prior to breeding and AI did not result in an advantage.

Pregnancy rates on d 28 and 90 as well as days to conception were similar between treatments. Similarities in results may be due to the similar cyclic status between groups prior to breeding. A greater proportion of heifers born in the first and second 21 d calving period became pregnant compared to heifers born in the third 21 d period (Funston et al., 2012). This is in contrast to the current study, however age differences among heifer calving groups were greater in the study by Funston et al. (2012). No differences were observed in the calving distribution of heifers.

Implications

Heifers born to dams exposed to ovulation synchronization and artificial insemination were heavier at the initiation of the experiment; however, the natural service counterparts were similar at pasture turn out. Also, heifers born to dams exposed only to natural service tended to become cyclic earlier than those heifers born to dams exposed to AI and natural service. No differences were observed in the number of heifers that became pregnant to AI, became pregnant by the end of the breeding season, or the days to conception between the treatments. When comparing the different breeding system techniques, differences were only seen in initial

weights. Exposure of dams to AI did not result in advantages in growth, attainment of puberty, or pregnancy rate for female progeny measured in the current study.

Literature Cited

Barker, D. J. P., C. N. Martyn, C. Osmond, C. N. Hales, and C. H. D. Fall. 1993. Growth in utero and serum cholesterol concentration in adult life. BMJ. 307:1524-1527.

Byerley, D. J., R. B. Staigmiller, J. G. Berardinelli, and R. E. Short. 1987. Pregnancy rates of beef heifers bred either on pubertal or third estrus. J. Anim. Sci. 65:645-650.

Cushman, R. A., L. K. Kill, R. N. Funston, E. M. Mousel, and G. A. Perry. 2013. Heifer calving date positively influences calf weaning weights through six parturitions. J. Anim. Sci. 91:4486-4491.

Cushman, R. S., A. K. McNeel, and H. C. Freetly. 2014. The impact of cow nutrient status during the second and third trimesters on age at puberty, antral follicle count, and fertility of daughters. Livestock Science. 162:252-258.

FASS. 1999. Guide for the Care and Use of Agricultural Animals in Agriculture Research and Teaching. Fed. Anim. Sci. Soc., Savoy, IL.

Fox, D. G., C. J. Sniffen, and J. D. O'Connor. 1988. Adjusting nutrient requirements of beef cattle for animal and environmental variations. J. Anim. Sci. 66:1475-1495.

Freetly, H. C., L. A. Kuehn, and L. V. Cundiff. 2011. Growth curves of crossbred cows sired by Hereford, Angus, Belgian Blue, Brahman, Boran, and Tuli bulls, and the fraction of mature body weight and height at puberty. J. Anim. Sci. 89:2372-2379.

Funston, R. N., J. A. Mustgrave, T. L. Meyer, and D. M. Larson. 2012. Effect of calving distribution on beef cattle progeny performance. J. Anim. Sci. 90:5118-5121.

Gutierrez, K., R. Kasimanickam, A. Tibary, J. M. Gay, J. P. Kastelic, J. B. Hall, and W. D. Whittier. 2014. Effect of reproductive tract scoring on reproductive efficiency in beef heifers bred by timed insemination and natural service versus only natural service. Theriogenology 81:918-924.

Hall, J. B. 2013. Nutritional development and the target weight debate. Vet Clin. Food Anim. 29:537-554.

Hirschfeld, D. J., D. R. Kirby, J. S. Caton, S. S. Silcox, and K. C. Olson. 1996. Influence of grazing management on intake and composition of cattle diets. J. Range Mange. 49:257-263.

Kirby, C. J., M. F. Smith, D. H. Keisler, and M. C. Lucy. 1997. Follicular function in lactating dairy cows treated with sustained-release bovine somatotropin. J. Dairy. Sci. 80:273-285.

Lamb, G. C., J. E. Larson, T. W. Geary, J. S. Stevenson, S. K. Johnson, M. L. Day, R. P. Ansotegui, D. J. Kesler, J. M. DeJarnette, and D. G. Landblom. 2006. Synchronization of estrus and artificial insemination in replacement beef heifers using gonadotropin-releasing hormone, prostaglandin $F_{2\alpha}$, and progesterone. J. Anim. Sci, 84:3000-3009.

Lesmeister, J. L. P. J. Burfening, and R. L. Blackwell. 1973. Date of first calving in beef cows and subsequent calf production. J. Anim. Sci. 36:1-6.

NRC. 1996. Nutrient requirements of beef cattle. 7th. Natl. Acad. Press, Washington DC.

Perry, R. C., L. R. Corah, G. H. Kiracofe, J. S. Stevenson, and W. E. Beal. 1991. Endocrine changes and ultrasonography of ovaries in suckled beef cows during resumption of postpartum estrous cycles. J. Anim. Sci. 69:2548-2555.

Rodgers, J. C., S. L. Bird, J. E. Larson, N. Dilorenzo, C. R. Dahlen, A. Diconstanzo, and G. C. Lamb. 2012. An economic evaluation of estrus synchronization and timed artificial insemination in suckled beef cows. J. Anim. Sci. 90:4055-4062.

Sprott, L. R. 1999. Management and financial consideration affecting the decision to synchronize estrus in beef females. J. Anim. Sci. 77:1-10.

