# APPLICATION OF VACCINATION PROTOCOLS TO MANAGE BEEF CATTLE PRODUCTIVITY AND MITIGATE PRODUCTION RISK

A Dissertation

by

WILLY JUSTIN HORNE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2009

Major Subject: Animal Science

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# ABSTRACT

Application of Vaccination Protocols to Manage Beef Cattle Productivity and Mitigate Production Risk.

(May 2009)

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The U.S. beef industry is very large with many inter-connected facets. Nutrition and health are key components of a system striving to compete economically while striving to produce a high quality product. The decisions made in one part of the system may often determine outcomes in the other parts of the system. Therefore, it is necessary to look at the beef industry in a systems type of framework. Each management decision is likely tied to a result that may alter several other management questions.

At the cow/calf level, producers must decide whether or not to vaccinate their calves. Vaccination leads to reduced disease incidence and severity in the feedyard, thus being beneficial to the feeder. However, if the feedlot does not respond economically in any way, producers may feel that it is not warranted to vaccinated calves. Pre-conditioning programs work in the same manner as they may have beneficial effects for the feeder but not for the harvester. Therefore, pre-conditioning may not be a program that is valued back to the farm level. Answers to these kinds of questions are hard to ascertain. Each segment has its own demands and drivers, which determine how much it can reward to other segments for their efforts. Because the market is continuously changing, the target rewards are changing as well. Therefore targets cannot be

theorized, rather exact relationships should be shown. In this dissertation, it is intended to characterize the relationships vaccination protocols and other management strategies can have on various aspects of cattle performance in various industry segments.

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# CHAPTER I

# INTRODUCTION: THE IMPORTANCE OF SYSTEMS THINKING IN BEEF CATTLE PRODUCTION RESEARCH

Systems thinking is a framework that is based on the belief that the component parts of a system can best be understood in the context of relationships with each other and with other systems, rather than in isolation. The only way to fully understand why a problem or element occurs and persists is to understand the part in relation to the whole (Capra, 1996). The U.S. beef production system is a multi-faceted industry with many inter-related parts. Each segment of the beef industry represents a phase in the life of the beef animal. While these phases may or may not be merely a continuation of the previous phase, the biological system within that phase is undoubtedly linked to all of the phases. No matter how old the animal is, it still has to have adequate nutrition, water, and air to breathe.

For the beef animal, dietary conditions require that nutrients supply energy and protein from which life is sustained at the cellular level. Water also must be provided so that cell function can occur. Oxygen has to be supplied so that respiration may occur. At the most basic level, these three things must be available for life to continue.

In the biological system the most basic element of life is the cell. The properties of all cells are the same. These properties are: (1) Cells must be able to self-replicate and assemble. A single bacterial cell placed in a sterile nutrient medium can give rise to a billion identical "daughter" cells in 24 hours. Each cell contains thousands of different molecules, some

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This dissertation follows the style of the Journal of Animal Science.

extremely complex; yet each resulting cell is a faithful copy of the original, its construction directed entirely from information contained within the genetic material of the original cell. (2) The cells must be able to sense and respond to alterations in their surroundings by adapting their internal chemistry (Nelson and Cox, 2005).

Despite these common properties, and the fundamental unity of life they reveal, very few generalizations about living organisms are absolutely correct for every condition. This poses a significant problem when trying to optimize a production system made up of living animals under a variety of management types and environments. In fact, this means that no holistic approach to the industry will be correct for every animal in every situation. However, it is possible to identify key parts of a system and make generalizations as to how the animal will respond based on research and experience. This is where a systems approach to identifying best operational conditions of the beef industry is needed, a broad scope, but narrow focus of each part from the cell level upwards.

Many, many books have been written examining every part of the biological system. Many more have been written outlining the entire system and have tried to tie all of the pieces together. Without all knowing power, we shall never be able to put everything together. But by using the systems approach we can merely outline the big components of a beef animal's life from the time it is born to the time it is harvested.

To outline a beef animal's phases of life from birth to harvest, it is easiest to characterize the phases into three main production groups. The three main groups can be characterized as the cow/calf, stocker, and feedlot phases. These groups may intersect, overlap, or be completely separate depending upon the particular situation. Two main components of life exist in all of these sectors; health and nutrition. At the basic level, health and nutrition does not change from

one sector to another. However, management practices applied alter the health and nutrition status of the animal. This literature review will address the interaction that health and nutrition status have in the life of the animal. The health aspects must be broken down into subcategories of basic immune system, calf-hood immunity, and cytokines. Then vaccination interactions will be examined with the above subcategories. Management applications on stress and nutrition and its interaction with vaccination applicability can then be looked at. To move slightly more broad again, nutrition can be broken into the subcategories of minerals, pre-feedlot nutrition, and preconditioning exercises. Each of these pieces is meant to show that this system works as a holistic system and that a change in any one part will often lead to changes in the rest.

## Health

Health of an animal can refer to any part of the overall condition of the animal. The two systems primarily responsible for the overall condition of the animal are the immune and endocrine systems. These systems work together to keep homeostasis within the animal.

**Immune system.** The immune system works to protect the animal from foreign substances, including microbes, as well as macromolecules such as proteins and polysaccharides, regardless of the physiologic or pathologic consequence of such a reaction (Abbas and Lichtman, 2005). The mechanisms of the immune system can be categorized into those that are dependent on antigen recognition by antibodies or lymphocytes (specific, acquired) and those that occur independent of such recognition events (nonspecific, innate, native). Although specific and nonspecific mechanisms can each act independently to promote host defenses, more often they act in combination and therefore provide greater protection than either system can alone (Barrington and Parish, 2001).

Non-immune defense mechanisms include effects such as enzymes in secretions, acids in the stomach, fatty acids in epithelium, and normal flora that colonize mucosal surface. The principal components of innate immunity are (1) physical and chemical barriers, such as epithelia and antimicrobial substances produced at epithelial surfaces; (2) phagocytic cells (neutrophils, macrophages) and natural killer (NK) cells; (3) blood proteins, including members of the complement system and other mediators of inflammation; and (4) proteins called cytokines that regulate and coordinate many of the activities of the cells of innate immunity. The mechanisms of innate immunity are specific for structures that are common to groups of related microbes and may not distinguish fine differences between foreign substances. Innate immunity provides the early lines of defense against microbes (Abbas and Lichtman, 2005). Non-immune defense mechanisms can be suppressed by stress, malnutrition, low level infections, or exposure to toxins (Barrington and Parish, 2001).

In contrast to innate immunity, there are other immune responses that are stimulated by exposure to infectious agents and increase in magnitude and defense capabilities with each successive exposure to a particular microbe. Because this form of immunity develops as a response to infection and adapts to the infection, it is called adaptive immunity. The adaptive immune system has an extraordinary capacity to distinguish among different, even closely related microbes and molecules, and for this reason is also called specific immunity (Abbas and Lichtman, 2005).

There are two types of adaptive immune responses, referred to as humoral immunity and cell-mediated immunity, that are mediated by different components of the immune system and function to eliminate different types of microbes. Humoral immunity is mediated by molecules in the blood and mucosal secretions, termed antibodies, that are produced by cells called B

lymphocytes (also known as B cells). Cell-mediated immunity, also called cellular immunity, is mediated by T lymphocytes (also known as T cells). Intracellular microbes, such as viruses and some bacteria, survive and proliferate inside phagocytes and other host cells, where they are inaccessible to circulating antibodies. Defense against such infections is a function of cell-mediated immunity, which promotes the destruction of microbes residing in phagocytes or the killing of infected cells to eliminate reservoirs of infection (Abbas and Lichtman, 2005).

Protective immunity against a microbe may be induced by the host's response to the microbe or by the transfer of antibodies or lymphocytes specific for the microbe. The form of immunity that is induced by exposure to a foreign antigen is called active immunity because the immunized individual plays an active role in responding to the antigen.

Immunity can also be conferred on an individual by transferring serum or lymphocytes from a specifically immunized individual. The recipient of such a transfer becomes immune to the particular antigen without ever having been exposed to or having responded to that antigen. Therefore, this form of immunity is called passive immunity (Abbas and Lichtman, 2005).

**Calf immunity.** Upon leaving the sterile uterine environment, neonates are exposed to environmental conditions that are laden with microorganisms. Although they are capable of mounting an immune response, neonates are best characterized as being immunonaive (Barrington and Parish, 2001). This inability to initiate a successful immune response is attributable to the immaturity of protective mechanisms and the time delay in the initiation and production of mechanisms necessary for the generation of humoral and cell-mediated immunity. Passive immunization is a useful method for conferring resistance rapidly, without having to wait for an active immune response to develop. An example of passive immunity, in most mammals, is the transfer of maternal antibodies to the fetus, which enables newborns to combat infections

before they acquire the ability to produce antibodies themselves (Abbas and Lichtman, 2005). However, in bovine animals this passive transfer does not occur in utero. Maternal immunoglobulins, immune cells, and various cytokines are supplied to the bovine neonate through colostrum because the syndesmochorial structure of the placenta prevents prepartum transfer (Barrington and Parish, 2001). The ingestion of colostrum is essential for providing neonates with immunologic protection during at least the first 2 to 4 weeks of life (Chase et al., 2008).

In normal, full-term neonatal calves, colostral absorption is accomplished through intestinal cells by the neonatal receptor FcRn and endocytosis using "transport vacuoles" (Israel et al., 1995; Bainter, 2007). This absorptive capacity begins to decrease 6 to 12 hours after birth and ends by 48 hours after birth (Sangild, 2003; Bainter, 2007). Calves that ingest colostrum shortly after birth have significant concentrations of immunoglobulin (Ig) in serum, whereas colostrum-deprived calves have only trace amounts of immunoglobulin during the first 3 days of life (Clover and Zarkower, 1980). Levels of circulating IgA, $IgG_1$, and $IgG_2$ do not reach appreciable levels in colostrum deprived calves until 16 to 32 days after birth (Husband and Lascelles, 1975).

Colostrum also provides the calf with cytokines (Hagiwara et al., 2000). These immunologic hormones help in the development of the fetal immune response. Interleukin (IL) 1-beta (IL-1 beta), IL-6, tumor necrosis factor (TNF-α), and interferon-gamma (IFN-γ)are present in bovine colostrum and are associated with a proinflammatory response and may help in the recruitment of neonatal lymphocytes into the gut to aid in normal immune development. The high levels of two anti-inflammatory cytokines, IL-4 and transforming growth factor beta-1, suppress local secretion of proinflammatory cytokines in the intestine and allow gut microbial

fermentation (Chase et al., 2008). A serum IgG concentration assay at 48 hours of age can be used as an objective measure for defining the threshold between adequate passive transfer and failure of passive transfer (Guidry et al., 1980).

Another component of colostrum is cells. Colostrum contains between 1 x $10^6$ and 3 x $10^6$ cells/mL, which are almost exclusively leukocytes (Lee et al., 1980). Animals that receive colostrum containing maternal leukocytes develop antigen-presenting cells faster (Reber et al., 2005) than animals that do not receive colostrum. This is important because antigen-presenting cells are the keystone cell for development of an acquired immune response to pathogens or vaccines (Chase et al., 2008).

Certainly one of the major challenges in developing an active immune response in young calves has been interference from maternal immunity through colostrum (Morein et al., 2002). This problem has been demonstrated with several pathogens, including BVD (Ellis et al., 2001), bovine herpesvirus-1 (BHV-1) (Lemaire et al., 2001), and *Mannheimia (Pasturella) haemolytica* (Hodgins and Shewen, 1998). In these trials, development of an immune response to vaccination was measured by the presence or absence of antibodies in the blood of the vaccinated animal. Assays that measure antibodies detect humoral immunity, but give no information about T cell immunity. In general, T helper cell (CD4 T cells) responses are assumed to occur concurrently with humoral responses due to the requirement for T cell help in generation of a humoral response. Measuring serum antibody does not provide a complete picture of the animal's immune response because the activities of the cell mediated immunity are not evaluated (Endsley et al., 2003).

Nonnecke et al. (2005) found that vaccination of week-old dairy calves with *M. Bovis* resulted in non-existent antibody responses. However, the early vaccination did induce a Th1

response that was comparable to adult cattle sensitized in an identical manner. Responses were characterized by antigen-induced proliferation of CD4 T cells and secretion of IFN-γ and TNF-α. It was concluded that the bovine neonate can respond completely to a potent inducer of cell-mediated immunity but that the animal's maturity influences antigen-elicited antibody responses.

Furthermore, circumvention of maternal antibody neutralization is affected by concentrations of antibody delivered to the calf through colostrum. Producers typically vaccinate calves after maternal antibody concentrations decrease (van Oirschot et al., 1999). Depending on the immune status of the dam and the efficiency of colostral immunoglobulin transfer, the maximum maternal antibody titers derived from colostrum should be less than 1:32. This titer level may be reached anywhere from 70 to 160 days of age (Munoz-Zanzi et al., 2002). This leaves a period of time during which calves are vulnerable to infection.

It has been shown that a single dose of modified-live virus (MLV) vaccine containing BVD administered to calves at 4 to 5 weeks of age could stimulate a strong protective immune response in the face of high concentrations of maternal antibodies (Zimmerman et al., 2006). In that study, a viral challenge was included to determine that the protective response did indeed protect the calves from challenge later in life. Research is limited using challenges to enforce the idea that a cell mediated response can indeed be produced and will protect the calf from future challenges.

There has been research demonstrating that vaccination in the face of maternal antibodies can induce a cell mediated response including the production of CD4 and CD8 T cell responses as well as production of certain cytokines even though an antibody response was not produced (Endsley et al., 2003). The detection of cytokine production is important because cytokines function to mediate the inflammatory processes of the human body (Romagnani, 2000).

**Cytokines.** Cytokines can be categorized by the many different functional activities they mediate, and any cytokine may have multiple effects. Some cytokines activate innate immune cells such as phagocytes and natural killer cells and stimulate their participation in inflammatory processes, whereas others suppress and resolve inflammation. Several cytokines promote the activation of and antibody production by B cells, as well as antibody class switching of B cells. Certain cytokines have effects further upstream in the ontogeny of cells, in that they direct the maturation and mobilization of distinct classes of cells (Roth, 2007). Successful defense against the majority of infections requires an early T helper (Th1) cell-mediated inflammatory response (type 1 response). Interferon-γ, interleukin-2 (IL-2), and tumor necrosis factor α (TNF-α) are particularly important type 1 cytokines. Type 2 responses (those mediated by Th2 cells) are generally characterized by high antibody production and often by recruitment of eosinophil and mast cell activity. Of the type 2 cytokines, IL-4, IL-10, and IL-13 are among the most dominant and best characterized. Importantly, cytokines from type 1 responses tend to suppress type 2 responses, and vice versa, so that one or the other response predominates (Roth, 2007).

The Th1 type cytokines are produced mainly by lymphocytes, antigen presenting cells (APCs), and natural killer cells (NK-cells). They induce cell-mediated immunity (Bais et al., 2007). Th2 type cytokines (IL-4, IL-6, IL-8, IL-10), produced by lymphocytes and mast cells, are immuno-inhibitory for cell-mediated responses and predominately induce humoral immunity (Clerici et al., 1998; Spellberg and Edwards, 2001).

Cytokines may also be categorized as proinflammatory and anti-inflammatory. The proinflammatory cytokines such as TNF-α, IL-1 and IL-8 induce the mobilizing immune system cells to proliferate and produce more cytokines; thus initiating the inflammatory cascade. Anti-inflammatory cytokines such as IL-10 function to dampen or control the inflammatory response.

Proinflammatory cytokines are primarily responsible for initiating a potent defense against exogeneous pathogens (Cruz et al., 2008). In contrast, anti-inflammatory cytokines are crucial for down regulating the elevated inflammatory process and maintaining homeostasis for the correct functionality of vital organs (Howard et al., 1993). Homeostasis is critical for animal survival. Excessive production of any of these mediators may significantly contribute to shock, multiple organ failure, and death (van Dissel et al., 1998; Taniguchi et al., 1999; Fasshauer et al., 2003).

Although all essential immune components are present in neonates at birth, many of the components are not functional until calves are at least 2 to 4 weeks of age and may continue to develop until puberty (Reber et al., 2006). The placenta produces progesterone, prostaglandin E2, and cytokines (eg, IL-4 and Il-10) that suppress cell-mediated and memory (Th1) responses. As part of the parturition process calves produce high levels of cortisol that remain elevated for the first week of life (Mao et al., 1994). The cumulative effect of these hormones is to suppress immune responses and direct the immune response away from the Th1 response. These hormones also promote short-term Th2 immune responses, particularly production of IgM (Chase et al., 2007). Endogenous production of IgM in colostrum-deprived calves does not begin to appear in circulation until 4 days after birth and does not reach expected functional levels until 8 days of age. Levels of the calf's own circulating IgA and IgG have been shown to not reach appreciable levels until 16 to 32 days after birth (Husband and Lascelles, 1975).

Experiments performed in 2-day-old mice have demonstrated that potent adjuvants can break the Th2 bias. Sendai virus vaccines adjuvanted with immune-stimulating complexes stimulated a Th1 immune response prominent in IFN-γ, whereas a Sendai virus vaccine adjuvanted with the traditional $Al(OH)_3$ adjuvant produced a Th2 response (Morein et al., 2002).

To date, only two experimental vaccine systems have demonstrated the ability to break the Th2 bias in young livestock. The first experiment used small DNA sequences, called oligodeoxynuclotides, as a vaccine adjuvant given to day-old piglets. The piglets responded with significant cellular proliferation and IFN-γ production to the adjuvant. They also produced significant antibody titers within the first week after vaccination (Linghua et al., 2006).

Neonatal calves vaccinated subcutaneously 8 hours after birth with attenuated *Mycobacterium bovis* developed effective Th1 immunity, but failed to produce significant antibody responses (Nonnecke et al., 2005). Chase et al. (2008) reported that the take home message from those two studies was that cell-mediated responses to vaccines can be induced early; however, animals may need to be as old as 3 to 4 weeks before vaccines induce corresponding antibody responses that develop 10 to 14 days after vaccination.

**Stocker and feedlot cattle vaccines.** In cattle over 3 months of age, many vaccines have demonstrated the ability to induce the Th2 response which yields antibody formation. BVD vaccines have been available for use in cattle for over 40 years in the U.S (Fulton, 2007). Over 160 BVD vaccines alone were listed in the *Compendium of Veterinary Products* (2003). These vaccines met all of the requirements for safety, purity, potency, and efficacy by the USDA's Center for Veterinary Biologics Code of Federal Regulations Sections 113.311 and 113.215 (available at: www.Aphis.usda.gov/vs/cvb/index.htm). The requirements for efficacy are that the vaccines induce protection against clinical illness after challenge with virulent disease.

Nearly all of the presently licensed vaccines are conventional vaccines containing either killed or modified-live (MLV) whole bacteria or viruses. Most of the killed vaccines contain either aluminum hydroxide or oil and water adjuvants, which have been used for many years. Recently, vaccines have been approved with newer-type adjuvants (Roth and Henderson, 2001).