Steichen, P. L. 2013. The effect of artificial insemination or natural service breeding systems on reproductive performance, calving characteristics, weaning characteristics, and steer backgrounding performance in a commercial beef herd. Masters Thesis. North Dakota State Univ., Fargo.

Steichen, P. L., S. I. Klein, Q. P. Larson, K. M. Bischoff, V. G. R. Mercadante, G. C. Lamb, C. S. Schauer, B. W. Neville, and C. R. Dahlen. 2014. Effects of artificial insemination and natural service breeding systems on calving characteristics and weaning weights of resulting progeny. ASAS Joint Annual Meeting, Kansas City, MO. (Abstr).

CHAPTER 3. IMPACT OF PRE-BREEDING VACCINATION WITH MODIFIED-LIVE OR INACTIVATED VIRAL VACCINES ON SUBSEQUENT REPRODUCTIVE PERFORMANCE

Abstract

Five hundred and fifty-nine Angus crossbred females (410 cows and 149 heifers) were used to compare pregnancy attainment and calving distributions of females administered either a killed or modified-live pre-breeding vaccine per label recommendations. Cows were stratified by days postpartum while heifers were stratified by birth date, then all females were randomly assigned to receive one of three treatments; 1) Sterile saline administered i.m. on d -60 and -30 relative to breeding (**Control**, n = 185), 2) Sterile saline administered i.m. on d -60 relative to breeding and a modified-live vaccine (Bovi-Sheild Gold FP5 L5 HB, Zoetis, Inc., Florham, NJ, USA) administered i.m. on d -30 relative to breeding (**MLV**, n = 188), or 3) Killed vaccine (Vira-Sheild 6+L5 HB, Novartis Animal Health US, Inc., Larchwood, IA, USA) administered s.q. on d -60 and -30 relative to breeding (**KV**, n = 186). Females were separated based on age and managed as three groups, heifers (15 month at breeding), young cows (2-4 years of age at breeding) and old cows (5-11 years of age at breeding). All vaccines were administered according to manufacturer's label recommendations and consisted of 3 different lots and serials. All females were exposed to the 7-d CO-Synch + CIDR synchronization protocol with a single fixed-time artificial insemination (TAI) at 54 h after CIDR removal for heifers and 60-66 h after CIDR removal for cows. Clean-up bulls were placed in breeding pastures 10 d after AI and remained with females until 56 d after AI. Presence of a viable fetus was determined at d 28, 56, and 90 relative to TAI. At parturition, date, birth weight, calf vigor, and calving ease (1 – 5 with

1 = no assistance, easy birth; 5 = cesarean delivery) were recorded. No differences were observed among treatments in the proportion of females pregnant (d 28: $P = 0.94$, d 56: $P = 0.36$, and d 90: $P = 0.19$) There were also no differences in calving date in the calving season or proportion of females calving in each of the 21 d calving intervals ($P \geq 0.11$). More calving difficulty ($P = 0.05$) was observed in females in the control treatment compared with females in the MLV or KV treatments (1.09, 1.01, 1.04, for control, modified-live, and killed, respectively). However, no differences were observed among treatments in calf birth weight ($P = 0.27$) or calf vigor ($P < 0.01$). More calving difficulty ($P < 0.01$), poorer calf vigor ($P < 0.01$), and lighter birth weights of calves were observed in heifers compared with the young or old cow groups. When modified-live or killed pre-breeding vaccines were administered per label recommendations no impacts on pregnancy attainment or calving distribution were observed.

Introduction

The ability to maintain overall herd health is essential to the reduction of economic loss (Payne et al., 2013) and improvement of reproductive efficiency in beef herds (NAHMS, 2009). Infectious agents can have negative effects on ovulation, fertilization, and conceptus survival (Givens, 2006). Herd health can be improved via a vaccination program that promotes herd immunity from various pathogens (Anderson and May, 1985). For example, Aono et al. (2013) reported that a higher proportion of vaccinated cattle became pregnant compared with unvaccinated contemporaries. While not all cattle are vaccinated, most could benefit from an immunization program developed in consultation with a veterinarian to control the spread of specific pathogens in a herd (NAHMS, 2009).

Vaccinations include inactivated (killed) or modified-live virus, bacterium, or combination of virus and bacterium. Although modified-live and inactive vaccinations both

reduce the risk of pathogen proliferation, modified-live vaccinations provide greater protection against viremia (Rodning et al., 2010). Modified-live vaccinations provide a wider range of protection by the activation of all immune phases including humoral and cell-mediated response (Griffin et al., 2002; Detmer and Glenting, 2006). However, negative effects of modified-live vaccines can be observed when the vaccinations are not administered according to label recommendations.

Reduced progesterone and estradiol concentrations, luteal function, and pregnancy rates were observed when naïve heifers were vaccinated with modified-live viral vaccines 8 d before breeding (22 d after labeled recommendation) compared with heifers administered a saline dose (untreated controls) and killed vaccines (Perry et al., 2013). In addition, use of modified-live vaccines during estrus synchronization lowered the proportion of females becoming pregnant following the first estrus cycle compared to nonvaccinated females (Chaing et al., 1990). However, reports evaluating reproductive performance after labeled use of modified-live vaccinations are lacking. Our hypothesis was that females administered on-label pre-breeding modified-live vaccinations would have similar pregnancy rates as those administered a killed vaccine. Therefore, the objective of the study was to compare the pregnancy and calving characteristics among previously vaccinated beef females administered either a modified-live or killed pre-breeding vaccine per label recommendations.