Vaccine products may contain high numbers of MLV or killed organisms, subunits of killed organisms, or inactivated toxins (waste products) of organisms known to cause a particular disease (Faries, 1999).

A vaccine containing inactivated toxins is called a toxoid while a vaccine containing killed bacteria is called a bacterin. Adjuvants are added to bacterins to increase effectiveness of the antigens. Adjuvants slow the release of the antigen into the body and prolong the immune response (Faries, 1999).

Vaccines can be classified as either noninfectious or infectious. Noninfectious vaccines are unable to infect and replicate. They are usually weaker in their ability to simulate an immune response (Faries, 1999). Noninfectious vaccines include killed vaccines, bacterins, toxoids, leukotoxoids, and chemically altered vaccines. Infectious vaccines contain a virulent organism that is modified or reduced (attenuated) so that it no longer causes disease, but it is able to infect and replicate. A MLV vaccine is an infectious vaccine that establishes a desired infection in the vaccinated animal. Immunity prevents the desired infection from being established. Infectious vaccines include MLV vaccines that are not body temperature sensitive, and MLV vaccines that are chemically altered (Faries, 1999).

The advantages of a MLV vaccine are that they require lesser amount of virus than do killed vaccines because the pathogen replicates in the host to build immunogenic mass. In general, MLV vaccines require only one dose for initial immunization but do require more rigid handling procedures because the vaccine virus is susceptible to inactivation by chemicals and/or exposure to higher temperatures (Fulton, 2007). Upon administration of a MLV vaccine, the viral strains replicate in the susceptible bovine, resulting in viremia (Cortese et al., 1997; Grooms

et al., 1998; Fulton et al., 2003). The duration of viremia is between 3 and 7 days after which the virus is cleared as the calves develop antibodies (Fulton et al., 2003).

Killed vaccines have advantages and disadvantages. From a production cost standpoint, killed vaccines are expensive because larger amounts of virus are required to prepare each dose of the vaccine as compared to MLV vaccines and there is the added cost of adjuvants. The process of virus inactivation for the production of killed vaccines is likely to also inactivate possible contaminants if any; however, this is not guaranteed unless the final product is tested for replicating virus. One disadvantage is that two doses are generally required for immunization. The first dose acts as acts as a priming method by developing memory cells, and the second dose acts as a booster. When the killed vaccine is boostered, a secondary anamnestic response occurs.

The duration of protection provided by vaccines tends to vary among studies reviewed. Cortese et al. (1998a) reported that cattle receiving a MLV BVD Type 1 vaccine induced antibodies to numerous BVD Type 1 and BVD Type 2 strains detectable through 18 months after vaccination. In other studies, there was a decline in BVD antibody titers by 140 days after vaccination (Fulton et al., 1995; Fulton and Burge, 2000). Revaccination at day 140 with either a killed or a MLV vaccine did induce increased antibodies in calves, especially those with low titers. Fulton (2007) surmised that this rapid anamnestic response points out that, while antibody titers may decline or disappear, an improved immune response remains in effect.

One must note that although some vaccines, directed at specific conserved proteins, such as toxoid vaccines, may completely prevent a particular disease, vaccines against complex disease agents that have multiple antigenic strains are unlikely to be capable of such levels of protection. Respiratory vaccines are better viewed as disease modifiers than absolute preventative agents (Callan and Garry, 2002).

Vaccines are effective at not only reducing the individual's own susceptibility, but also its ability to shed infectious agents to other calves (Frank et al., 1994; Frank et al., 2003). However, vaccines are not the only steps necessary to reducing spread of diseases. Management practices that reduce pathogen introduction, exposure and transmission are important initial steps upon entry into the feedlot (Snowder et al., 2006). Strategies that reduce stress placed upon the animal are also essential. Newly received feedlot cattle typically face two problems that contribute to a high incidence of respiratory disease (Gaylean et al., 1999). First, stress associated with weaning and transportation has a negative effect on the immune system (Blecha et al., 1984). Secondly, this stress typically occurs at a time when the animal is exposed to a variety of infectious agents as a result of marketing/transportation/management practices (Gaylean et al., 1999).

## Stress

Stress can have many negative effects on the health status of calves at feedlot entry. Stressors activate the hypothalamic pituitary adrenal axis (HPA). This activation results in a physiologic change or adaption so that the animal can deal with the threat and have an "adaptive response" (Chrousos, 2000; Black, 2002; Elenkov and Chrousos, 2002; Bailey et al., 2003). The transportation stress period can endure for as long as 15 d after arrival at the feedlot (Purdy et al., 2000). Numerous attempts have been made to reduce the impact of Bovine Respiratory Disease (BRD) through management practices, including preconditioning programs (Fulton et al., 2002). These preconditioning programs are designed to establish an effective immune response well in advance of any natural exposure. In addition to vaccination, castration, and dehorning, these programs involve weaning and nutritional components. Preconditioning programs usually require weaning of calves 30 to 45 d before shipment to allow the calf time to adjust to being

weaned and change in diet. Cattle that originated from a known preconditioning program performed significantly better in the feedlot. Preconditioned cattle have been shown to have significantly higher ADG, be more efficient, and have lower morbidity and mortality rates (Roeber and Umberger, 2002). Pritchard and Mendez (1990) reported that perhaps behavior modification associated with the preshipment weaning procedure is more important in determining intake by newly received cattle than is minor respiratory illness.

## Nutrition

Nutrition can interact with stress by exasperating preweaning nutritional deficiencies and limiting nutrient supply through decreased feed intake (Cole, 1996). Muggli et al. 1987, reported greater DMI for steer calves that were preconditioned for 30 d before shipment to a receiving facility as compared to steers that were weaned immediately before shipping. Decreasing energy intake during the receiving period seems to affect ADG (Duff and Gaylean, 2007). Calves fed low-quality, hay-based diets during receiving were unable to compensate for lost gain during subsequent finishing (Lofgreen, 1983; 1988).

Deficiencies in minerals such as Cu and Zn can decrease an animal's immune response, thereby increasing susceptibility to disease (Suttle and Jones, 1989). Nonetheless, research on the effects of supplemental Cu and Zn on calf health has yielded conflicting results, and, the mechanisms by which these minerals work in conjunction with the immune response are not understood fully (Galyean et al., 1999; Salyer et al., 2004).

**Zinc.** The earliest and most important clinical signs of zinc deficiency in ruminants, as in other species, are loss of appetite, parakeratosis and impaired wound healing (Miller et al., 1965). It is, therefore, possible that zinc deficiency weakens the first line of resistance to infection, i.e., the skin and other stratified epithelia, and also reduces the supply of major

nutrients for sustaining the increased metabolic rate following an infectious challenge. Nevertheless, losses from infections, when they occur, are probably secondary to the major debilitating effects of the deficiency (Suttle and Jones, 1989).

**Copper.** The role of Cu in host defenses has been examined in several species. Copper deficiency depresses lymphocyte responsiveness in rats (Bala et al., 1991), swine (Bala et al., 1992), and sheep (Suttle and Jones, 1989). Decreased neutrophil function has also been associated with copper deficiency (Xin et al., 1991). Wright et al. (2000) evaluated the effects of Cu supplementation in a pre-weaning creep supplement on the performance and immune status of stressed calves. The results suggest that pre-weaning Cu supplementation has minimal impact on performance, immune response or morbidity in stressed calves. Research of supplementation with Cu before and during the receiving period at the feedlot also shows that supplementation does not impact performance or health characteristics of steers (Beck et al., 2001). A review by Galyean et al. (1999) suggested that Cu deficiency, and, Cu deficiency coupled with high Mo and Fe, have inconsistent effects on immune function and furthermore, suggests that Cu deficiency may not affect specific immune function in calves. Supplementation of Cu to animals with adequate status is not likely physiologically beneficial to the animal or economically beneficial to the producer (Wright et al., 2000).

**Selenium.** Effects of Se deficiency or supplemental Se on the humoral immune response in cattle has been variable (Swecker et al., 1989). In stressed calves, supplemental dietary Se (0.1 mg of Se / kg of diet) resulted in higher serum IgM concentrations 17 d after inoculation with *Pasturella haemolytica* (Reffett et al., 1988). In other stressed calves, though, Se injection had no effect on antibody titers to IBR virus or parainfluenza type-3 virus (Reffett et al., 1986). Droke and Loerch (1989) conducted five trials with steers new to the feedlot environment to see

the effects of injections with Se on performance, health, and antibody response. Although increases in serum IgG titers to *P. haemolytica* were noted with the addition of Se at various times after vaccination, performance and health were not affected by treatments.

**Pre-feedlot diet composition -** Assuming that pre-feedlot mineral status is adequate, type of diet prior to feedlot entry affects feedlot production and health. Galyean et al. (1994) showed greater morbidity for calves preconditioned in drylot than calves on wheat pasture. It was reported that the costs associated with morbidity are the most important determinants of profitability of feedlot cattle (Gardner et al., 1996). Morbidity rates have been reported to account for approximately 8% of all production costs without consideration of losses due to reduced performance (Griffen et al., 1995).

There is some evidence that preconditioning cattle is recognized as valuable by feedlot buyers. Data from Superior Livestock auctions indicate that preconditioned cattle received a $3.33/cwt. premium compared with cattle not preconditioned. A survey of feedlot managers indicated that managers were willing to offer a premium of $5.25/cwt. more than non-preconditioned calves (Avent et al., 2002). It was thought that cattle feeders knew more clearly than cow-calf producers the performance and profitability differences associated with preconditioned calves, but that they did not pay price premiums closely representing those expected benefits. Results of the Avent et al. (2002) study suggest that feedlot managers do indeed know what performance differences exist. However, these differences are not as pronounced as most cow/calf producers would expect.

**Economics of preconditioning -** On an economic basis, preconditioning cattle on grass pasture is most favorable. Branded commercial medicated feeds, fed ad libitum, can cost more than $40 per animal for a 21 d preconditioning period (St. Louis, 2003). Avent et al. (2002)

reported that this cost could be as much as $60 per animal. On a biological basis, several studies reported less sickness and greater gains by turning calves out on pasture after initial metaphylaxis, rather than feeding hay and supplements in a drylot (Galyean et al., 1994; Paisely et al., 2000). There is evidence that buyers are willing to pay some premium for preconditioned calves, but by itself, not enough to cover preconditioning costs (Avent et al., 2002).

Feedlot mortality may heavily impact the price premium a feedlot is willing to pay. Losses due to mortality can greatly affect the revenue of the pen. Roeber and Umberger (2002) reported that percent mortality decreased by 10% in cattle having undergone a preconditioning program. It was shown that ultimately mortality caused a decrease of $59.47 per animal when morbidity was classified as a class variable (Waggoner et al., 2007). Most research does not include mortality in the calculation of net returns. This, however, is not reflective of the industry. Total net returns in the industry are calculated based on total expenses per pen minus the revenue of the pen. This is then divided by the number of animals at the end of the finishing period to give net returns per head. When mortality is calculated in, net returns per animal may be much closer to the premium levels offered by the feedlots.

With the increase in value-based marketing feedlot operators have become increasingly interested in management practices that enhance the value of beef carcasses, while at the same time maintaining feed efficiency and reducing cost of gain (Roeber and Umberger, 2002). This means that both cow-calf producers and feedlot operators have to become more in-tune to health and nutrition practices that have the potential to increase overall profitability.

## Conclusion

When evaluating the U.S. beef production system, a systems approach can be useful. With the systems approach, evaluation of the relationships of the components can be conducted

without losing sight of the whole. In the end, beef producers want to produce a good quality, uniform product that is demanded by the consumer. In order to do this, it is becoming imperative that all segments of the beef industry work together. Changes in nutrition or health management programs at the cow/calf level can have great impacts on feedlot responses and carcass characteristics of the animal. In addition, management practices at the feedlot level can affect the value received at the cow/calf level. As consumers demand a higher quality product for a cheaper price, it is necessary that information flow both up and down the chain of the production setting. All segments need to understand how their decisions affect the rest of the industry. This literature review has attempted to highlight health and nutritional management inter-relationships that are known and have important implications in all production segments of the beef industry.

# CHAPTER II

# EVALUATION OF THE ACUTE PHASE RESPONSE IN THE NEONATE BOVINE MODEL FOLLOWING VACCINATION AGAINST BOVINE RESPIRATORY DISEASE COMPLEX

## Introduction

It is well established that bovine respiratory disease (BRD) causes economic losses in feedlot cattle (Duff and Galyean, 2007). Thorough vaccination protocols have been indicated to enhance production against BRD related losses. However, vaccination in itself is not protective; rather, the calf must develop a protective level of specific immunity to the target pathogens to confer protection in the face of a given level of challenge or exposure. It is believed that if the calves have antibody titer formation prior to feedlot entry, it may help mitigate loses caused by the disease. In order for antibody titer formation to occur, a cell-mediated immune response from vaccination needs to happen. Due to management concerns, it may be best for calves to be vaccinated when all of the animals are already being penned and worked for other reasons. As the number of times that the whole herd is gathered and worked is typically minimal, it may be necessary to vaccinate the calf at a very young age to ensure that it has been vaccinated prior to feedlot entry.

There is evidence that it may be possible to vaccinate the calf at birth to against active pathogens (Zimmerman et al., 2006). However, there are conflicting reports which suggest that: (1) maternal antibodies may neutralize the vaccine before it can cause a cell-mediated response; or (2) the neonate's immune system is not developed enough to respond to a vaccine (Tizzard,

2000). As the animal's immune system is very complex, it could be that either of the reports are correct or that an understood piece is correct.

There is evidence that cell-mediated immune responses may vary depending upon type of infection presented (Wu and Kurman, 1997). Cell-mediated immune responses are regulated by T lymphocytes [T-helper (Th) lymphocytes and cytotoxic lymphocytes (CTLs)] in cooperation with antigen presenting cells (APCs) [monocytes (MCs) and dendritic cells (DCs)]. These cells all release cytokines that can influence one another's synthesis and actions in the setting of an immuno-regulating cytokine network. Cytokines in immune responses to infection are often classified as immune-stimulating Th1-type cytokines and immuno-inhibitory Th2-type cytokines (Bais et al., 2007).

Classically, Th1 cytokines including IL-2 and IFN-γ, are involved in protection against intracellular pathogens; and TH2 cytokines, including IL-4 and IL-10, are required for protection against extracellular pathogens (Finkelman and Urban, 1992). However, others have proposed that *in vivo* cytokine immune responses may not be only restricted to the response of discrete subsets but that different combinations of cytokine responses can be elicited by infectious agents (Kelso, 1995). Canals et al. (1997) observed that infection with *Ostertagia ostertagi* reduced the percentage of T-cells, an increase in the percentage of B cells, and changes in cytokine mRNA expression characterized by decreased levels of IL-2 and increases in IL-4 and IL-10 transcription. Based on study results, they concluded that "together with the unrestricted cytokine secretion patterns of bovine T-cell clones, these results suggest that, in cattle, the Th1 and Th2 paradigm may not be as clearly delineated as in the mouse model." Because of this it is likely necessary to measure cytokines associated with both Th1 and Th-2 lymphocytes to obtain a better understanding of how neonate calves respond to vaccination.

Very little information is available in the bovine model as to when these different cytokines may be expressed. In the mouse model, Cruz et al. (2008) described the kinetics of cytokine secretion in response to an injection with snake venom. They showed that a spike occurred within the first 24 h after injection in all of the cytokines measured. However, depending upon the cytokine being measured, the release varied with time. In the human model, in-vitro analysis of whole blood cultures demonstrated that cytokine release happened anywhere from 20 to 100 h after a mitogenic challenge (Bais et al., 2007).

Because of the apparent role of cytokine release in the immunological cascade, knowledge of the cytokine response to vaccination in the neonate may provide insight into the temporal pattern of cytokine release in the bovine. Additionally, characterization of cytokine release will allow identification of key sampling times in field studies, and enhance the ability to collect data from larger populations without the necessity of intensive serial blood collection.

Therefore, the objectives of the present study were to: (1) determine cytokine profiles expressed as a result of vaccination, and (2) indentify optimal time points for measurement of cytokine secretion in neonatal Holstein calves.

## Materials and Methods

Holstein steers (n = 8) were assigned at random to one of two vaccination treatment groups that included vaccination with either a modified-live virus [Arsenal 4.1® (ARS)] or a killed virus vaccine [ViraShield 6™(VIRA)] for bovine respiratory disease. Treatment administration occurred within a week of animals' births. Blood samples and rectal temperature measurements were collected -1 h prior to treatment, hourly for the first 12 h after treatment administration and at h 18, 24, 30, 36, 48, 60 and 72. Individual animal weights were recorded at h 0, and h 48.

Blood samples were drawn via jugular venipuncture into evacuated tubes and centrifuged at 2,000 g, 4°C, for 20 minutes; serum was pipetted into 7mL polypropylene serum tubes and frozen at -80°C until they could be transported to the USDA-ARS Laboratory in Lubbock, TX.

Samples were analyzed in duplicate within a single assay. Serum concentrations of interleukin 4 (IL-4), interleukin 6 (IL-6), tumor necrosis factor-alpha (TNF-α) and interferon-gamma (IFN-γ) were determined using a bovine specific ELISA plate kit as per the instructions of the manufacturer (R&D Systems, Minneapolis, MN). Serum concentrations of interleukin 1 beta (IL1-β) and interleukin 2 (IL-2) were analyzed using a commercially available ELISA kit specific for bovine IL1-β and IL-2 (R&D Systems, Minneapolis, MN). Analyses were performed per manufacturer's guidelines.

Statistical analyses were performed in the mixed models procedures of SAS (SAS Inst. Inc., Cary, NC) as repeated measures with calf as the experimental unit. Cytokine levels were expressed in pg/mL as difference from baseline (samples taken immediately prior to treatment administration). Treatment, time, and treatment (time) were independent effects in the model. When results from the analysis produced $P < 0.01$, least squares means were separated for two-tailed t-tests.

## Results and Discussion

Cytokines are soluble protein mediators important for the orchestration of inflammatory responses (Romagnani, 2000; Cruz et al., 2008). Cytokine secretions are the major determinants of the effectors' functions of the cell-mediated (Th-1) or humoral responses (Abbas et al., 1993; Richeson et al., 2008). The production of Th1 and Th2 cytokines is strictly controlled by complex feedback mechanisms (van Dissel et al., 1998; Taniguchi et al., 1999; Fasshauer et al., 2003). The Th1 cytokines such as IL-1, TNF-α and IFN-γ mobilize in the immune system cells

to proliferate and produce more cytokines creating an inflammatory cascade. IL-4 and IL-10 are important in creating the Th2 response by dampening or inhibiting the inflammatory response (Chrousos, 2000; Agarwal and Marshall, 2001; Elenkov and Chrousos, 2002). Th1 cytokines are primarily responsible for initiating a potent defense against exogenous pathogens. In contrast, anti-inflammatory cytokines are crucial for down regulating the elevated inflammatory process and maintaining homeostasis for the correct functionality of VIRAl organs (Howard et al., 1993).