Materials and Methods

All cattle were managed according to the Federation of Animal Science Guide for the Care and Use of Agricultural Animals in Agriculture Research and Teaching (FASS, 1999). All procedures were reviewed and approved by the Institutional Animal Care and Use Committee of North Dakota State University.

Five hundred and fifty-nine Angus based crossbred females (410 mature cows and 149 virgin heifers) were managed at the Central Grasslands Research Extension Center (CGREC), located approximately 14 km NW of Streeter, ND. Females were separated based on age and managed as three groups, heifers (15 month at breeding), young cows (2-4 years of age at breeding) and old cows (5-11 years of age at breeding). Cows were stratified by days postpartum and heifers were stratified by birth date, then all females were randomly assigned to receive one of 3 treatments; 1) Sterile saline administered i.m. on d -60 and -30 relative to breeding (Control, n = 185); 2) Sterile saline administered i.m. on d -60 relative to breeding and a modified-live vaccine (Bovi-Sheild Gold FP5 L5 HB, Zoetis, Inc., Florham, NJ, USA) administered i.m. on d -30 relative to breeding (MLV, n = 188); or 3) A killed vaccine (Vira-Sheild 6+L5 HB, Novartis Animal Health US, Inc., Larchwood, IA, USA) administered s.q. on d -60 and -30 relative to breeding (KV, n = 188). All vaccines were administered according to manufacturer's label recommendations and consisted of 3 different lots and serials.

To achieve a common breeding date (d 0) all females were exposed to ovulation synchronization (7-d CO-Synch + CIDR for cows and heifers; Lamb et al., 2006, Larson et al., 2006, respectively) consisting of inserting a controlled internal drug releasing insert (CIDR,1.38 g Progesterone, Zoetis, Inc., Florham, NJ, USA) and 100 µg Gonadotrophin Releasing Hormone (GnRH) i.m. (2 mL Factrel, Zoetis, Inc.), followed in 7 d by CIDR removal and 25 mg $PGF2_{\alpha}$ i.m. (5 mL Lutalyse, Zoetis, Inc.), followed in 60-66 hours for cows and 54 ± 2 hours by 100 µg GnRH i.m. and fixed-time artificial insemination (AI). Angus clean-up bulls were placed in breeding pastures 10 d after AI and remained in breeding pastures with cow and heifers for 46 d (d 56 of experiment). All bulls passed a breeding soundness exam (Ball et al., 1983) just prior to turn out and were stocked at a rate of 25-31 cows per bull.

Transrectal ultrasonography (5-MHz linear array transducer, Aloka 500V, Corometrics, Wallingford, CT) was used to determine presence of a viable fetus (via detection of fetal heartbeat) on d 28 and 90. Scans on d 28 were used to determine the proportion of females that became pregnant to AI. Scans on d 90 were used to determine season ending pregnancy rates and pregnancy loss in females previously identified as pregnant to AI and natural service.

All females were turned out to pasture for summer grazing and housed in a drylot or winter pasture for the winter months. Pastures included northern mixed grass pastures consisting of Kentucky bluegrass (*Poa pratensis* L.), western snowberry (*Symphoricarpos occidentalis* Hook.), blue gamma (*Bouteloua gracilis* [H. B. K] Lag. Ex Griffiths), needle and thread [*Hesperostipa comate* (Trin. + Rupr.) Barkworth], and sun sedge (*Carex inops* spp. *Heliophila* L. H Bailey; Hirschfeld et al., 1996). While in the drylot, heifers were fed a ration once daily consisting of approximately 2 kg of corn/hd/d and a mixture of corn silage and grass hay (Steichen, 2013). While in the drylot, heifers were fed a ration once daily that met or exceeded their NRC (1996) requirements. Primiparous and multiparous cows were placed in winter pastures and fed a diet once daily consisting of alfalfa/grass hay.

At parturition, date, birth weight, calving ease and calf vigor were recorded. Calving ease was subjectively determined using a 1-5 scale with 1 = no assistance, 2 = assisted, easy, 3 = assisted, difficult, 4 = assisted, very difficult, and 5 = cesarean delivery (adapted from Colburn et al., 1997 and Steichen, 2013). Calf vigor was subjectively determined using a 1 to 5 scale with 1 = normal calf, 2 = weak calf that nursed without assistance, 3 = weak calf that was assisted to nurse (lived), 4 = weak calf that was assisted to nurse (died), 5 = stillborn (adapted from Wiggans et al., 2003 and Steichen, 2013).

The GLM procedure of SAS (SAS Inst. Inc., Cary, NC) was used to analyze all continuous data (final weight, calf birth date, calf adjusted birth date, calf birth weight, calving ease, and calf vigor). The GENMOD procedure of SAS was used to analyze the binomial data (pregnancy rate, loss, and calving distribution). Each model included the effect of treatment (natural service or artificial insemination) and management group (heifer, young, or old). Significance was declared at $P \leq 0.05$.