A balanced ratio of pro- and anti-inflammatory cytokines is important for appropriate immune response (Cruz et al., 2008). To determine the magnitude of the cytokine response caused by vaccination, we measured levels of cytokines in serum of neonatal calves. The release (difference from baseline concentration) of IL-6 across sampling times was 5 times greater ($P = 0.03$) in calves treated with VIRA than in those treated with ARS (Table 1). Interleukin-6 is produced by a variety of cells types during infection, trauma, and immunological challenge. The functional properties of IL-6 are extremely varied and this is reflected by the terminology originally used to describe the activities of this cytokine. It has been described to have both pro- and anti-inflammatory effects, as well as being involved in a variety of immune responses (Cruz et al., 2008). The results obtained in this study suggest that animals in the VIRA group produced significantly more IL-6 at 39.51 ± 8.16 pg/mL than those in the ARS group which produced 7.69 ± 8.16 pg/mL (as seen in Table 2).

This study did not show an effect of vaccine type on IL-2 secretion. However, it did show a significant influence of time on IL-2 serum concentrations (Table 1). Serum concentrations peaked at h 60 but returned to baseline levels by 72 h (Figure 1). Interluekin-2 is a cytokine whose immune function is not clearly understood. It has been reported to have both an anti-inflammatory role as well as a pro-inflammatory role depending upon the study it is being

**Table 1.** *P*-values of treatment, time, and treatment by time interactions of cytokine release (reported as change from baseline) in response to vaccination against bovine respiratory disease in neonatal calves.

| | Trt | Time | Trt x Time | Residual variance | Calf variance |
|---|---|---|---|---|---|
| IL1-b | 0.10 | <0.01 | 0.03 | 111.77 | 0.43 |
| IL2 | 0.86 | <0.01 | 0.98 | 128.1 | 0.84 |
| IL4 | 0.14 | 0.08 | 0.89 | 366.94 | 0.58 |
| IL6 | 0.03 | 0.10 | 0.17 | 2181.94 | 0.44 |
| IFN-g | 0.85 | 0.37 | 0.46 | 30366.00 | 0.86 |
| TNF-a | 0.18 | 0.07 | 0.54 | 256.11 | 0.67 |

[1] Cytokines include: IL1-b (Interleukin 1 – β); IL2 (Interleukin 2); IL4 (Interleukin 4); IL6 (Interleukin 6); IFN-γ (Interferon gamma); and TNF-α (Tumor necrosis factor alpha).

**Table 2.** Least squares means of cytokine secretion (reported as change from baseline) in response to vaccination against bovine respiratory disease in neonatal calves.

| | Vaccine | | |
|---|---|---|---|
| Cytokine | Arsenal 4.1 | ViraShield 6 | *P*-value |
| IL1-b | 6.81 ± 1.8 | 11.76 ± 1.8 | 0.10 |
| IL2 | -4.64 ± 3.7 | -5.56 ± 3.7 | 0.86 |
| IL4 | 12.29 ± 4 | 2.73 ± 4 | 0.14 |
| IL6 | 7.69 ± 8.2 | 39.51 ± 8.2 | 0.03 |
| IFN-g | 24.81 ± 59 | 8.13 ± 59 | 0.85 |
| TNF-a | -3.91 ± 3.8 | 4.31 ± 3.8 | 0.18 |

[1] Cytokines include: IL1-b (Interleukin 1 – β); IL2 (Interleukin 2); IL4 (Interleukin 4); IL6 (Interleukin 6); IFN-g (Interferon gamma); and TNF-a (Tumor necrosis factor alpha).

evaluated in. It is believed that IL-2 is a central mediator of immune responses and plays a role in homeostasis (Howard et al., 1993).

Tumor necrosis factor-α is a pro-inflammatory cytokine which plays an important role in the immune response to infections and cancer and in the regulation of inflammation (Aderka, 1996). The present study shows that the elevation of serum concentrations of TNF-α occurs at h 24 and remains throughout the remainder of the study (Figure 2). The main effect of vaccination was not significant in influencing TNF-α production (Table 1). In this study, the serum concentrations of IFN-γ were similar for both groups (Table 1). Response of IFN-γ was modest until h 60 at which it started to increase rapidly in some calves (Figure 1). However, due to the larger standard error associated with the IFN-γ response, time did not play a statistically significant role. IFN-γ is produced by a variety of cell types and plays a role in the early stages of host response to viruses and parasites. IL-4 promotes humoral immunity by stimulating the growth and activation of mast cells and eosinophils, the differentiation of B cells into antibody secreting B cells, and B cell immunoglobulin switching to IgE (Abbas et al., 1993; Chrousos, 2000; Marshal and Agarwal, 2000; Akdis et al., 2004). The present study showed that type of vaccination did not alter IL-4 production (Figure 3). There was a tendency for IL-4 to be influenced by time (Table 1). The study also showed that vaccination has the ability to stimulate IL-4 production and allow IL-4 to exert its modulatory effect on host inflammatory response.

The Th1 cytokine IL-1 is partially responsible for regulating TH2 cell development. However, it has been shown by Connor et al. (2005) that stress can inhibit the secretion and function of IL-1 while enhancing Th2 functions. IL-1β responded differently to type of vaccination given (Table 1). IL-1β peaked at h 5 in both treatment groups (Figure 4). The present study also shows that response of IL-1β to vaccination was significantly higher for

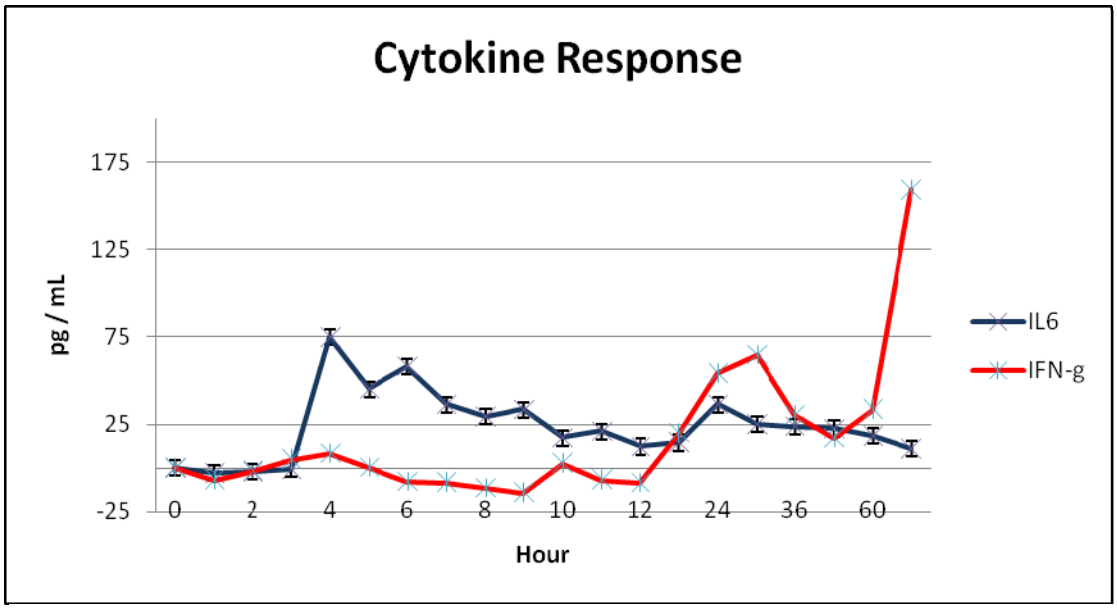


**Figure 1**. Effect of neonatal calf vaccination on interleukin 6 and interferon gamma levels. [1,2]

[1] LS Means are reported as changes from baseline.

[2] Treatment x time interactions: IL-6 ($P = 0.17$); IFN-γ ($P = 0.46$).

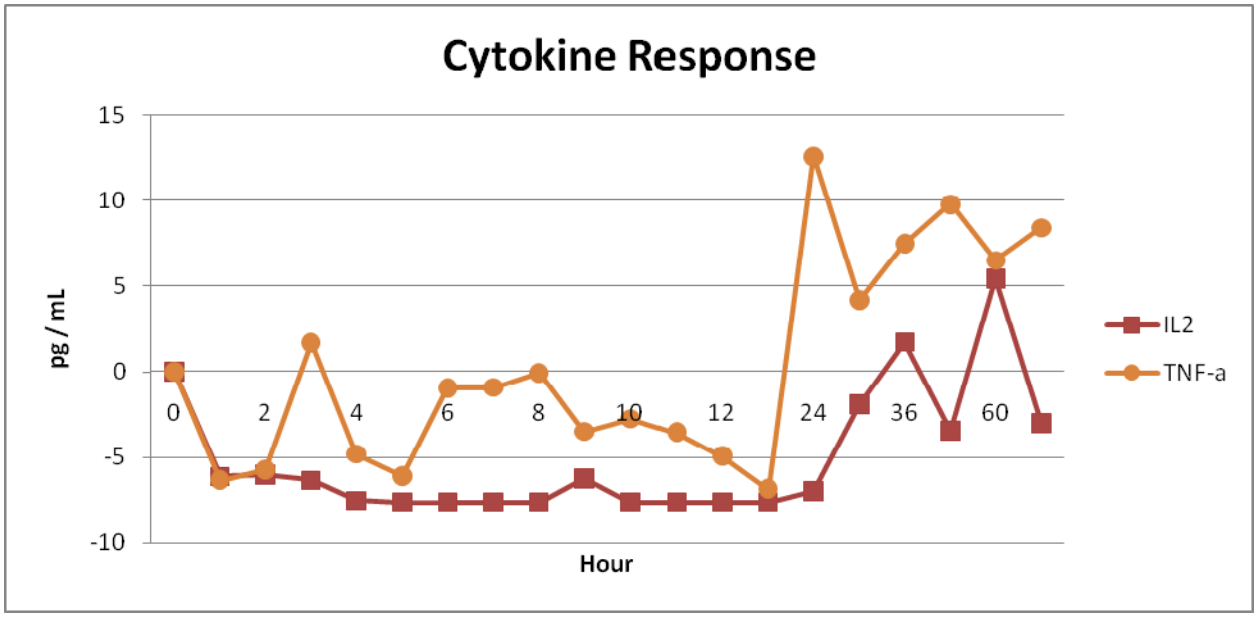


**Figure 2.** Effect of neonatal calf vaccination on interleukin 2 and tumor necrosis factor alpha levels. [1,2]

[1] LS Means are reported as changes from baseline.

[2] Treatment x time interactions: IL-2 ($P = 0.98$); TNF-α ($P = 0.54$).

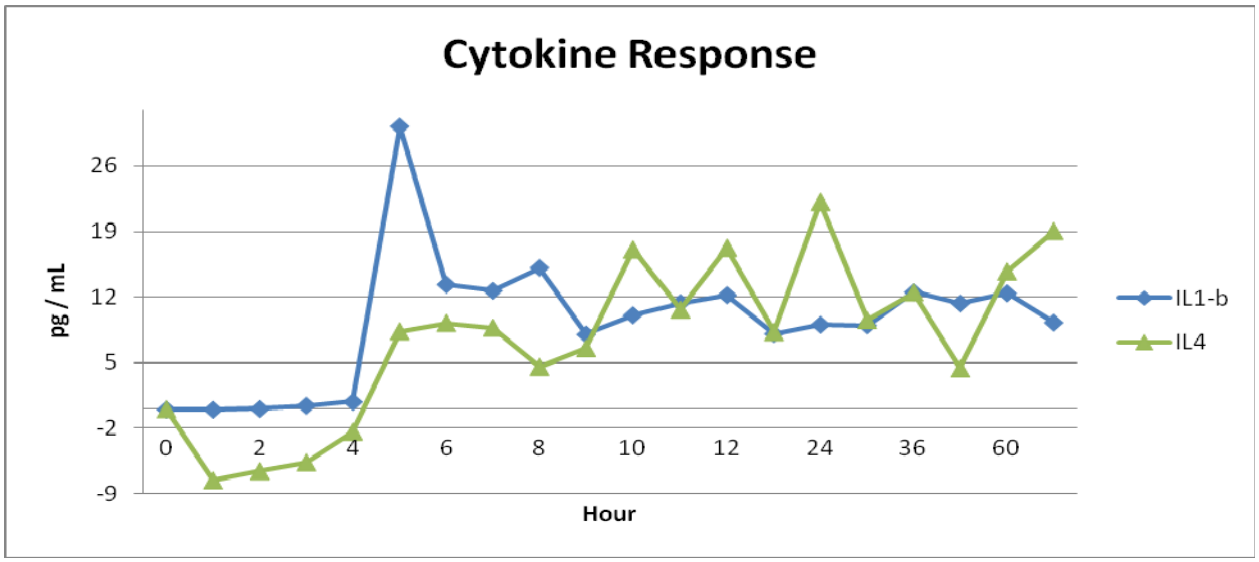


**Figure 3.** Effect of neonatal calf vaccination on interleukin 1 beta and interleukin 4 levels. [1,2]

[1] LS Means are reported as changes from baseline.

[2] Treatment x time interactions: IL1-β (P = 0.03); IL-4 (P = 0.89)

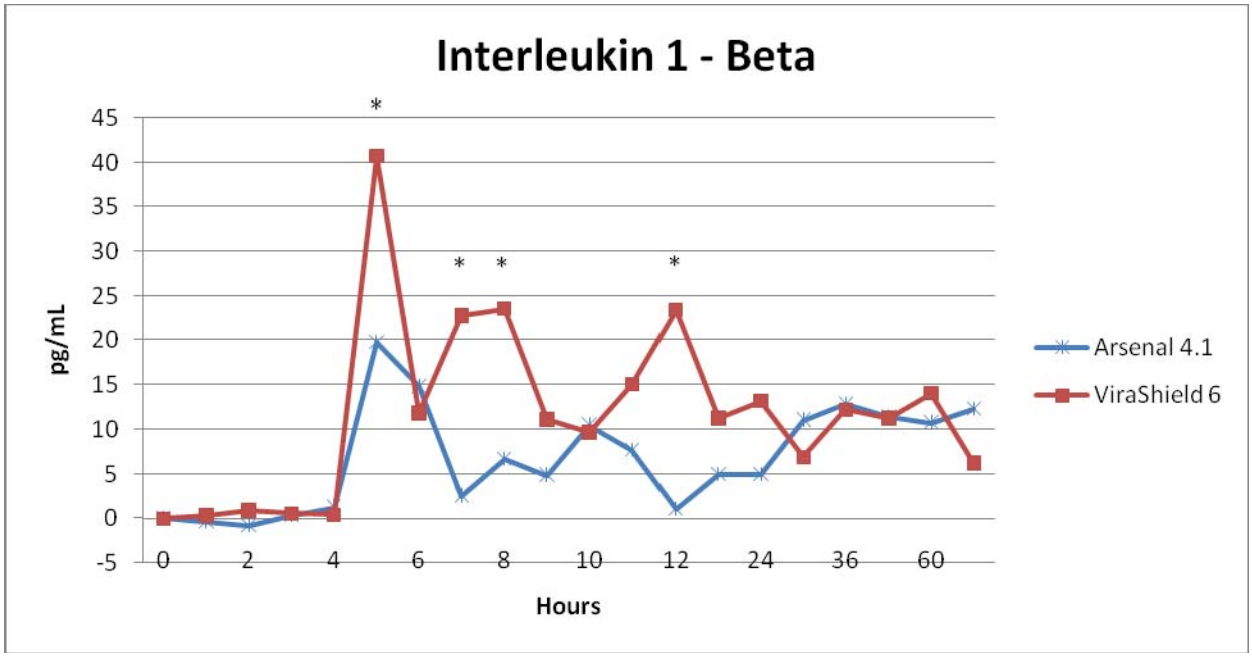


**Figure 4.** Interaction of vaccination and time on interleukin 1-β responses (change from baseline) in neonatal calves.

* ($P < 0.05$)

animals in the VIRA group at h 5, 7, 8, and 12.

Some of the cells of innate immunity, notably macrophages and NK cells, secrete cytokines that activate phagocytes and stimulate the cellular reaction of innate immunity, called inflammation. Inflammation consists of recruitment of leukocytes and proteins to eliminate the infectious agent. This inflammation can injure normal tissues. In the surrounding areas of inflammation, heat is produced. In cases with systemic inflammation, whole body temperatures may increase. Therefore, as a measure of inflammation we measured rectal temperatures of the calves.

Rectal temperatures were not influenced ($P = 0.83$) by type of vaccination given. Mean rectal temperature was 39.5 °C. Time did significantly alter temperature measurements (Figure 5). There was a tendency ($P = 0.09$) for vaccination treatment groups to have different temperatures over time (Figure 5). Animals in the ARS group had less changes in body temperature from baseline after h 6. At h 24 and h 48 animals in the ARS group returned to baseline.

Temperature changes in the ARS group after h 6 correspond to changes in ambient temperature. Results of this study suggest that it may be possible to get an accurate view of cytokine secretions without having to serially sample blood. Due to cytokine and rectal temperature spikes around h 5, and again after h 48, we suggest that multiple measurements need to be taken to get a true picture of cytokine release.

## Conclusions

While both vaccines stimulated cytokine production, the associated febrile response was not strongly correlated with the release of any specific cytokine. Our results demonstrate that different vaccines have differential effects on the magnitude and timing of release of various

cytokines. Understanding these differences and immunological sequelae to cytokine release may enhance development of vaccination strategies.

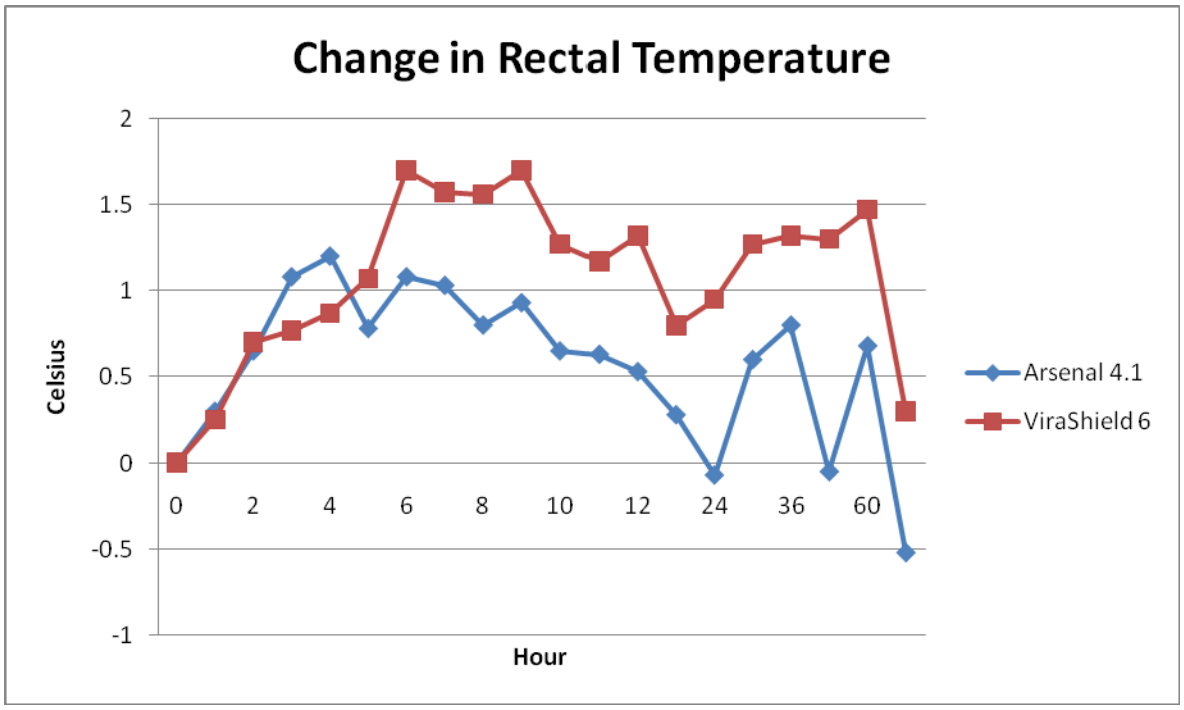


**Figure 5.** Change in rectal temperature from baseline (immediately prior to vaccine administration) of neonatal calves.

* ($P < 0.05$)

# CHAPTER III

# VACCINATION OF NEONATAL BEEF CALVES TO INDUCE A CELL-MEDIATED RESPONSE AGAINST BOVINE RESPIRATORY DISEASE COMPLEX

## Introduction

One of the primary drawbacks of most preweaning vaccination programs is that calf immunity may not be fully activated prior to pathogen exposure during comingling. A common recommendation is that ranchers vaccinate calves with some type of modified live or killed viral vaccine at weaning time. At this same time, calves are loaded, shipped, commingled, and further transported to a feedyard or stocker operation. The high incidence of infection in beef animals between the time of weaning and 9 months of age has prompted producers to begin vaccinating calves at a younger age (Rush et al., 2001).

According to current dogma, animals with maternal antibodies will not benefit from vaccination. It is believed that the maternal antibodies will "block" vaccine antigens before they elicit a response from the calf's own immune system. As part of the parturition process calves produce high levels of cortisol that remain elevated for the first week of life. The cumulative effect of these hormones and maternal antibodies is to suppress immune responses and direct the immune response away from TH1 responses. These also promote short-term TH2 immune responses, which utilize maternal antibodies but create no memory cells (Chase et al., 2008). However, there is developing research that indicates that neonatal calves can be immunologically primed by vaccinations even in the presence of maternal antibodies.

In 2008, Zimmerman et al. published a report showing that vaccinating calves at 5 weeks of age with a modified-live virus (MLV) Bovine Viral Diarrhea (BRD) vaccine induced a strong protective immune response in these young calves, even when plasma concentrations of maternal

antibodies were high. Similar results have been observed in calves that received Infectious Bovine Rhinotracheitis (IBR) and Bovine Viral Diarrhea (BVD) vaccines while still receiving passive maternal antibodies to these viruses (Brar et al., 1978). Brar et al. (1978) showed that while passive immunity initially prevented a detectable response, priming for a secondary response did occur. Calves that were vaccinated a second time, when maternal antibodies were no longer present, developed a higher antibody titer more rapidly than those that had not received a priming vaccination.

Another research trial also showed that the bovine neonate can mount a vigorous, adult like cell-mediated response when vaccinated at an early age. Researchers vaccinated calves with *Mycobacterium bovis* bacillus Calmette-Guerin at 1 week and 7 weeks of age and found that early vaccination of calves was associated with a Th1-like response to the antigen comparable to the response of adult cattle sensitized in the same manner (Nonnecke et al., 2004). However, they also showed with the BRSV model, as Ellis et al. (1996) did earlier, that although the calves developed adult-like cell-mediated immune responses *in vivo* and *ex vivo*, their humoral responses (characterized by serum antibody) were minimal relative to responses of vaccinated adult cattle. These results show promise that a cell mediated response can be elicited from a viral respiratory vaccine given within a week of birth. However, additional questions arise.

The primary question is whether or not a vaccination within a week of birth would effectively prime the calf's immune system to the level necessary for the animal to mount an adequate response when faced with the stressors of comingling and weaning several months later. Because many producers tag and/or weigh calves within a week of birth, this would provide an initial opportunity to administer a product, with a booster vaccination given at more traditional time points (such as branding), prior to exposure of the calf to the pathogen.

Therefore, the calf would have greater cellular immunity before it was shipped, reducing the need for a holding or preconditioning period.

The second question, which has not been adequately addressed in the literature, is whether or not a killed virus vaccine is as effective as a modified live virus vaccine in promoting a strong cell-mediated response when given to neonatal calves. This question has great importance in application, as producers may have reservations about giving a live virus vaccine to calves suckling pregnant cows, and few products are currently labeled for such use.

Therefore the objectives of this study were to: (1) determine if a cell-mediated response to the bovine respiratory disease complex can be initiated in the presence of maternal antibodies, (2) ascertain if early stimulation of a cell-mediated response can illicit greater lifetime immunity in the beef animal, and (3) discover the effectiveness of a modified live virus vaccine versus a killed vaccine in cell-mediated responses when administered to the neonatal calf.

## Materials and Methods

Fifty-two beef calves from Brangus dams and a Braunvieh sire were used for this study. Dams were either 5 or 6 years of age. Calves were randomly assigned at birth to one of five treatment groups receiving either ViraShield®6 (Killed; **K**) or Arsenal 4.1™ (Live; **L**). ViraShield®6 is a killed viral vaccine to Bovine Viral Diarrhea virus (BVD) type 1, BVD type 2, Infectious Bovine Rhinotracheitis (IBR), Parainfluenza-3 ($PI_3$) and Bovine Respiratory Syncytial Virus (BRSV). Arsenal 4.1™ is a modified-live virus (MLV) vaccine to BVD Type 1, BVD Type 2, IBR, $PI_3$, and BRSV. Treatment groups included: Control (**CON**l); Killed at d 0 followed by Killed at d 100 (**KK**); Killed at d 0 followed by Live at d 100 (**KL**); Killed at d 0 followed by Killed at d 150 (**KNK**); Live at d 0 followed by Killed at d 100 (**LK**) (shown in Table 3).

Both steers and heifers were used for this study (Table 4). Steer calves were castrated by knife after the 6 h blood draw at birth. All calves were worked within 3 d of birth. The calf birth date distribution is shown in Figure 6.

Blood samples were collected on d 0 of the trial prior to treatment application at h 0 for cytokine, serum neutralizing antibody titer to BVD Type 1 and IBR, total serum protein, and serum Immunoglobulin G (IgG) analyses. Day 100 and subsequent time measurements were determined by taking median date of calf birth and adding 100 days.

Body temperature was measured rectally at each collection time. Collection times included: d 0 (hours 0, 6, 48), d 21 (hour 0), d 100 (hours 0, 6, 48), d 158 (hours 0, 6, 48), d 200 (hour 0), and d 250 (hour 0). For all time points h 0 was at 0830 hours.

Body weights were measure on each day that sampling occurred. Blood samples were collected for cytokine analyses at d 0, d 100, d 158. Collection on each of the three days occurred at hours 0, 6, and 48. Blood samples were collected for serum neutralizing antibody titers to IBR and BVD Type 1 analyses on d 0, d 21, d 100, d 158, d 200, and d 250 at h 0.

Blood samples were drawn via jugular venipuncture into evacuated tubes, allowed to clot on ice, and centrifuged at 2,000 g, 4°C, for 20 minutes. Serum was divided into 3, 2 ml aliquots and pipetted into storage vials. One aliquot was frozen at -20 °C and sent to Texas Veterinary Medical Diagnostic Laboratory (TVMDL, Amarillo, TX) for quantification of serum neutralizing antibody titers to BVD Type 1, and IBR. A second aliquot was frozen at -80°C until it could be transported to the USDA-ARS Research Laboratory in Lubbock, TX.

IgG and total protein samples were handled in the same manner as the cytokine samples through the freezing process. IgG analysis was conducted at Texas A&M University using a sandwich ELISA specific to bovine IgG. Total serum protein levels were determined using a commercially available bicinchoninic acid protein kit (BCA1, Sigma Aldrich, Saint Louis, MO). Analyses were conducted according to manufacturer directions.

For cytokine analyses, samples were analyzed in duplicate within a single assay. Serum concentrations of interleukin 4 (IL-4), interleukin 6 (IL-6), tumor necrosis factor-alpha (TNF-α) and interferon-gamma (IFN-γ) were determined using a bovine specific ELISA plate kit as per manufacturer instructions (R&D Systems, Minneapolis, MN). Serum concentrations of interleukin 1 beta (IL1-β) and interleukin 2 (IL-2) were analyzed using a commercially available ELISA kit specific for bovine IL1-β and IL-2 (R&D Systems, Minneapolis, MN). Analyses were performed per manufacturer's guidelines.

A group of 5 heifers from another herd on the ranch were used for a as a positive control. Cytokine data were not measured on these calves. All other data were collected on the ranch calves. Ranch calf treatment included receiving a modified live virus vaccine at d 100 and at d 150.

Statistical analyses were performed using the mixed models procedures of SAS (SAS Inst. Inc., Cary, NC). Rectal temperatures, body weight, and serum neutralizing antibody titers were analyzed as repeated measures with day as the repeated term. Cytokine data were analyzed first as repeated measures with hour nested within day as the repeated term. When the day by treatment interaction was significant, cytokine data were then analyzed with hour as the repeated term and the "by day" statement added to the model.

**Table 3.** Treatment distribution of calves receiving either a modified live virus vaccine or killed vaccine at birth to bovine viral diarrhea and infectious bovine rhinotracheitis.

| | Birth | d 100 | d 158 | d 200 | d 250 |
|---|---|---|---|---|---|
| Ranch | N | K | L | L | - |
| Neg Control | N | N | K | L | - |
| K / K | K | K | N | L | - |
| K / L | K | L | N | L | - |
| K/N/K | K | N | K | L | - |
| L / K | L | K | N | L | - |

* Day 200 Vaccination is to guarantee that all animals fulfill the Caprock Feeders criteria.
** Treatments groups include: N (None); K (killed vaccine); L (modified live virus vaccine)

**Table 4.** Distribution of treatments by gender (numbers of animals).

| | | Treatment | | | | |
|---|---|---|---|---|---|---|
| | | Control | K-N-K | K-L | K-K | L-K |
| **Gender** | Steer | 6 | 5 | 5 | 5 | 5 |
| | Heifer | 4 | 5 | 6 | 5 | 5 |

* Treatments include Con (Control – No vaccine given); KK (Killed vaccine given at birth and at day 100); KL (Killed vaccine given at birth and a Modified-live virus vaccine given at day 100); KNK (Killed vaccine given at birth and at day 158); LK (Modified-live virus vaccine given at day 0 and a killed vaccine given at day 100).

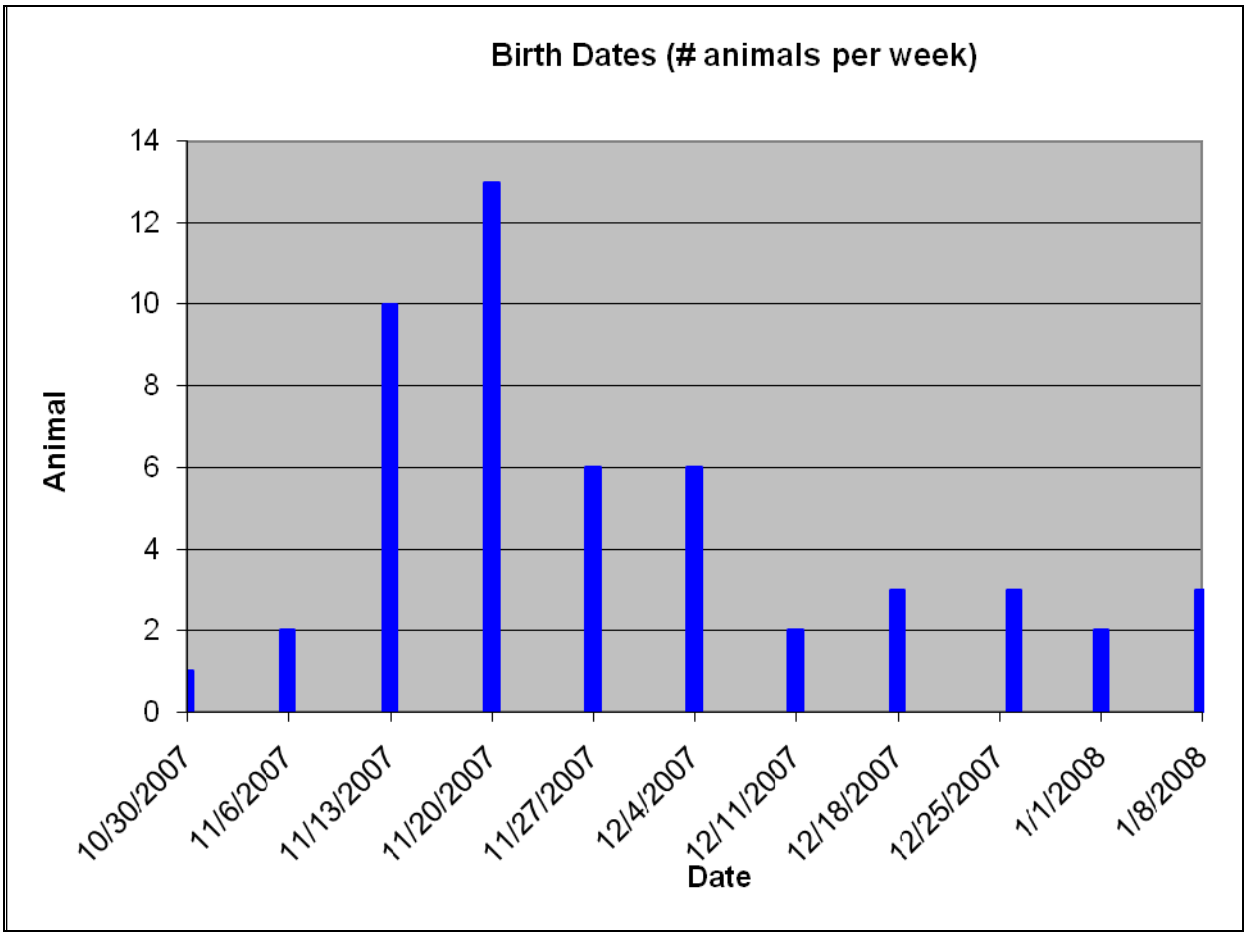


**Figure 6.** Birth date distribution of animals by week.

Serum-neutralizing antibody titer count data were transformed to $\log_2$ prior to analyses, and the results are expressed in this form (i.e., the values represent $x$ in the form $2^x$; data were not back-transformed for presentation). Average daily gain was computed as the average weight gain (kg) divided by time between weight collections (d) for specific time periods. Cytokines were expressed in pg/mL as the difference from baseline within collection day. Hour 0 measurements within the day were used as baseline.

Level of significance was set at $P < 0.05$. If effects were declared significant, Fisher's Least Significant Difference (PDIFF) option in the LSMEANS statement of SAS (SAS Institute, Cary, NC) was used to separate means. PROC CORR was used to examine correlations among all variables on and between hour within day. Only significant ($P < 0.01$) correlations are reported.

## Results and Discussion

**Body temperature.** No treatment by time interactions were observed for rectal temperature. Differences due to day were observed, and mean rectal temperature across treatment group is reported in Figure 7. Changes in rectal temperature closely followed changes in ambient temperature experienced at time of sample collection.

**Immunoglobulin G.** Serum IgG levels collected shortly after birth represent passive transfer from the dam, and thus reflect quantity and quality of colostral intake by calves (Musgli et al., 1987). All calves had high circulating blood serum IgG levels that ranged from 7.09 to 7.92 g/L with a coefficient of variation of 5.2%. Arthington et al. (2000) reported that colostrum deficient calves had circulating IgG levels in serum of less than 1 g/L and that calves supplemented with high quality colostrum had up to 12 g/L IgG.

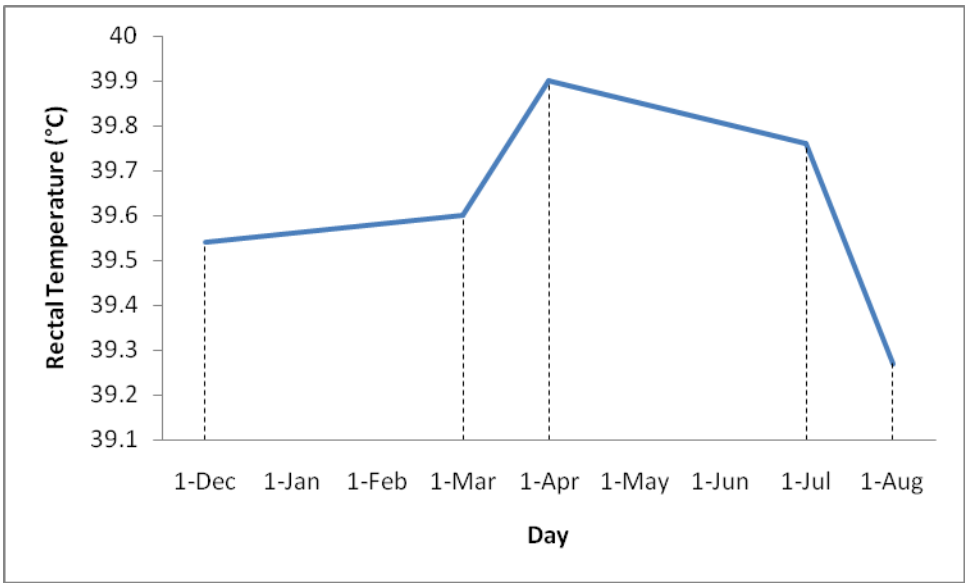


**Figure 7.** Mean rectal temperatures (°C) in groups of calves vaccinated neonatally against BVD and IBR. Temperature different ($P<0.01$) from one time period to the next except for the period between December 2007 and March 2008.

**Body weight.** Body weight increased over time ($P < 0.01$, Figure 8) as expected in young growing animals. Treatment did not interact with day to alter weight gains of the calves ($P = 0.69$). Day was significant, and mean weights across treatment are shown in Figure 3. In addition, the main effect of treatment was also significant for weight gain (Table 5). Calves in the control group had the highest ($P < 0.05$) weaning weights of the calves in this study at 309.39 kg. Animals that received the MLV vaccine at birth or the animals that received the killed vaccine at birth and day 158 were intermediate to the control and the KK and KL treatment groups. Average daily gains were also affected by the type of treatment given ($P < 0.01$). Animals receiving the control treatment had the highest average daily gains while animals receiving the KNK treatment had intermediate average daily gains to that of the other groups. Animals in the KL group had the lowest ($P < 0.05$) average daily gains at 1.49 kg/d.