Results

Vaccination

The proportion of females pregnant on d 28 and 90 as well as the loss of pregnancies from d 28 to 90 were similar among treatments ($P \geq 0.19$; Table 3.1.). Control females had greater ($P = 0.05$) calving difficulty than killed vaccine or modified-live vaccine treated females (Table 3.2). However, date of birth of the calf in the calving season, calf birth weight, and calf vigor were similar ($P \geq 0.27$). Also, no differences in the distribution of calves born in 21 d calving intervals ($P \geq 0.11$) were observed (Figure 3.1.).

Table 3.1. Effect of vaccination type on pregnancy status of beef females

	Treatment[1]			
Item	Control	KV	MLV	*P* – value
No. of females	185	188	185	-
Pregnancy rate[2], %				
d 28	45.41 (84/185)	43.01 (81/188)	44.15 (83/188)	0.94
d 90	90.81 (168/185)	95.14 (178/188)	92.55 (171/185)	0.19
Pregnancy loss[3]	6.32 (12/185)	6.25 (12/188)	3.29 (6/185)	0.26

[1]Treatments: Control = saline treated females on d -60 and -30, KV = killed vaccine administered s.q. on d -60 and -30 relative to breeding, MLV = saline administered i.m. on d -60 relative to breeding and a modified-live vaccine administered i.m. on d -30.
[2]Pregnancy status checked on d 28 and 90 relative to timed-AI.
[3]Pregnancy loss defined as any pregnancy terminated between d 28 and 90.

Table 3.2. Calving characteristics of beef females administered killed of modified-live pre-breeding vaccinations

	Treatment[1]				
Item	Control	KV	MLV	SEM	*P* - value
No. of females	185	188	185		-
Calving date[2], d	23.2	24.2	23.1	1.22	0.76
Calf BW[3], kg	40.0	37.5	37.0	1.40	0.27
Calving ease[4], 1-5 scale	1.09 [a]	1.02 [b]	1.0 [b]	0.02	0.05
Calf vigor[5], 1-5 scale	1.02	1.01	1.0	0.02	0.51

[1]Treatments: Control = Saline treated females, KV = A killed vaccine administered s.q. on d -60 and -30 relative to breeding, MLV = Sterile saline administered i.m. on d -60 relative to breeding and a modified-live vaccine administered i.m. on d -30 relative to breeding.
[2]DOB in calving season = Date of birth in the calving season; adjusted to evaluate all groups equally.
[3]Calf BW = Calf birth weight, kg.
[4]Calving ease = Scale of 1 – 5 with 1 = no assistance, 5 = cesarean delivery, adapted from Wiggans et al., 2003 and Steichen, 2013.
[5]Calf vigor = Scale of 1 – 5 with 1 = normal calf, 5 = stillbirth, adapted from Colburn et al., 1997 and Steichen, 2013.
[a,b]Means within rows lacking common superscript differ ($P \leq 0.05$).

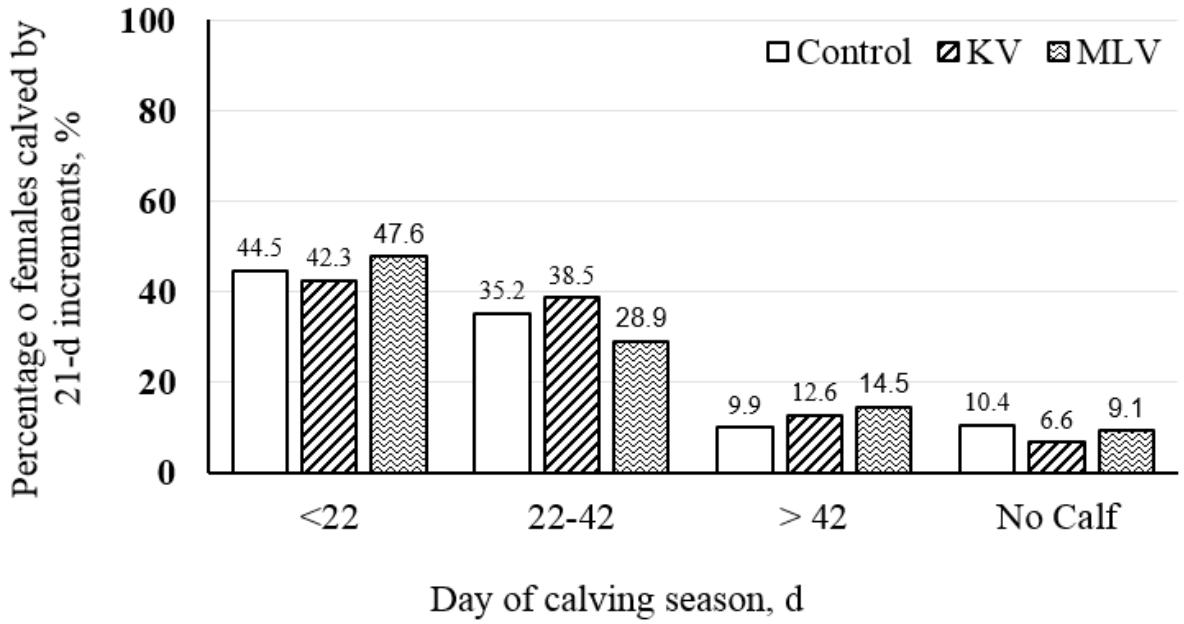

Figure 3.1. The percentage of females calved by 21-d increments of the calving season among vaccination treatments
Treatments: Control = Saline treated females, KV = A killed vaccine administered s.q. on d -60 and -30 relative to breeding, MLV = Sterile saline administered i.m. on d -60 relative to breeding and a modified-live vaccine administered i.m. on d -30 relative to breeding.