**Serum neutralizing antibody titers.** Serum neutralizing antibody titers against both BVD Type 1 and IBR varied over time ($P < 0.01$, Figure 3). Titer levels decreased over the period of the trial. However, at d 250, titer levels to BVD Type 1 increased compared to d 200 levels ($P < 0.01$). The significant day effect is consistent with previous reports of the contributions of maternal antibodies to resulting antibody levels of the calf. Brar et al. (1978) reported that antibody levels of calves decreased at a steady rate throughout the first 175 d of life. After of which, depending upon the vaccination strategy, the calves started producing titers of their own.

Longevity of antibody production due to passively acquired antibodies is highly dependent upon milk quality and yield given by the cow. Because of the high levels of IgG measured at the onset of this trial and the age of the dam, it is our belief that these calves received more than an adequate amount of passively transferred antibodies. Therefore, we did not expect to see much of an increase in titer levels prior to 175 d of life. After of which, we did hope to find that a

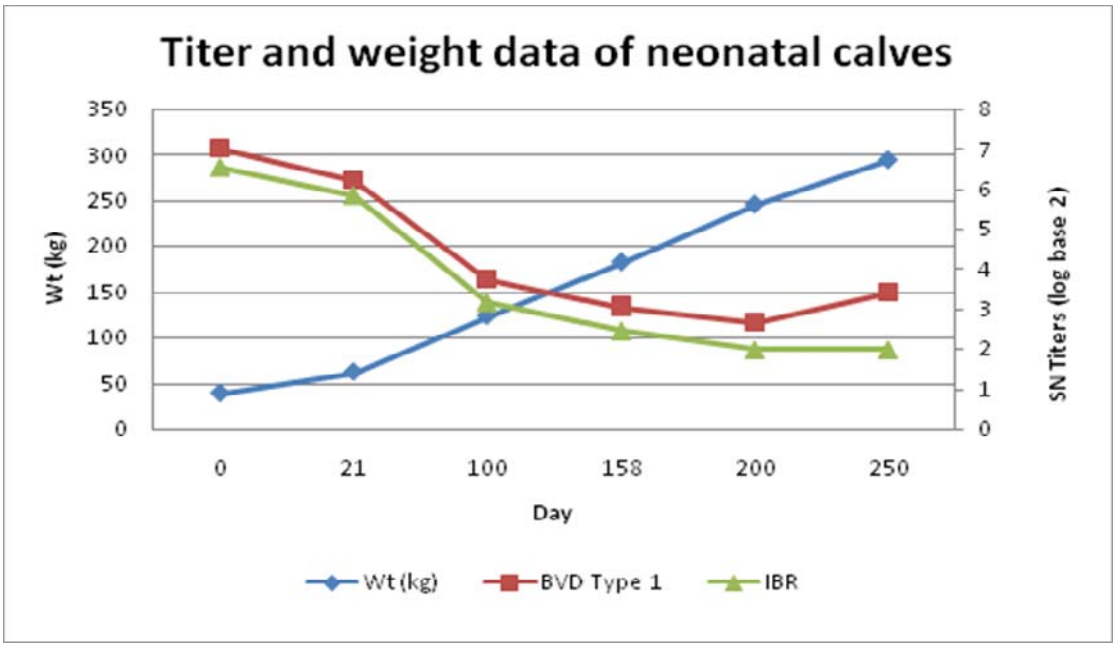


**Figure 8**. Weight gain and antibody titer levels of calves vaccinated with either a modified-live virus vaccine or a killed virus vaccine to bovine viral diarrhea virus (BVD) and infectious bovine rhinotracheitis (IBR).

**Table 5.** Least squares means for production data and antibody titer levels for calves receiving a neonatal vaccination to bovine respiratory disease.

| | Treatments | | | | | | |
|---|---|---|---|---|---|---|---|
| | Con | KK | KL | KNK | LK | SE | P-Value |
| BVD Type 1 | 3.67 [b] | 3.98 [ab] | 3.95 [ab] | 3.38 [b] | 4.72 [a] | 0.28 | 0.02 |
| IBR | 3.89 [a] | 3.08 [b] | 3.20 [b] | 3.23 [b] | 3.49 [ab] | 0.18 | <0.01 |
| Weaning Weight (kg) | 309.39 [a] | 285.38 [b] | 282.85 [b] | 290.18 [ab] | 300.02 [ab] | 8.31 | <0.01 |
| ADG (kg/day) | 1.64 [a] | 1.50 [b] | 1.49 [b] | 1.55 [ab] | 1.53 [b] | 0.03 | 0.02 |
| Temp (°C) | 39.60 [abc] | 39.51 [c] | 39.75 [ab] | 39.55 [bc] | 39.67 [ab] | 0.07 | 0.03 |

* Treatments include Con (Control – No vaccine given); KK (Killed vaccine given at birth and at day 100); KL (Killed vaccine given at birth and a Modified-live virus vaccine given at day 100); KNK (Killed vaccine given at birth and at day 158); LK (Modified-live virus vaccine given at day 0 and a killed vaccine given at day 100).

[ab] Different superscripts within a row differ ($P < 0.05$).

priming response had occurred and the calf's own immune system would start creating antibody titers that exceeded that of the controls. For the overall day effect, there was not a significant increase in titers to BVD at day 250, but it appeared that an upward trend could have been beginning. Titer levels for IBR did not change from d 200 to d 250.

Titers of serum neutralizing antibody against BVD Type 1 were measured at birth and throughout d 250 of the calf's life (Table 6). Animals vaccinated with the MLV at birth created significantly more antibody titers ($4.72_{log2}$) than animals in the control group ($3.67_{log2}$) or animals that received the killed vaccine at birth and at day 158 (KNK). Animals in the KK and KL groups were intermediate to the other treatment groups.

Animals in the control group had the highest ($P < 0.05$) IBR titer levels ($3.89_{log2}$). Calves that received the MLV vaccine at birth ($3.49_{log2}$) were intermediate to all other treatment groups in this study for IBR titer levels. Animals in the KK, KL, and KNK treatment groups were not significantly different from each other in their production of serum neutralizing antibody titers to IBR.

Because animals in the control group had the highest antibody titer levels to IBR, we re-examined the raw data to see if we could find a time in which calves in this trial were exposed to IBR. We were not able to find any point(s) in which it seemed they were exposed. Titer levels at birth were consistent with that of calves that received antibodies through passive transfer. The titer levels then dropped throughout the subsequent life of the animal with no apparent spikes that would have indicated a possible exposure. One possible explanation for the observed results might be by shedding of vaccine strains from calves vaccinated with the MLV. As virus can be transferred from one animal to the other through mucus or direct contact, it is hypothesized that

**Table 6**. P-values for cytokines of neonatal calves analyzed for the main effects of treatment (Trt) and day and the interaction of treatment and day.

| | Trt | Day | Hour | Trt x Day |
|---|---|---|---|---|
| IL-1 Beta | 0.10 | 0.07 | 0.12 | 0.07 |
| IL-2 | 0.72 | 0.12 | <0.01 | 0.91 |
| IL-4 | 0.56 | 0.38 | <0.01 | 0.55 |
| IL-6 | <0.01 | <0.01 | <0.01 | <0.01 |
| IFN-g | <0.01 | <0.01 | 0.01 | <0.01 |
| TNF-a | 0.75 | 0.08 | 0.35 | 0.11 |

it is possible for an unvaccinated animal to become exposed after coming in contact with a vaccinated animal.

**Cytokine analysis.** Serum samples were taken for cytokine analysis at 0, 6, 48 h for days 0, 100, and 158 of the trial. A treatment by day interaction occurred for most of the cytokines sampled. Figures 9 - 27 represent the treatment by hour interactions within day. We found only one treatment by hour interaction within day (Table 7). We believe that this interaction occurred because the IL-4 response of animals in the LK group spiked at h 48 on day 100. This spike caused a shift in slopes of the lines that differed from the slopes of the lines at h 6. In addition, we also found a spike in the LK group of IL-4 levels at h 48 on d 158. While this was not significant, there was a trend for the IL-4 to be increased by h 48. When looking at the overall plot of IL4 by day (Figure 28), it can be seen that animals in the LK group had the highest IL-4 levels on day 100 and 158.

We also observed a trend in IL-6 that is in agreement with our preliminary trial with Holstein calves where IL-6 spiked at h 6 and fell back again at h 48. This hour effect was significant at the $P < 0.01$ level for both day 100 and 158, but not at day 0 ($P = 0.13$). No other treatment by hour (within day) interactions were found for any of the investigated cytokines. The data are presented in Figures 9 through 26 for a representation of the trends.

IFN-g levels were tested in circulating serum after each vaccination was given. When looking at d 0 it can be seen that IFN-γ levels increased in the LK, KNK, and KK groups at both h 6 and 48 over that of the control group. When moving to d 100, it can be seen that animals in the LK, KK, and KL groups had higher ($P < 0.01$) cytokine levels at h 48 for IFN-γ over that of animals in the control group. It is not surprising that animals in the KNK group had similar IFN-γ levels to that of the control at d 100 as the KNK group did not receive a vaccination at day 100.

When moving out to d 158, we observed that animals in the KNK group had higher IFN-γ levels than animal in the other groups at h 48. This can be explained by the fact that only animals in the KNK group received a vaccination on d 158.

**Correlations.** Cytokine levels were not correlated with antibody titers to BVD or IBR ($P > 0.05$). We were able to observe correlations among cytokines within hour on d 0. For d 0, 6 h we found that IL1-β was correlated ($P < 0.01$) to IL-2 at a moderate level. IL4 was significantly correlated to IFN-γ at a strong level. TNF-α was significantly correlated to IL-6 and IFN-γ at moderate levels.

At d 0, h 48 we found a significant correlation among IL-2 and IL-6 (r = 0.52). In addition, a strong correlation (r = 0.81) was found between IL-4 and IFN-γ. While not as strong as the correlation at h 6, this correlation did remain throughout h 48.

There were several correlations among cytokines on d 158, and mainly existed within hour. Cytokine levels on the same day but different hours were not strongly correlated. We did find that on d 158, h 6 IL1-β was significantly correlated to TNF-α at a coefficient of 0.68. IFN-γ was also significantly correlated to IL-6 (r = 0.45).

On day 158, h 48 we found that several cytokines were significantly correlated to each other. IL-6 and IL1-β had a correlation coefficient of 0.72 while IL-6 and IL-2 had a correlation of 0.88. As mentioned above, we also found a correlation between IL-6 and IL-2 on d 0, h 48 that was not as strong at the correlation on day 158. TNF-α was correlated to IL1-β, IL-2, and IL-6 with coefficents of 0.53, 0.66, and 0.83, respectively. We did not find correlations among cytokines across different days.

**Table 7**. P-values for cytokines of neonatal calves, analyzed with hour as a repeated measure, by day.

| | Day 0 | | | Day 100 | | | Day 158 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Treatment | Hour | Interaction | Treatment | Hour | Interaction | Treatment | Hour | Interaction |
| IL1-B | 0.06 | 0.19 | 0.78 | 0.03 | 0.39 | 0.57 | 0.62 | 0.17 | 0.47 |
| IL2 | 0.76 | <0.01 | 0.97 | 0.46 | 0.27 | 0.51 | 0.64 | 0.65 | 0.32 |
| IL4 | 0.58 | 0.04 | 0.95 | 0.09 | <0.01 | 0.03 | 0.17 | 0.10 | 0.10 |
| IL6 | <0.01 | 0.13 | 0.17 | 0.06 | 0.01 | 0.42 | 0.32 | <0.01 | 0.28 |
| TNF-a | 0.39 | 0.26 | 0.86 | 0.36 | 0.77 | 0.29 | 0.17 | <0.01 | 0.48 |
| IFN-g | 0.31 | 0.61 | 0.86 | 0.07 | <0.01 | 0.27 | <0.01 | 0.08 | 0.31 |

* P-values given here because treatment by day interaction was significant for the cytokine models. All cytokines were reported as change from baseline measurement (h 0) within day.

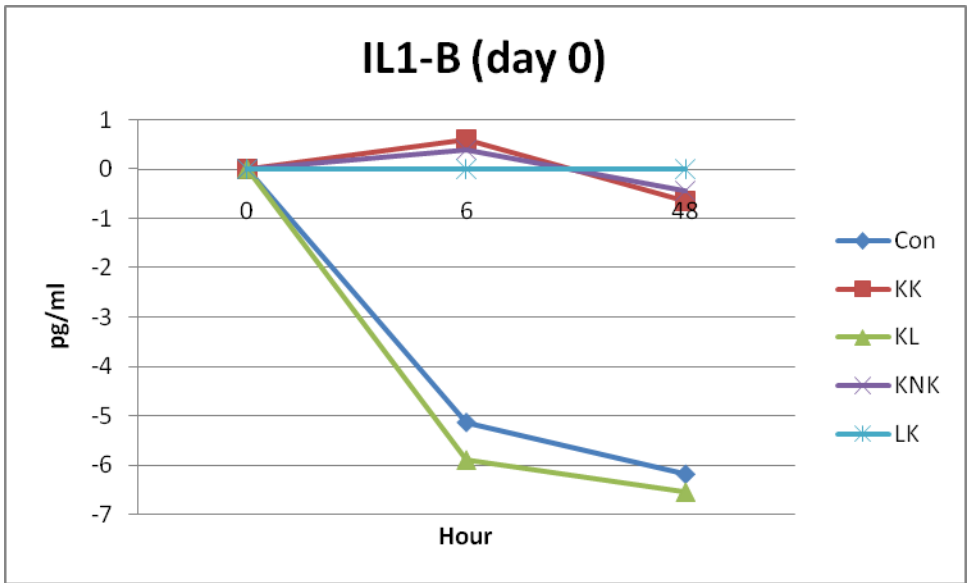


**Figure 9.** Interleukin 1 beta levels (represented as change from hour 0) at day 0 of neonatal calves vaccinated within three days of birth.

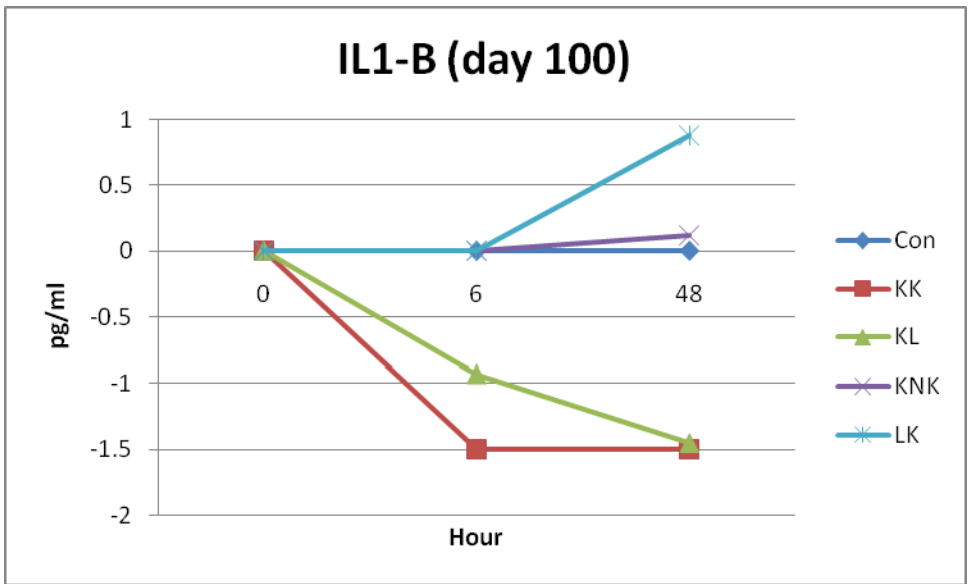


**Figure 10.** Interleukin 1 beta levels (represented as change from hour 0) at day 100 of neonatal calves vaccinated within three days of birth.

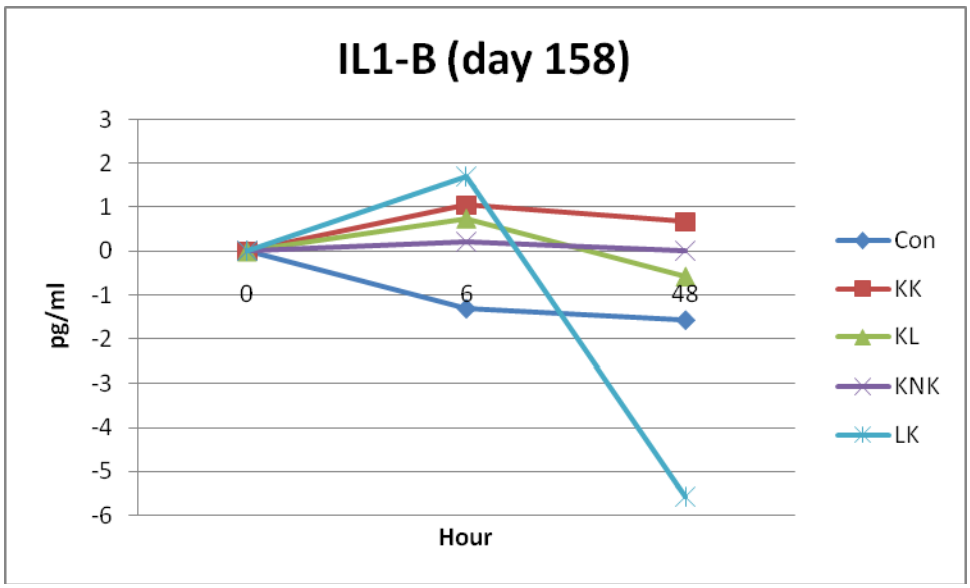


**Figure 11.** Interleukin 1 beta levels (represented as change from hour 0) at day 158 of neonatal calves vaccinated within three days of birth.

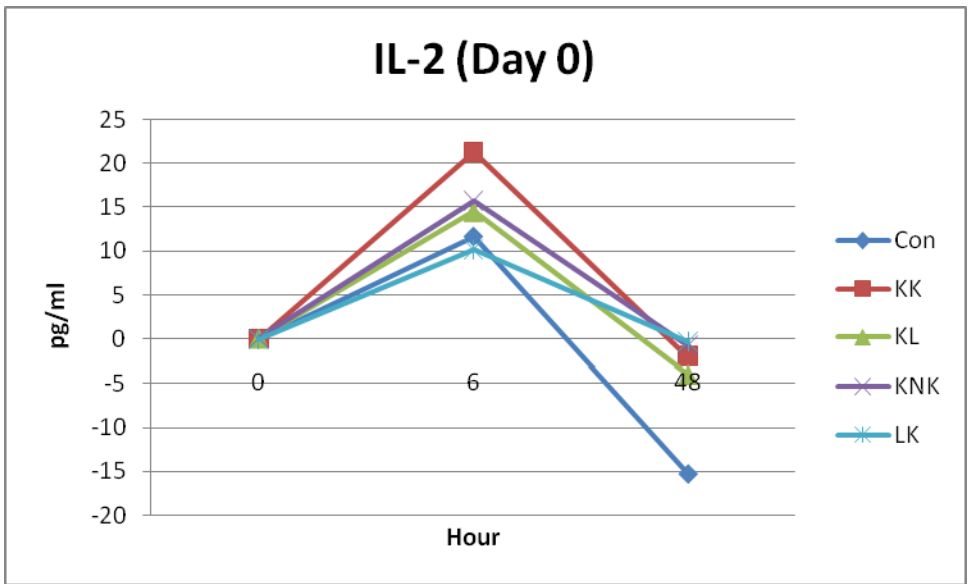


**Figure 12.** Interleukin 2 levels (represented as change from hour 0) at day 0 of neonatal calves vaccinated within three days of birth.