Group

A greater proportion ($P < 0.01$) of young cows became pregnant to AI compared to heifers or cows in the old group (Table 3.3.). Vaccine treatment did not have an effect ($P = 0.18$) on the proportion of females that became pregnant by the end of the breeding season (d 90). When evaluating calving, old cows calved later ($P < 0.01$) in the calving season than did young cows or heifers (Table 3.4). Heifers had smaller calves ($P < 0.01$), more calving difficulty ($P < 0.01$), and calves were less vigorous at birth ($P < 0.01$) compared to either cow group.

Table 3.3. Effect of contemporary group on pregnancy status of beef females[1]

	Group[2]			
Item	Heifer	Young	Old	*P* - value
No. of females	149	195	214	-
Pregnancy3, %				
d 28	33.56 (50/149)[b]	61.21 (119/195)[a]	33.67 (72/214)[b]	< 0.01
d 90	90.62 (135/149)	95.31 (186/195)	91.71 (196/214)	0.18
Pregnancy loss[4]				

[1]Group: Heifer = 15 month at breeding, Young cows = 2-4 years of age at breeding, and Old cows = 5-11 years of age at breeding.
[2]Pregnancy status checked on d 28 and 90 relative to timed-AI.
[3]Pregnancy status checked on d 28 and 90 relative to timed-AI.
[3]Pregnancy loss defined as any pregnancy terminated between d 28 and 90.
[a,b]Means within rows lacking common superscripts differ ($P \leq 0.05$).

Table 3.4. Calving characteristics of beef females administered killed of modified-live pre-breeding vaccinations among management group

Item	Group[1]			SEM	*P* - value
	Heifer	Young	Old		
No. of females	149	195	214		-
DOB in calving season[2], d	21.3[b]	19.0[b]	30.2[a]	1.22	< 0.01
Calf BW[3], kg	34.0[b]	40.2[a]	40.3[a]	3.05	< 0.01
Calving ease[4], 1-5 scale	1.1[a]	1.0[b]	1.0[b]	0.02	< 0.01
Calf vigor[5], 1-5 scale	1.1[a]	1.0[b]	1.0[b]	0.02	< 0.01

[1]Group: Heifer = 15 month at breeding, Young cows = 2-4 years of age at breeding, and Old cows = 5-11 years of age at breeding.
[2]DOB in calving season = Date of birth in the calving season; adjusted to evaluate all groups equally.
[3]Calf BW = Calf birth weight, kg.
[4]Calving ease = Scale of 1 – 5 with 1 = no assistance, 5 = cesarean delivery, adapted from Wiggans et al., 2003 and Steichen, 2013.
[5]Calf vigor = Scale of 1 – 5 with 1 = normal calf, 5 = stillbirth, adapted from Colburn et al., 1997 and Steichen, 2013.
[a,b]Means within rows lacking common superscripts differ ($P \leq 0.05$).

A greater proportion ($P < 0.01$) of young cows calved in the first 21 d of the calving interval (Figure 3.2.). In the second 21 d calving interval, a greater proportion ($P < 0.01$) of young cows and heifers became pregnant. A greater proportion ($P < 0.01$) of old cows became pregnant in the third 21 d calving interval compared to heifer or young cows. No differences were observed in the proportion of cows and heifers that did not calve ($P = 0.22$).

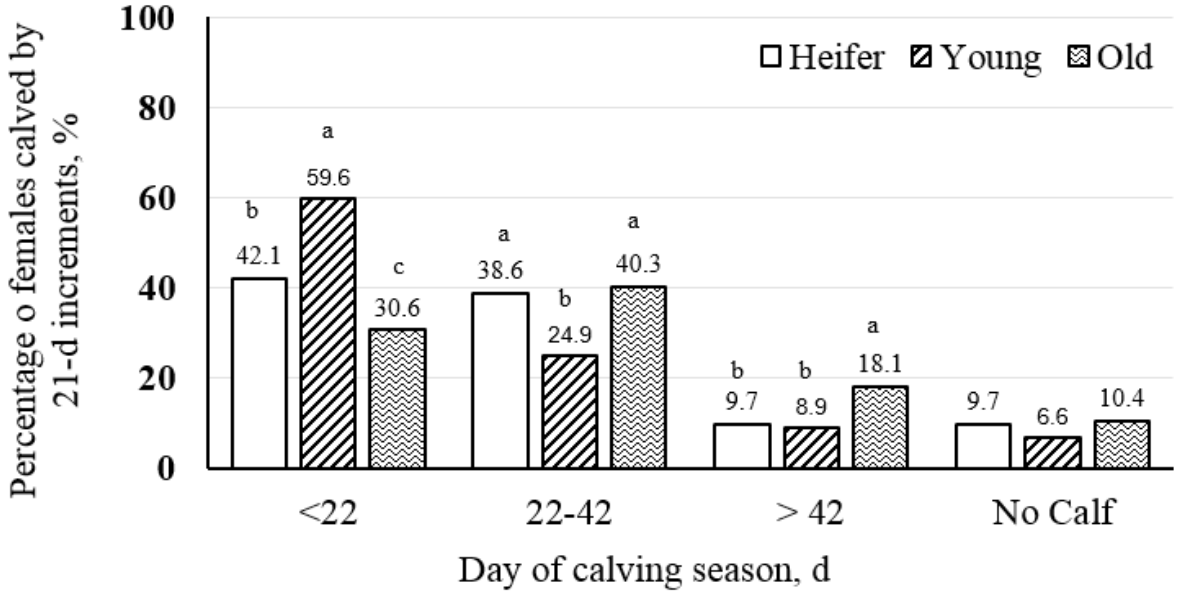

Figure 3.2. . The percentage of females calved by 21-d increments of the calving season among management groups
Group: Heifer = 15 month at breeding, Young cows = 2-4 years of age at breeding, and Old cows = 5-11 years of age at breeding.
[a,b,c]Means lacking common letter differ ($P \leq 0.05$).

Calf sex

A difference ($P = 0.05$) was observed in body weights of calves. Bull calves were heavier than their heifer counterparts (Figure 3.3.).

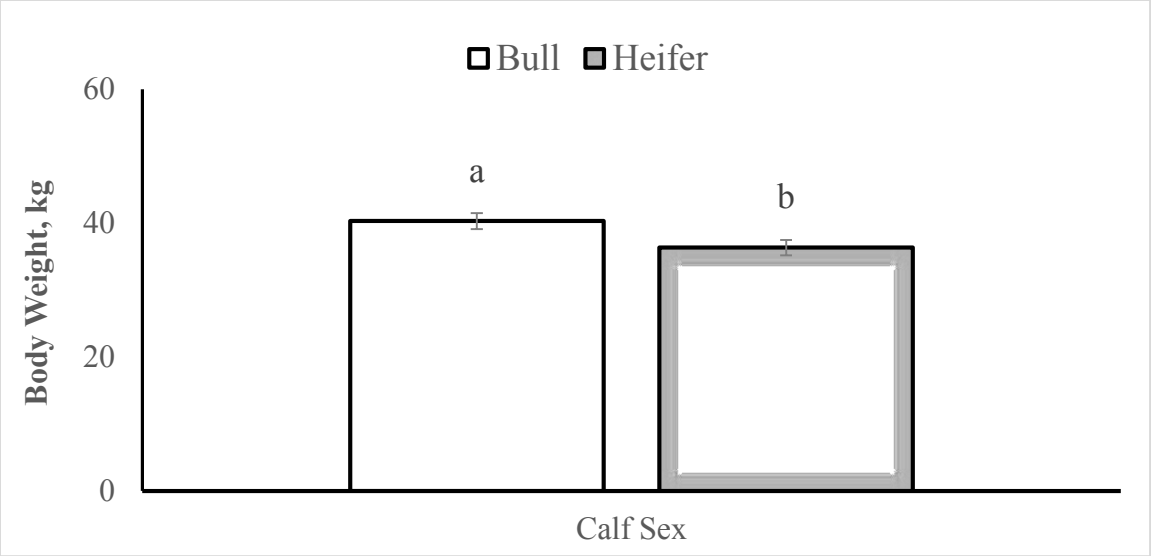

Figure 3.3. Effect of calf sex on calf birth weight
[a,b]Means lacking common letter differ ($P \leq 0.05$).

Discussion

The current study was conducted to evaluate the effects of modified-live and killed virus vaccinations on subsequent reproductive performance when administered according to label recommendations. No differences were seen in pregnancy rates or calving distribution among treatments when vaccination were administered according to manufacturer recommendations. In contrast, pregnancy rates, progesterone and estradiol concentrations, and luteal function were decreased when modified-live vaccinations were administered at the initiation of estrus synchronization (22 d after label recommendation) compared to untreated controls and heifers vaccinated with inactivated virus (Perry et al., 2013). Similarly, pregnancy rates were decreased when modified-live vaccinations were administered during the estrus synchronization period (after label recommendations) compared with untreated controls (Chiang et al., 1990). Vaccinations elicit an immune response for the purpose of building antibodies and creating a memory of a particular pathogen (Pashine et al., 2005). If administration and subsequent immune

response to the pathogen within the vaccine occur at the time of early fetal life, negative responses may ensue. In many cases vaccinations administered to cattle prior to breeding include reproductive diseases such as BVDV, IBR, leptospirosis, and respiratory diseases BRSV and parainfluenza 3. Bovine viral diarrhea virus has a predilection to both oviduct epithelial cells and granulosa cells within the reproductive tissue of female cattle (Booth et al., 1995). Fertility can be drastically impacted with the infection of oviduct epithelial and granulosa cells, as infection could carry over further into other reproductive tissues, when females are not vaccinated. A rise in temperature of a specific tissue, in many cases reproductive tissues, due to immune response from a vaccine, may be enough to cause embryonic mortality (Vanroose et al., 2000). Decreased pregnancy rates in previous studies may be caused by such a response. In the case that inactivated vaccines were administered at the same time of modified-live vaccines with no negative effects (Perry et al., 2013), it must be understood that differences in immune response occur with different vaccines. Inactivated virus vaccinations elicit a humoral response, a reduced amount of immune response than a modified-live vaccination. Modified-live vaccinations elicit cell-mediated immunity, a more intense immune response with longer lasting effects (Detmer and Glenting, 2006). Although previous studies have evaluated use of modified-live vaccinations when administered off-label, use of such vaccines on-label resulted in contrasting data. Use of modified-live vaccines, when used as intended by the manufacturer, may be a safe option for stronger immune protection in a cow herd.