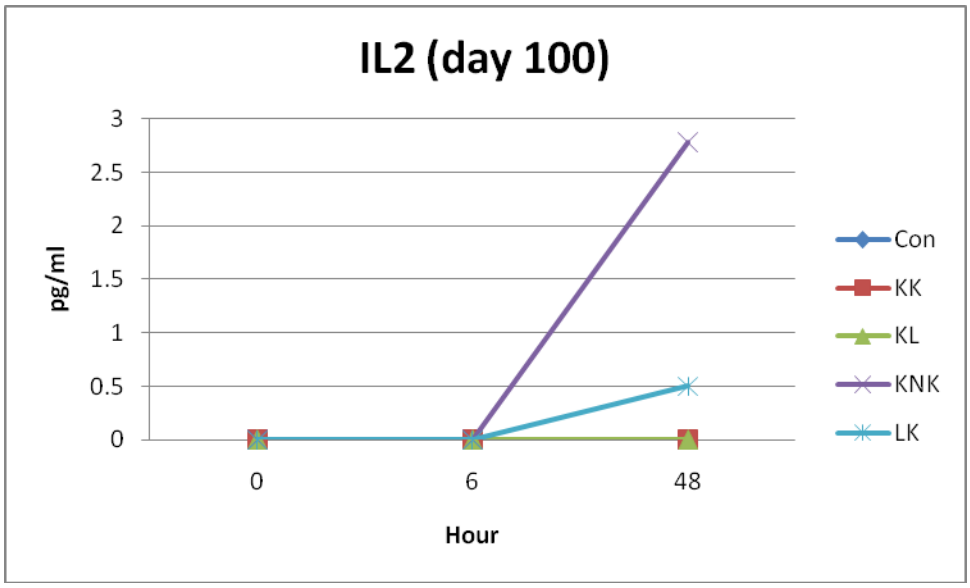


**Figure 13.** Interleukin 2 levels (represented as change from hour 0) at day 100 of neonatal calves vaccinated within three days of birth.

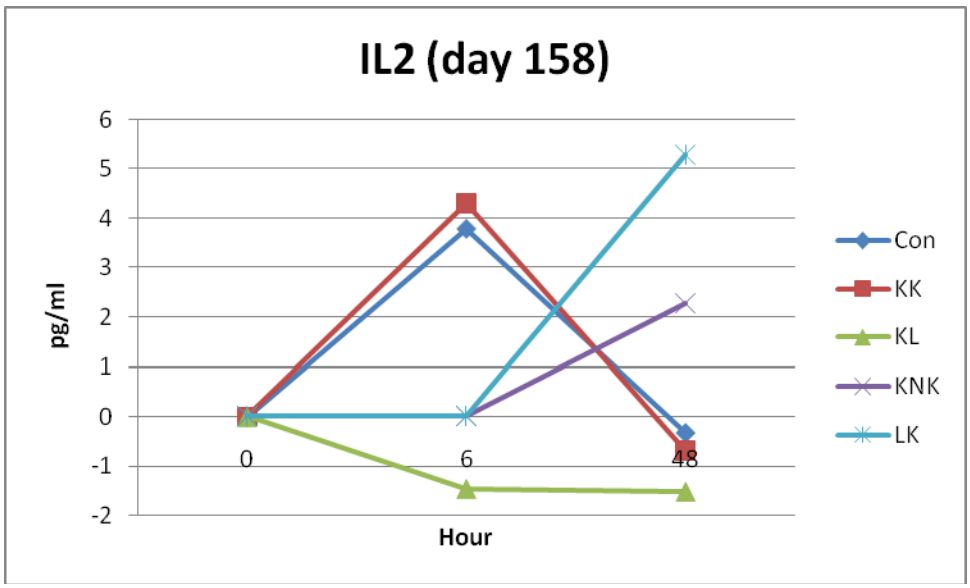


**Figure 14.** Interleukin 2 levels (represented as change from hour 0) at day 158 of neonatal calves vaccinated within three days of birth.

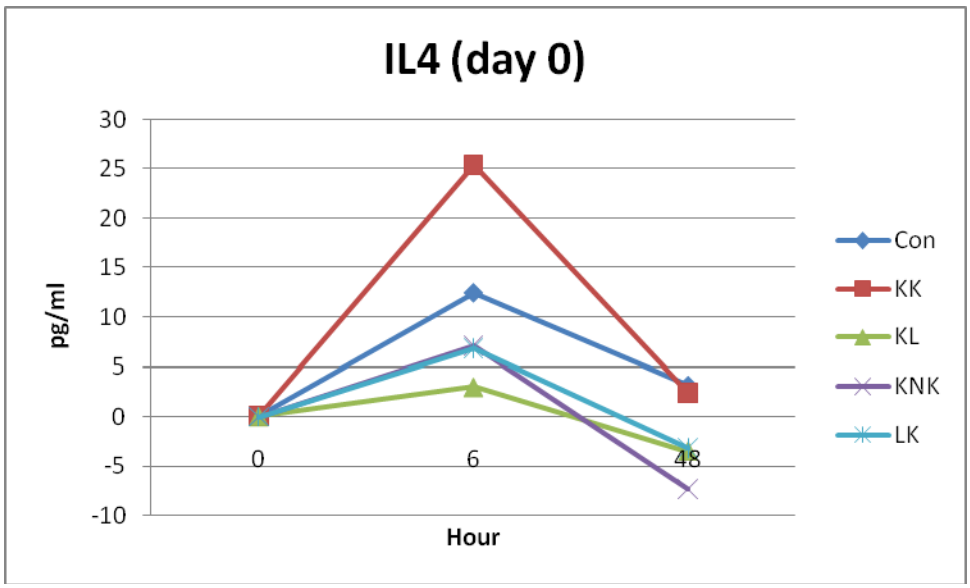


**Figure 15.** Interleukin 4 levels (represented as change from hour 0) at day 0 of neonatal calves vaccinated within three days of birth.

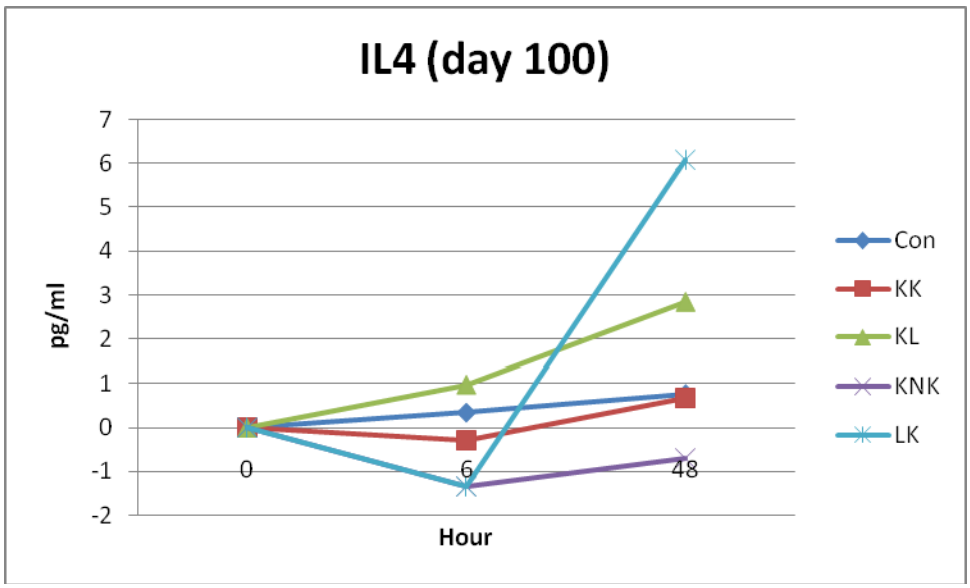


**Figure 16.** Interleukin 4 levels (represented as change from hour 0) at day 100 of neonatal calves vaccinated within three days of birth.

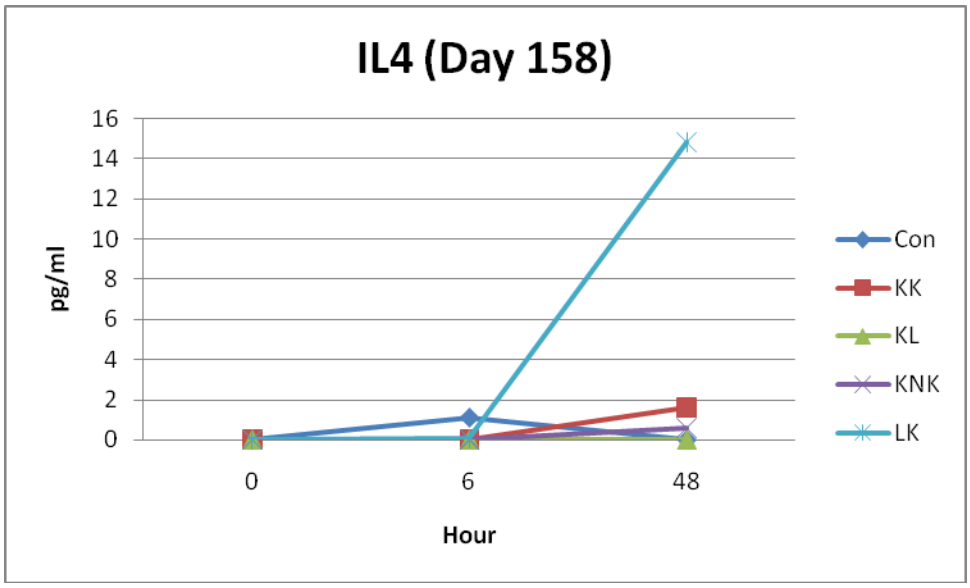


**Figure 17.** Interleukin 4 levels (represented as change from hour 0) at day 158 of neonatal calves vaccinated within three days of birth.

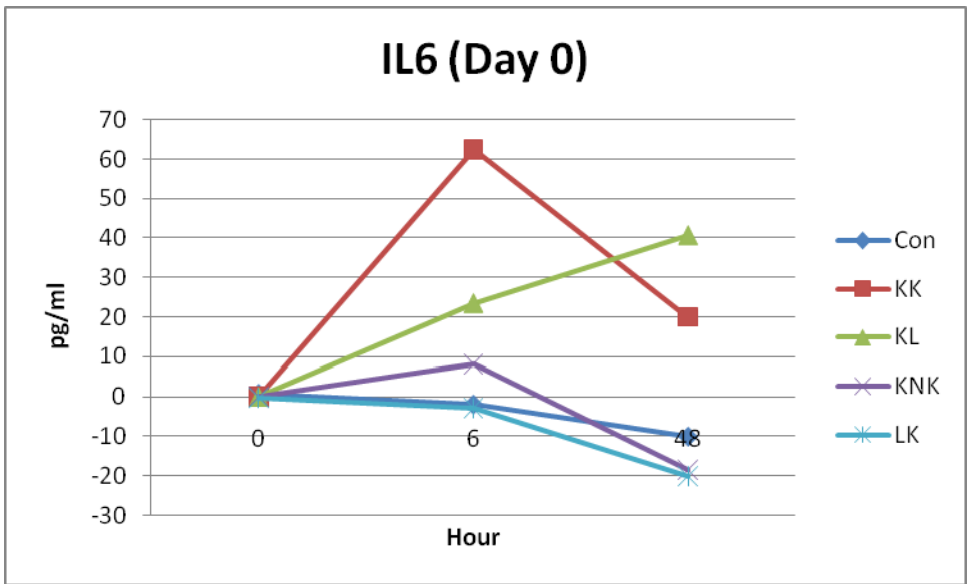


**Figure 18.** Interleukin 6 levels (represented as change from hour 0) at day 0 of neonatal calves vaccinated within three days of birth.

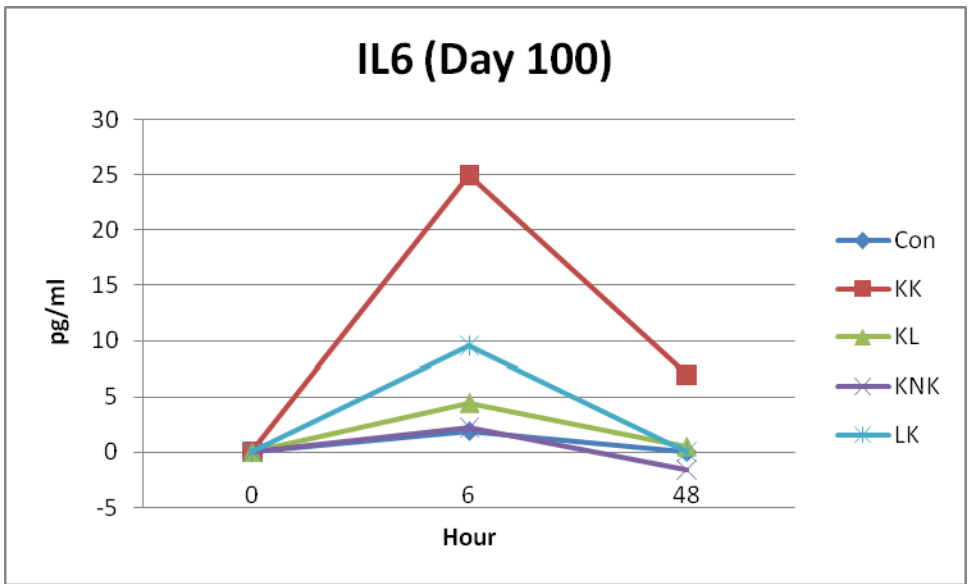


**Figure 19.** Interleukin 6 levels (represented as change from hour 0) at day 100 of neonatal calves vaccinated within three days of birth.

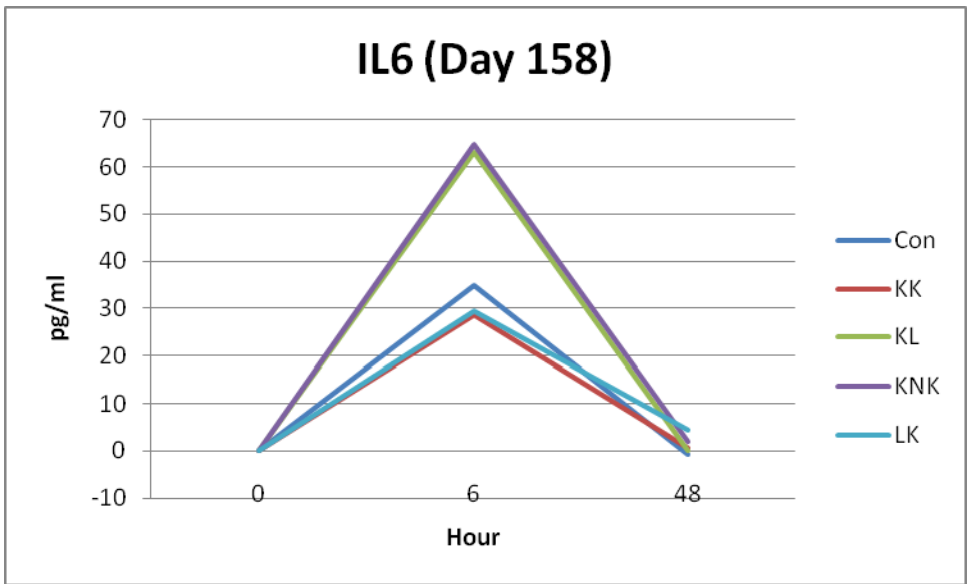


**Figure 20.** Interleukin 6 levels (represented as change from hour 0) at day 158 of neonatal calves vaccinated within three days of birth.

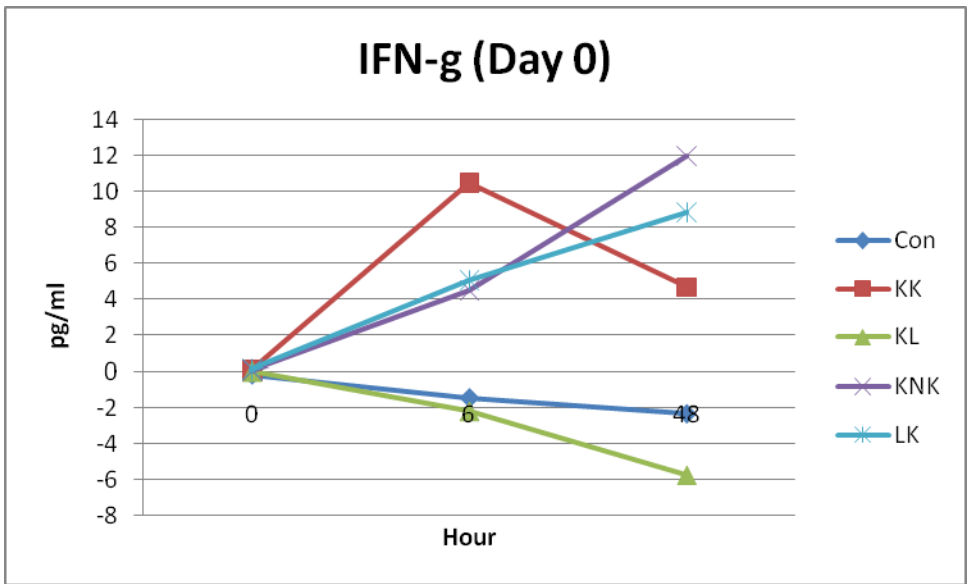


**Figure 21.** Interferon-gamma levels (represented as change from hour 0) at day 0 of neonatal calves vaccinated within three days of birth.