In the current study, a greater proportion of unvaccinated control females had difficulty calving. Calving ease is a subjective measurement, ranging from 1 – 5, with 1 = no problem, 5 = extreme difficulty (Wigginset al., 2003). Direct calving ease is a sire measurement associated with the ease of a bulls offspring's birth on cows bred to that particular bull (Laster et al., 1973).

All bulls used in the current study, however, were similar. Management tools involving culling heavy birth weight heifers with small pelvic measurement may be recommended for elevated calving difficulty (Colburn et al., 1997). Although a difference was seen in the current study, little practical use may be obtained from such a low figure.

Heifers had greater incidence of calving difficulty, poor calf vigor and calved smaller offspring. Dystocia, or calving difficulty, is inversely related to age. Dystocia is increased in 2 year old cows compared to 3, 4, or 5 year old cows (Laster et al., 1973). In agreement, a study evaluating the national average management considerations for cows and heifers at calving, a greater proportion of heifers had difficulty calving compared to cows (Dargatz et al., 2004). Calf vigor is associated with the amount of assistance needed during calving. Calves born to females with increased assistance at calving had lower vigor, resulting in a higher calf vigor score (Barrier et al., 2012). Dam age may also influence the birth weight of her first calf. Competition for nutrients between a growing dam and a growing fetus may depress the birth weight of the fetus (Holland and Odde, 1992). Once mature weight is obtained by the cow, calf birth weights will increase relative to the dam's mature size (Holland and Odde, 1992). Group differences were seen in the proportions of females calving at different points in the calving season. Results are congruent with pregnancy data observed in the present study. Because of the age and size of heifers at the time of breeding and calving, decreased birth weight, calf vigor, and increased calving difficulty may be observed.

Bull calves were heavier at birth than heifer calves. In agreement with much of the current data, male calves generally had an advantage in weight over female calves, due to differences in hormone production (Holland and Odde, 1992). Male calves were 2.6 kg larger than their female counterparts (Bellows et al., 1971).

Implications

Use of modified-live vaccinations according to manufacturer label recommendation, did not hinder pregnancy rates compared to use of a killed virus vaccine or an untreated control. Females not vaccinated for protection against reproductive disease prior to the breeding season had greater incidence of calving difficultly. However it is unclear if it is an anomaly in the data. Secondary results indicated that heifers gave birth to smaller calves with greater calving difficulty and poorer calf vigor. Based on the current data, use of modified-live vaccinations according to label recommendations did not affect female attainment of pregnancy, calf loss, calf birth date, calf birth weight, or calf vigor score.

Literature Cited

Anderson, R. M. and R. M. May. 1985. Vaccination and herd immunity to infectious disease. Nature. 318:323-329.

Aono, F. H., R. F. Cooke, A. A. Alfieri, and J. L. M. Vasconcelos. 2013. Effects of vaccination against reproductive disease on reproductive performance of beef cows submitted to fixed-time AI in Brazilian cow-calf operations. Theriogenology. 79:242-248.

Ball, L., R. S. Ott, R. G. Mortimer, and J. C. Simons. 1983. Manual for breeding soundness examination of bulls. Journal of the Society for Theriogenology. 12:1-65.

Barrier, A. C., E. Ruelle, M. J. Haskell, and C. M. Dwyer. 2012. Effect of a difficult calving on the vigour of the calf, the onset of maternal behavior, and some behavorial indictors of pain in the dam. Preventative. Vet. Med. 103:248-256.

Bellows, R. A., R. E. Short, D. C. Anderson, B. W. Knapp, and O. F. Pahnish. 1971. Cause and effect relationships associated with calving difficulty and calf birth weight. J. Anim. Sci. 33:407-415.

Booth, P. J., D. A. Stevens, M. E. Collins, and J. Brownlie. 1995. Detection of bovine viral diarrhea virus antigen and RNA in oviduct and granulosa cells of persistently infected cattle. J. Reprod. Fert. 105:17-24.

Chiang, B. C., P. C. Smith, K. E. Nusbaum, and D. A. Stringfellow. 1990. The effect of infectious bovine rhinotracheitis vaccine on reproductive efficiency in cattle vaccinated during estrus. Theriogenology. 33:1113-1120.

Colburn, D. J., G. H. Deutscher, M. K. Nielson, and D. C. Adams. 1997. Effects of sire, dam traits, calf traits, and environment on dystocia and subsequent reproduction of two-year-old heifers. J. Anim. Sci. 75:1452-1460.

Dargatz, D. A., G. A. Dewell, and R. G. Mortimer. 2004. Calving and calving management concerns of beef cows and heifers on cow-calf operations in the United States. Theriognology. 61:997-1007.

Detmer, A. and J. Glenting. 2006. Live bacterial vaccines- a review and identification of potential hazards. Microbial Cell Factories. 23:1-12.

FASS. 1999. Guide for the Care and Use of Agricultural Animals in Agriculture Research and Teaching. Fed. Anim. Sci. Soc., Savoy, IL.

Givens, M. D. 2006. A clinical, evidence-based approach to infectious causes of infertility in beef cattle. Theriogenology. 66:648-654.

Griffin, D., S. Ensley, and G. Dewell. 2002. Understanding vaccines. University of Nebraska-Lincoln Extension Publication. G1445.

Hirschfeld, D. J., D. R. Kirby, J. S. Caton, S. S. Silcox, and K. C. Olson. 1996. Influence of grazing management on intake and composition of cattle diets. J. Range Mange. 49:257-263.

Holland, M. D., and K. G. Odde. 1992. Factors affecting birth weight: a review. Theriogenology. 38:769-798.

Lamb, G. C., J. E. Larson, T. W. Geary, J. S. Stevenson, S. K. Johnson, M. L. Day, R. P. Ansotegui, D. J. Kesler, J. M. DeJarnette, and D. G. Landblom. 2006. Synchronization of estrus and artificial insemination in replacement beef heifers using gonadotropin-releasing hormone, prostaglandin $F_{2\alpha}$, and progesterone. J. Anim. Sci, 84:3000-3009.

Larson, J. E., G. C. Lamb, J. S. Stevenson, S. K. Johnson, M. L. Day, T. W. Geary, D. J. Kesler, J. M. DeJarnette, F. N. Schrick, A. DiCostanzo, and J. D. Arseneau. 2006. Synchronization of estrus in suckled beef cows for detected estrus and artificial insemination and timed artificial insemination using gonadotropin-releasing hormone, prostaglandin $F_{2\alpha}$, and progesterone. J. Anim. 85:332-342.

Laster, D. B., H. A. Glimp, L. V. Cundiff, and K. E. Gregory. 1973. Factors affecting dystocia and the effects of dystocia on subsequent reproduction in beef cattle. J. Anim. Sci. 36:695-705.

National Animal Health Monitoring Service (NAHMS). 2009. Vaccination of cattle and calves on U.S. beef cow-calf operations: Info Sheet. Natl. Anim. Health Monit. Ser., Fort Collins, CO.

NRC. 1996. Nutrient requirements of beef cattle. 7^{th}. Natl. Acad. Press, Washington DC.

Pashine, A., N. M. Valiante, and J. B. Ulmer. 2005. Targeting the innate immune response with improved vaccine adjuvants. Nature. Med. Supp. 11:563-568.

Payne, C. A., B. V. Ley, and S. E. Poock. 2013. Setting the stage for long-term reproductive health. Vet. Clin. Food. Anim. 29:555-565.

Perry, G. A., A. D. Zimmerman, R. F. Daly, R. E. Buterbaugh, J. Rhoades, D. Schloz, A. Harmon, and C. C. L. Chase. 2013. The effects of vaccination on serum hormone concentrations and conception rates in synchronized naïve beef heifers. Theriogenology. 79:200-205.

Rodning, S. P., M. S. D. Marley, Y. Zhang, A. B. Eason, C. L. Nunley, P. H. Walz, K. P. Riddell, P. K. Galik, B. W. Broderson, M. D. Givens. 2010. Comparison of three commercial vaccines for preventing persistent infection with bovine viral diarrhea virus. Theriogenology. 7:1154-1163.

Steichen, P. L. 2013. The effect of artificial insemination or natural service breeding systems on reproductive performance, calving characteristics, weaning characteristics, and steer backgrounding performance in a commercial beef herd. Masters Thesis. North Dakota State Univ., Fargo.

Vanroose, G., A. de Kruif, and A. Van Soom. 2000. Embryonic mortality and embryo-pathogen interactions. Anim, Reprod. Sci. 60-61:131-143.

Wiggans, G. R., I. Misztal, C. P. Van Tassell. 2003. Calving ease (Co) variance components for a sire-maternal grandsire threshold model. J. Dairy Sci. 86:1845-1848.

CHAPTER 4. OVERALL CONCLUSIONS

Reproductive performance and efficiency are vital components of any profitable cow-calf production system. Producers may be able to enhance profitability with the use of selected management strategies, such as heifer selection and development. Selecting heifers with decreased age at puberty, allows heifers to be able to become pregnant earlier in the breeding season which may increase profitability.

Artificial insemination and estrus synchronization create the opportunity to increase calf age and weight at weaning, due to more calves being born in the first 21 d period of the calving season. When specifically evaluating heifer progeny from dams exposed to AI, age and weight at weaning was increased as expected, but no influence on the growth rate or attainment of puberty and pregnancy in heifers was observed.

Vaccinations are administered for the purpose of inducing an immune response as well as reducing the risk of disease and economic loss. When modified-live vaccinations are given off-label, negative effects including decreased pregnancy rates and fetal infections have been observed. When modified-live and killed virus vaccines were administered according to label recommendations, attainment of pregnancy and calving characteristics including calf birth weight, calf birth date and calf vigor were not affected.