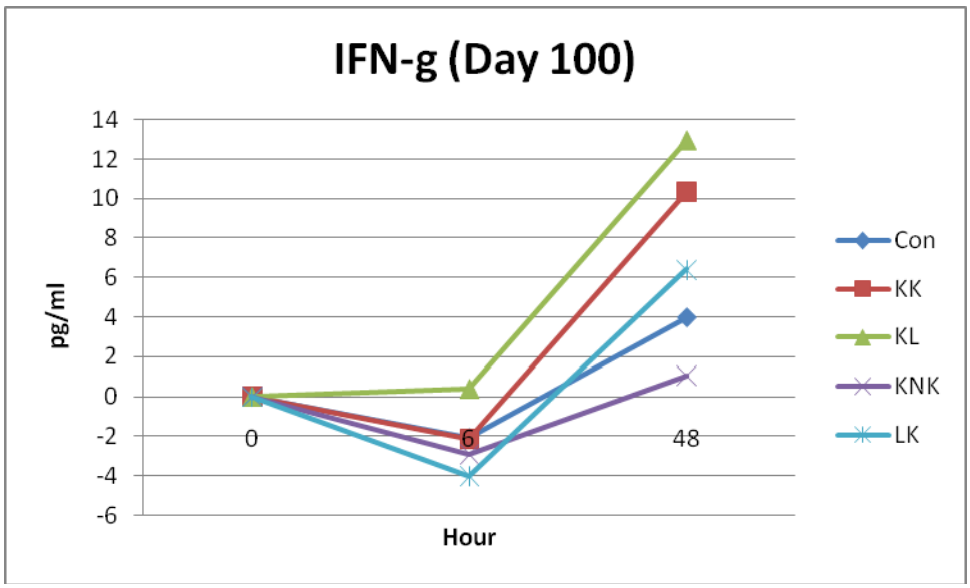


**Figure 22.** Interferon-gamma levels (represented as change from hour 0) at day 100 of neonatal calves vaccinated within three days of birth.

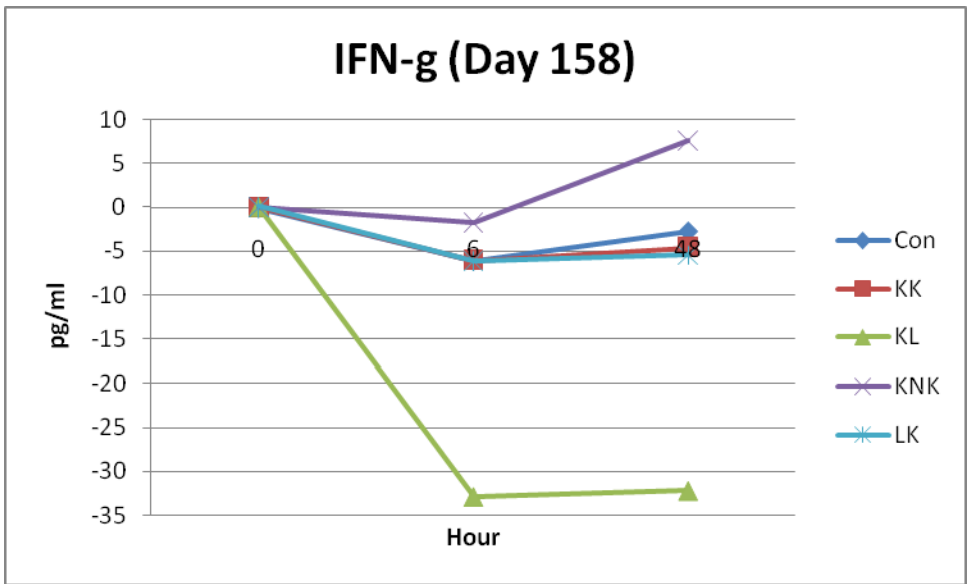


**Figure 23.** Interferon-gamma levels (represented as change from hour 0) at day 158 of neonatal calves vaccinated within three days of birth.

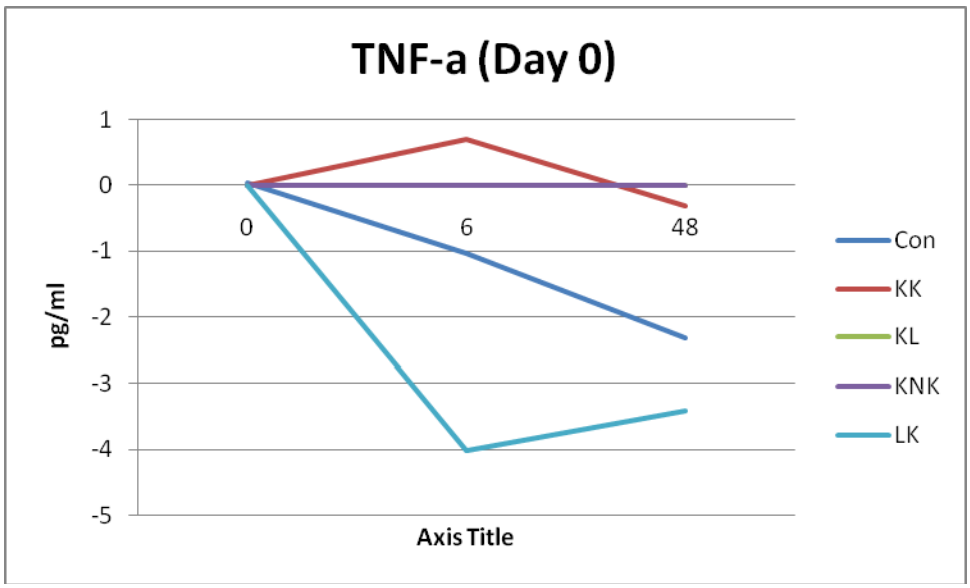


**Figure 24.** Tumor necrosis factor-alpha levels (represented as change from hour 0) at day 0 of neonatal calves vaccinated within three days of birth.

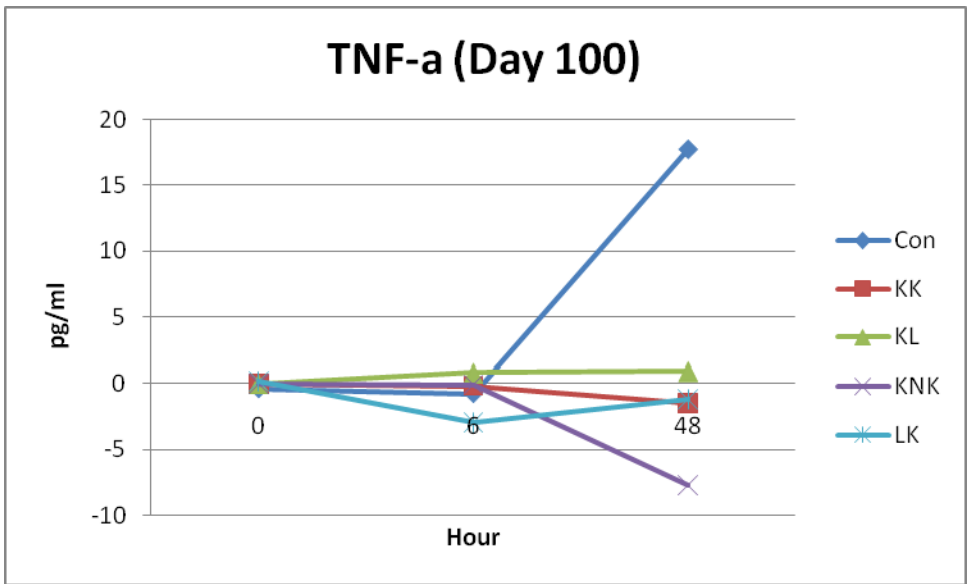


**Figure 25.** Tumor necrosis factor-alpha levels (represented as change from hour 0) at day 100 of neonatal calves vaccinated within three days of birth.

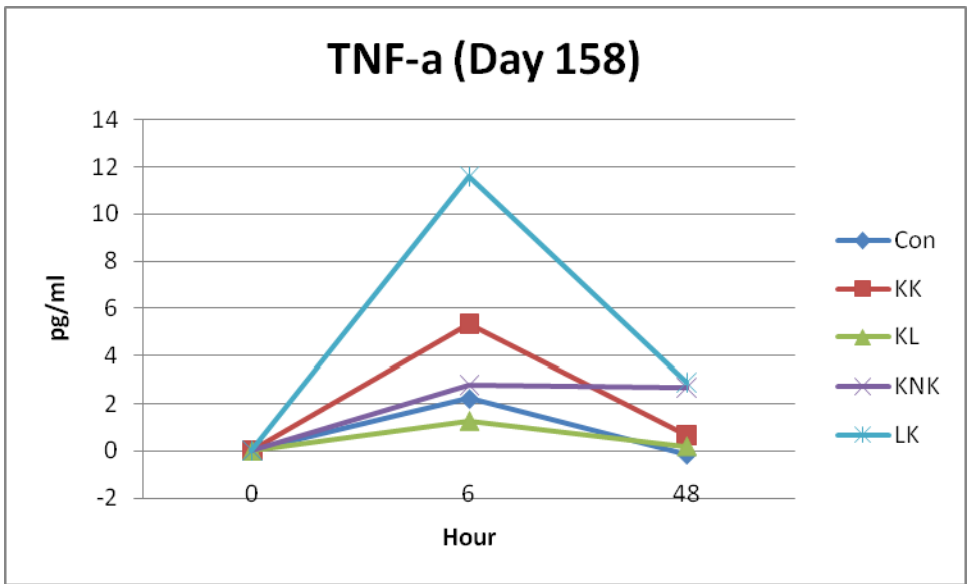


**Figure 26.** Tumor necrosis factor-alpha levels (represented as change from hour 0) at day 158 of neonatal calves vaccinated within three days of birth.

**Table 8**. P-values for cytokines of neonatal calves analyzed for the main effects of treatment and day and the interaction of treatment and day when treatments listed by type of vaccine given at birth.

| | Trt | Day | Hour | Trt x Day |
|---|---|---|---|---|
| IL-1 Beta | 0.19 | 0.02 | 0.04 | <0.01 |
| IL-2 | 0.71 | <0.01 | <0.01 | 0.71 |
| IL-4 | 0.08 | <0.01 | 0.22 | 0.58 |
| IL-6 | 0.06 | <0.01 | <0.01 | 0.32 |
| IFN-g | 0.35 | <0.01 | 0.48 | 0.07 |
| TNF-a | 0.34 | 0.38 | 0.45 | 0.25 |

**Table 9.** Least squares means and standard errors of treatment categories as represented by type of vaccine given at birth to beef calves.

| | Con | | Kill | | Live | | SE |
|---|---|---|---|---|---|---|---|
| IL-4 | 8.07 | ab | 7.01 | b | 13.02 | a | 3 |
| IL-6 | 7.23 | b | 17.54 | a | 13.17 | ab | 3.77 |
| BVD Type 1 | 3.67 | b | 3.77 | b | 4.72 | a | 0.28 |
| IBR | 3.9 | a | 3.17 | c | 3.49 | b | 0.22 |
| Weight (kg) | 162.98 | a | 148.69 | b | 154.3 | ab | 4.3 |
| ADG (kg/day) | 1.75 | a | 1.6 | b | 1.62 | b | 0.04 |

* Main effect of treatment was significant ($P < 0.01$). Treatments include Con (control – nothing given at birth); Kill (killed vaccine given at birth); Live (modified-live virus vaccine given at birth).

[ab] Different superscripts within row different ($P < 0.01$).

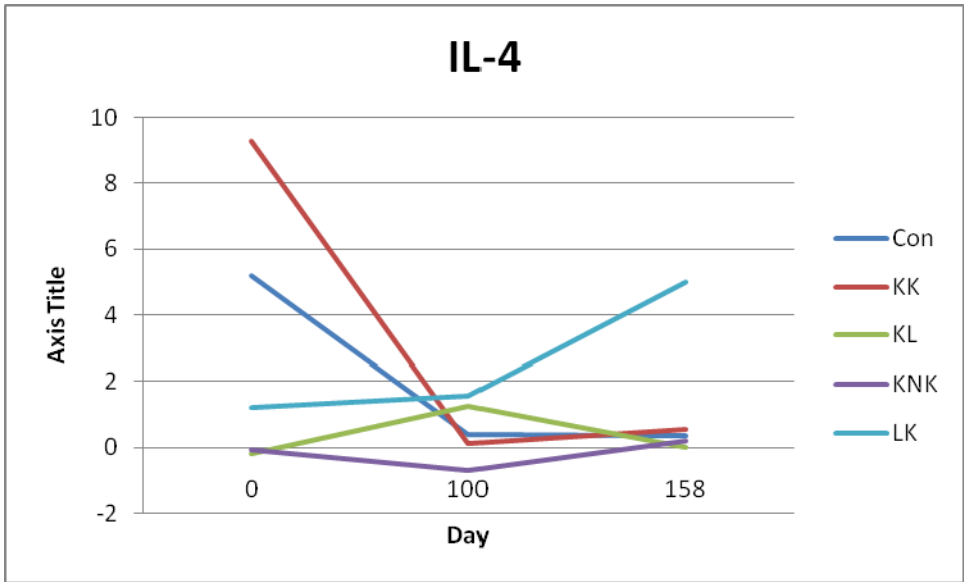


**Figure 27.** Changes in least squares means for interleukin-4 circulating in serum from baseline (hour 0) of neonatal calves given a vaccine to the bovine respiratory disease complex.

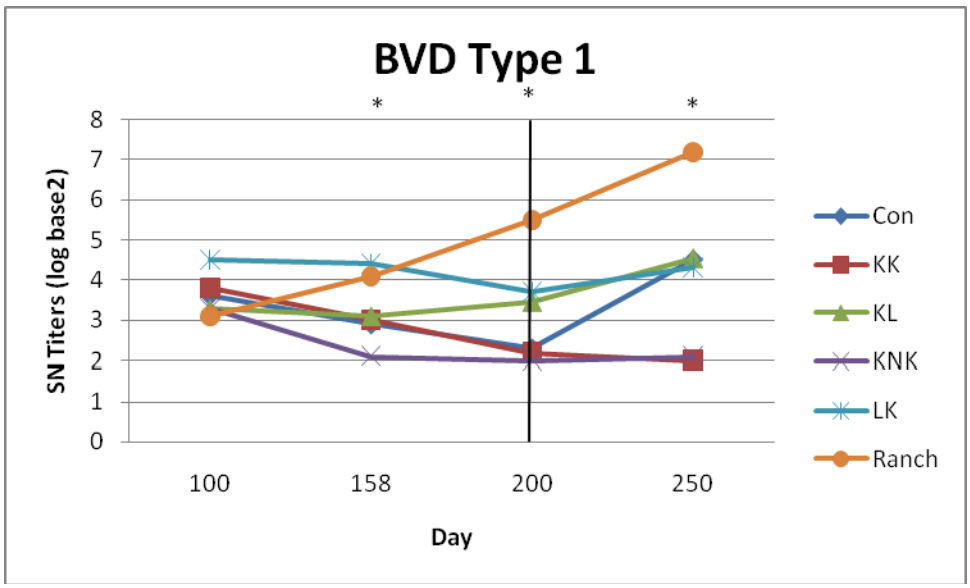


**Figure 28.** Least squares means for serum neutralizing antibody titers to bovine viral diarrhea virus type 1.
* Significant ($P < 0.01$) differences exist between treatments within day
** All animals were re-vaccinated with a modified live virus vaccine at day 200 to meet contractual specifications with the feedlot.
*** Treatments include Con (Control – No vaccine given); KK (Killed vaccine given at birth and at day 100); KL (Killed vaccine given at birth and a Modified-live virus vaccine given at day 100); KNK (Killed vaccine given at birth and at day 158); LK (Modified-live virus vaccine given at day 0 and a killed vaccine given at day 100); Ranch (Killed vaccine given at day 100 and a live vaccine given at day 158)

**Pooled analysis.** We also decided to look at the data based only on the first shot received in an attempt to determine if first shot given strongly influenced outcomes. Therefore, animals in the LK group will be listed as Live. Animals in the KK, KL, and KNK groups will be grouped as Killed. The control animals will remain control. These data was only analyzed for the production effects (not cytokine effects).

Again, we only observed significant ($P < 0.01$) main effects (Table 6). No treatment by time interaction occurred. Least squares means of the pooled treatment categories are shown in Table 5. As with the other analysis, we found that animals receiving the modified-live virus vaccines had significantly higher IL-4 and antibody titers to BVD.

In 2006, Zimmerman et al. demonstrated that a single dose of a MLV vaccine containing BVDV administered at 4 to 5 weeks of age stimulated a strong protective response in calves in the face of high concentrations of maternal antibodies. Our results also indicate that a MLV vaccine can stimulate a strong immune response. However, since we vaccinated within three days of birth, we can say that the MLV vaccine can induce a priming response in the neonate.

Based on the IL-4 results and the serum neutralizing titer levels to BVD Type 1, it can be concluded that a priming and secondary response did occur in animals that received a modified-live virus vaccine at birth and a killed vaccine at d 100. The IL-4 results indicate that proliferation of B-cells occurred in the LK group.

A study by Endsley et al. (2003) showed that a priming effect due to vaccination with a modified-live virus vaccine occurred in calves with high levels of maternal antibodies present. They went on to indicate that the cellular priming effect occurred while the BVD humoral immune response was blocked. Calves vaccinated with MLV BVD vaccine at 7 weeks of age developed BVD-specific $CD4^+$ and γδ-T-cell responses, whereas calves vaccinated with an

inactivated vaccine at the same time did not develop BVD-specific T-cell responses. While these results are consistent with our findings, our studies did differ in the serum-neutralizing antibody response to BVD when the calves were given a killed vaccine. They found that calves vaccinated with either a MLV or killed BVD vaccine in the face of circulating maternal antibodies developed a memory antibody response to BVD upon subsequent vaccination. However, in this study, we found that serum neutralizing antibody titers to BVD Type 1 and IBR declined after infection. As we did not challenge the calves, we cannot infer as to protection levels of the calves. However, in studies by Ridpath et al. (2003) and Zimmerman et al. (2006) it was shown that antibody serum titer levels to BVD continued to decrease after vaccination, and only increased after challenge with virulent BVD.

Serum neutralizing titer levels to BVD Type 1 did not indicate that we had an anamnestic response when all calves were vaccinated at d 200 with a MLV to meet contractual demands. Figure 23 shows the least squares means of the calves prior to and after receipt of this MLV vaccine. Calves in the Ranch group (n = 5), following traditional ranch practices of this producer, had significantly higher antibody titer levels to BVD than all other treatment groups at $4.98_{log2}$ on d 250. These results do not agree with those of Cortese et al. (1998b) who reported that vaccinating once with a MLV vaccine to BVD Type 1 had increasing or stable concentrations of serum antibodies for up to 18 months after vaccination. They, however, used calves that were older (greater than 6 months of age) and therefore had more advanced immune systems.

Calves in the Ranch group had similar IBR titers to that of the Control calves; thus indicating further that maternal transfer played a larger role in antibody production to IBR than

did vaccination. Cows in this herd were vaccinated yearly (in the fall of the year) with a modified live virus vaccine to IBR, BVD Type 1 and BVD Type 2.

While we were able to show a priming response with the cytokines, we also believe that we were able to show that we had elicited an immune response not indicated by antibody titer levels. Cytokine results indicate that at h48, animals receiving a vaccination would increase circulating levels of IFN-γ. As the animals were vaccinated with a viral vaccine, it can be understood why an antiviral cytokine would be secreted in their presence.

In addition, on each day that cytokines were measured, we saw an increase in IL-6 at h 6. Abbas et al. (2005) reported that some of the selected functions of IL-6 are antigen specific immune responses, inflammatory responses, B cell differentiation and T cell activation. We cannot differentiate with our results, which of these responses were induced by inoculation with the vaccine; we were, however, able to show that IL-6 levels were increased 6 h post vaccination.

## Conclusions

As beef calves are often vaccinated at time of branding, when calves are 1 to 3 months of age (Zimmerman et. al., 2006), these results become very important to the cattle industry. We have documented that vaccination at birth with a MLV vaccine can protect calves from the perinatal period to early adolescence. We were able to induce a cytokine response in the face of maternal antibodies.

This project showed that at this early age, average daily gains and subsequent weights may be reduced below that of control animals. However, as we had no signs of clinical infection, these results must be taken with the idea in mind that vaccination is an insurance measure to prevent disease outbreak. And therefore, while animals may not gain as much as those not

receiving a vaccine, they also are not protected against disease and the losses associated with the disease.

# CHAPTER IV
# EFFECTS OF FEED INTAKE AND CARCASS CHARACTERISTICS IN FEEDER CATTLE VACCINATED WITH ARSENAL 4.1® OR VISTA™ 5 SQ

## Introduction

Respiratory disease is one of the largest health problems associated with post weaning stages of beef production (NAHMS, 1997). Morbidity associated with the Bovine Respiratory Disease (BRD) complex reduces performance, production efficiency, and product quality; increases input costs and mortality; and results in a value loss of between $90 and $150 per case (Texas A&M University, Ranch to Rail, unpublished data). A variety of bacterial and viral infectious agents play a role in the etiology of BRD. Viral pathogens are considered primary insults to the immune system that result in progressive colonization and infection with pneumonic bacteria. Viral agents isolated from animals with BRD include infectious bovine rhinotracheitis virus (IBR), bovine respiratory syncytial virus (BRSV), bovine viral diarrhea virus (BVD), and parainfluenza 3 virus ($PI_3$). The large per case cost of BRD provides motivation for producers to utilize prophylaxis when available, and the initiative role of viral agents in the disease complex suggests that effective immunization against these pathogens creates value through risk reduction when and if the immunization process is effective and does not present secondary complications.

Live-virus vaccines are available which produce high and sustained immunological responses to these antigens (Vaughn and Sweiger, 1997). However, concern exists that live-virus vaccines may induce a large febrile response. While this response is beneficial to the animal at the cellular level (cytokines mediating an acute phase response), it results in increased energy expenditure, decreased feed consumption, and thus decreased weight gains. Because different

modified live virus vaccine products contain different antigenic strains, it may be possible for calves to have differential febrile and performance responses to those vaccines.

The objective of this trial was to evaluate immunological and production responses by weaned beef calves to two commercially available vaccines [Arsenal 4.1® (ARS) (modified-live virus vaccine and Vista™ 5 SQ (VISTA) (killed vaccine). Titer formation, body temperature, fat deposition, feed consumption, and subsequent carcass composition measurements of beef cattle receiving these vaccines were measured as an indication of the animal's response to the vaccine.

## Materials and Methods

**Animals.** One hundred seven Angus-Nellore crossbred steers of known origin and no prior exposure to viral vaccinations prior to the initiation of the trial were utilized. All steers were confirmed to be free from persistent infection (PI) with BVD and were confirmed seronegative to BVD and IBR prior to trial initiation. Lack of PI was confirmed through evaluation of an ear notch sample by antigen capture ELISA at the Texas Veterinary Medical Diagnostic Laboratory (TVMDL, Amarillo, TX). Blood serum samples were also tested at Texas Veterinary Medical Diagnostic Laboratory (TVMDL, Amarillo, TX) using serum neutralization tests to confirm sero-negativity to BVD and IBR.

**Treatments.** Animals were assigned to pens equipped with Calan® gated feed bunks (n = 4 per pen) based on animal height (to allow for optimum adjustment of the gates). Pens were then stratified by average body weight and assigned to treatments. Animals receiving different treatments were not commingled within pens to minimize potential artifact seroconversion due to contact among animals receiving different treatments.

Calves within a pen received one of three vaccination treatments: Negative control (physiological saline), Arsenal 4.1®, Novartis Animal Health US, INC., Larchwood, IA, or

Vista™ 5 SQ, Intervet Inc., Millsboro, DE. All treatments were applied at 2 ml subcutaneously in the neck, as per label directions.

**Intake.** Individual intake was measured with the use of the Calan gate system. Prior to the start of the trial, animals were trained to eat out of the individual Calan gates. Treatments were applied after training was complete. Individual feed delivery was based on the prior day's consumption and was recorded daily. Orts were recorded weekly (d 7, 14, 21, 28, 35, and 42).

Once the initial phase of the trial was completed, cattle were moved to a group feeding situation. Steers were placed at random into two pens and fed ad libitum throughout the conclusion of the trial. The diet fed throughout is presented in Table 10.

**Sample collection.** Rectal temperature was measured via digital rectal thermometer on days 0, 1, 3, 7, 14 and 28 following treatment application. Body weight was recorded at day -30, 0, 14, 28, and 42 as part of the first phase of the trial. During the second phase of the trial, steers were weighed every 28 days until they were harvested.

Blood samples were drawn via jugular venipuncture into evacuated tubes on days 0, 14, 28 and 42 and sent to TVMDL for quantification of serum neutralizing antibody titers to BVD Type 1, BVD Type 2, and IBR. On days 0 and 49, fat thickness over the $12^{th}$ rib (fat thickness), longissimus dorsi face area (ribeye area, REA), and percentage intramuscular fat (IMF) were measured via ultrasonography with an Aloka 500V ultrasound unit fitted with a linear array probe by a certified technician.

Animals were fed to a common fat thickness endpoint based on visual estimation (10 mm) and harvested in three groups. All harvest groups had representatives from each treatment

**Table 10.** Calculated composition (as fed) of basal diet fed to steers.

| Ingredient | Percentage[a] |
|---|---|
| Basal diet composition | |
| Ground milo | 20.00 |
| Ground corn | 31.25 |
| Cottonseed meal | 9.00 |
| Cottonseed hulls | 25.00 |
| Molasses | 10.00 |
| Premix[b] | 3.00 |
| Ammonium chloride | 0.25 |
| R-1500[c] | 1.50 |
| | |
| Dry Matter, % | 88.9 |
| Crude Protein, % | 11.5 |
| NEm (Mcal/kg) | 1.60 |
| NEg (Mcal/kg) | 1.00 |
| Crude Fiber, % | 14.5 |
| Calcium, % | 0.85 |
| Phosphorous, % | 0.39 |

[a]As-fed basis

[b]Composition of premix: ground limestone, 60%; trace mineralized salt, 16.7% (NaCl, 98%; Zn, 0.35%; Mn, 0.28%; Fe, 0.175%, Cu, 0.035%, I, 0.007%, Co, 0.007%); mono-dicalcium phosphate, 13%; potassium chloride, 6.7%; Vitamin premix, 3.3% (vitamin A, 2,200,000 IU/kg; vitamin D, 1,100,000 IU/kg, vitamin E, 2,200 IU/kg); Zinc oxide, 0.33%.

[c]R-1500 contains 1.65 g monensin sodium (Rumensin™) per kg.

group. Group 1 was harvested at d 157, group 2 at d 192, and group 3 at d 283. During the harvest process, hot carcass weight was secured and animal identity was transferred to its corresponding carcass. Following a 48 h chill period, the carcasses were presented to USDA personnel for grading. Trained personnel from Texas A&M University collected quality grade and yield grade data (USDA, 1996). Ribeye area, kidney pelvic and heart fat, overall maturity, marbling, color, texture, firmness, heat ring, dark cutter, and hump scores measurements were collected according to the methods outlined by AMSA (1991).

Whole loin samples were secured following this chill period. Samples were then transported to the Texas A&M University Meats Laboratory for further analysis. Strip loins were fabricated into 2.54 cm steaks. Steaks were vacuum packaged and stored at 2-4 °C in the dark until a 0, 14, or 21 day postmortem aging time was obtained.

**Tenderness evaluation.** Steaks were thawed at 4 °C for 24 h and cooked to a medium degree of doneness (~70 °C). Six 1.27 cm diameter round cores were removed parallel to the longitudinal orientation of the muscle fibers. Cores were sheared perpendicular to the longitudinal orientation of the muscle fibers for the Warner Bratzler Shear (WBS) force determination.

**Statistical analysis.** Mixed-model procedures of SAS (v. 9.1.3; SAS Institute, Cary, NC) were used for analyses. Rectal temperature (°C) and dry matter intake (percentage of initial BW) were considered repeated measures of animals and pen nested within treatment was used as the random subject effect. Due to the unequal spacing of time lags, a spatial power covariance structure was fit to the repeated measures model.

Serum-neutralizing antibody titer count data were transformed to $\log_2$ prior to analyses, and the results are expressed in this form (i.e., the values represent $x$ in the form $2^x$; data were not

back-transformed for presentation). Average daily gain was computed as the average weight gain (lb) divided by time between weight collections (d) for specific time periods. Time periods used for ADG calculations were phase 1 (d 0 to 42), phase 2 (d 42 to harvest) and overall (d 0 to harvest).

Initial body weight (d -30) of the animals varied, while the dose of the vaccine treatment was constant, so that the potential for varying response to treatment as a function of BW at the time of treatment application existed. Therefore, for analyses of all response variables, a multi-step covariance analysis process was performed to determine the influence of initial BW on responses as per Littell et al. (1996). When initial weight interacted with treatments, estimates of treatment effects were established at the mean of the initial weight of the animals, one standard deviation above the mean and one standard deviation below the mean to define the nature of the interaction.

Carcass data were analyzed with harvest date as a random effect. Day of aging was included as a main effect in the tenderness evaluation model.

When analyses produced a significant F-test ($P < .05$), least squares means were separated through two-tailed t-tests (PDIFF option).

## Results and Discussion

**Dry matter intake.** Dry matter intake was collected from days 0 to 42, and was evaluated as a proportion of body weight (PctDMI). Time, ($P < 0.01$) treatment, ($P < 0.01$) and their interaction ($P < 0.01$) influenced PctDMI in this experiment (Figure 29). Intake sharply declined within the *first* six d of the trial, but recovered by the same magnitude over the

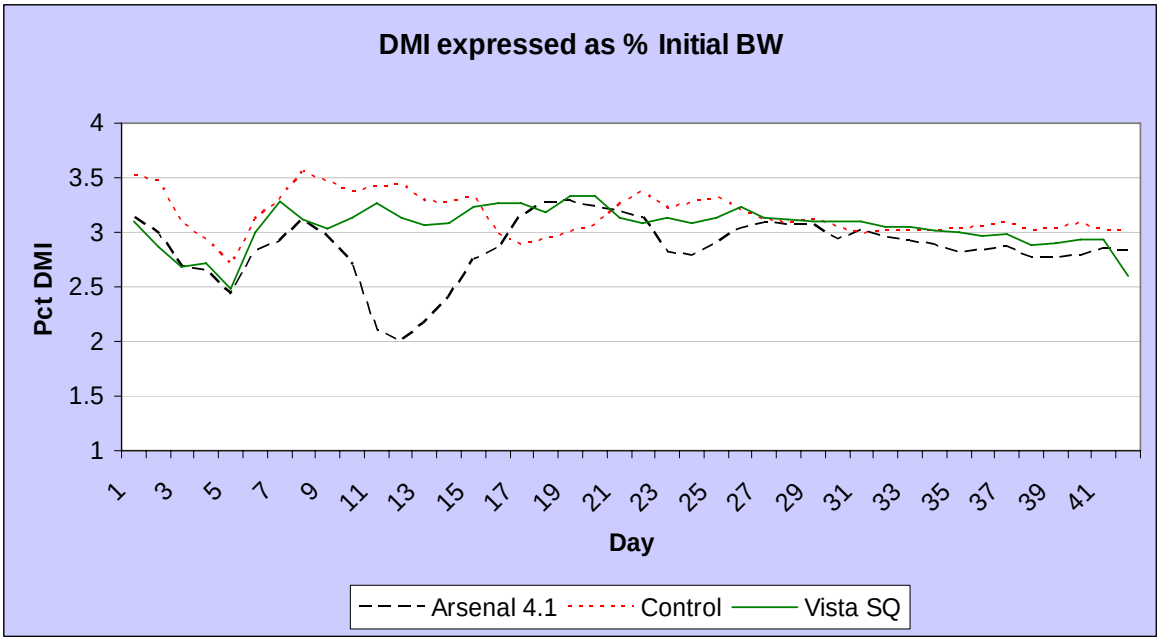


**Figure 29.** Dry matter intake (% of initial body weight) for steers vaccinated with Arsenal 4.1, Vista SQ, or physiological saline (Control).[a,b,c]

[a]: Time (day) effect, $P < 0.01$
[b]: Treatment effect, $P < 0.01$
[c]: Treatment X time effect, $P < 0.01$; steers treated with Arsenal 4.1 had lower intake than steers from other treatment groups from days 10 through 17.

subsequent 3 d. Because all treatments exhibited a similar response over this time period, this variation in intake was likely due to handling and adaptation to measurement stress rather than to treatment effects. However, from d 10 to 17 intake varied depending on treatment. Cattle vaccinated with Vista™ 5 SQ had PctDMI intake similar to control cattle, but those vaccinated with Arsenal 4.1® had a second sharp decline in intake from d 9 to d 12, such that PctDMI in steers treated with Arsenal 4.1® was lower ($P < 0.01$) than PctDMI in Vista™ 5 SQ or Control treated steers, which did not differ ($P = 0.42$). This was followed by an increase over the next 6 days. From d 18 to d 42, PctDMI did not differ among treatment groups.

**Feed efficiency.** Feed efficiency was also evaluated for days 0 to 42, and was calculated as total ratio of total feed consumed to weight gain of each animal. No treatment differences existed ($P = 0.13$) in phase one. The initial weight of the animal was used as a covariate in the model ($P = 0.06$). Least squares means for the feed to gain ratios were 8.52, 9.17, and 11.29 for animals in the Arsenal 4.1®, Vista™ 5 SQ, and control treatment categories, respectively.

**Rectal temperature.** Rectal temperature had a tendency ($P = 0.08$) to be affected by treatment and was significantly ($P < 0.01$) affected by day. Rectal temperature had a tendency ($P < 0.06$) to be influenced by the interaction of treatment and day. In this model, the covariate of initial body weight was significant ($P < 0.01$) and therefore included in final analysis. For all days measured after initiation of the project, cattle in the control group had the numerically highest rectal temperatures followed by the cattle receiving the Vista™ 5 SQ vaccination and then by animals receiving the Arsenal 4.1® treatment. However, the differences in temperatures did not become significantly different until days 14 and 28 (Figure 30). On d 14 and 28, rectal temperature in cattle receiving Arsenal 4.1® was lower ($P < 0.01$) than cattle in the Control and

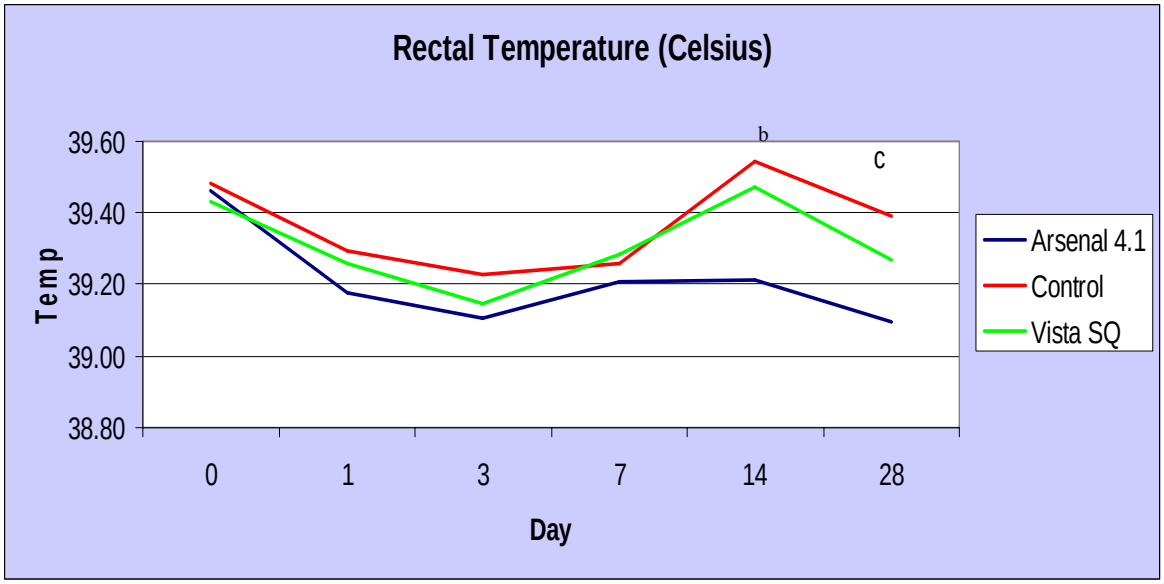


**Figure 30.** Rectal temperatures over time of steers vaccinated with Arsenal 4.1, Vista SQ, or physiological saline (Control).[a]

[a]: Treatment X time effect, P = 0.06
[b,c]: Steers treated with Arsenal 4.1 had lower (P < 0.01) rectal temperature than those treated with Vista SQ or Control, which were similar (P > 0.5)

Vista™ 5 SQ treatment groups. Cattle receiving the Control and Vista™ 5 SQ treatments were similar ($P > 0.21$) for both d 14 and 28 rectal temperature.

**Average daily gains.** Average daily gain was strongly influenced ($P < 0.01$) by the interaction between treatment and initial body weight in phase one (Figure 31). This caused us to generate among treatment comparisons for ADG at the mean initial weight, one standard deviation below the mean initial weight, and one standard deviation above the mean initial weight. From these estimates we were able to infer that cattle of different weight classes respond to the vaccinations differently. When treatments were compared in the light weight category (-1 SD) ADG was greatest in calves treated with saline ($P < 0.01$); those vaccinated with Vista™ 5 SQ or Arsenal 4.1® treatments had statistically similar ($P > 0.1$) ADG. ADG was similar ($P > 0.5$) among treatments when compared at mean initial BW. When compared within the heavy weight class (+1 SD) cattle that received Vista™ 5 SQ had greater ADG than those receiving saline injection ($P < 0.01$). Cattle receiving Arsenal 4.1® had ADG similar to those receiving Vista™ 5 SQ ($P = 0.5$); and tended ($P = 0.11$) to have ADG greater than those receiving saline.

In phase two, ADG was also strongly influenced ($P < 0.01$) by the interaction between treatment and initial body weight (Figure 32). However, the direction of the interaction changed from that of phase one. When treatments were compared in the light weight category (-1 SD) ADG was different ($P < 0.01$). ADG was greatest for cattle receiving Arsenal 4.1®, followed by those receiving Vista™ 5 SQ, and then by those in the control group. At mean initial BW, animals receiving Arsenal 4.1® had greater ($P < 0.05$) ADG than those receiving the control treatment. Vista™ 5 SQ was not significantly different than the other two treatments. In the heavy weight class (+1 SD), no significant differences existed between the treatment groups.

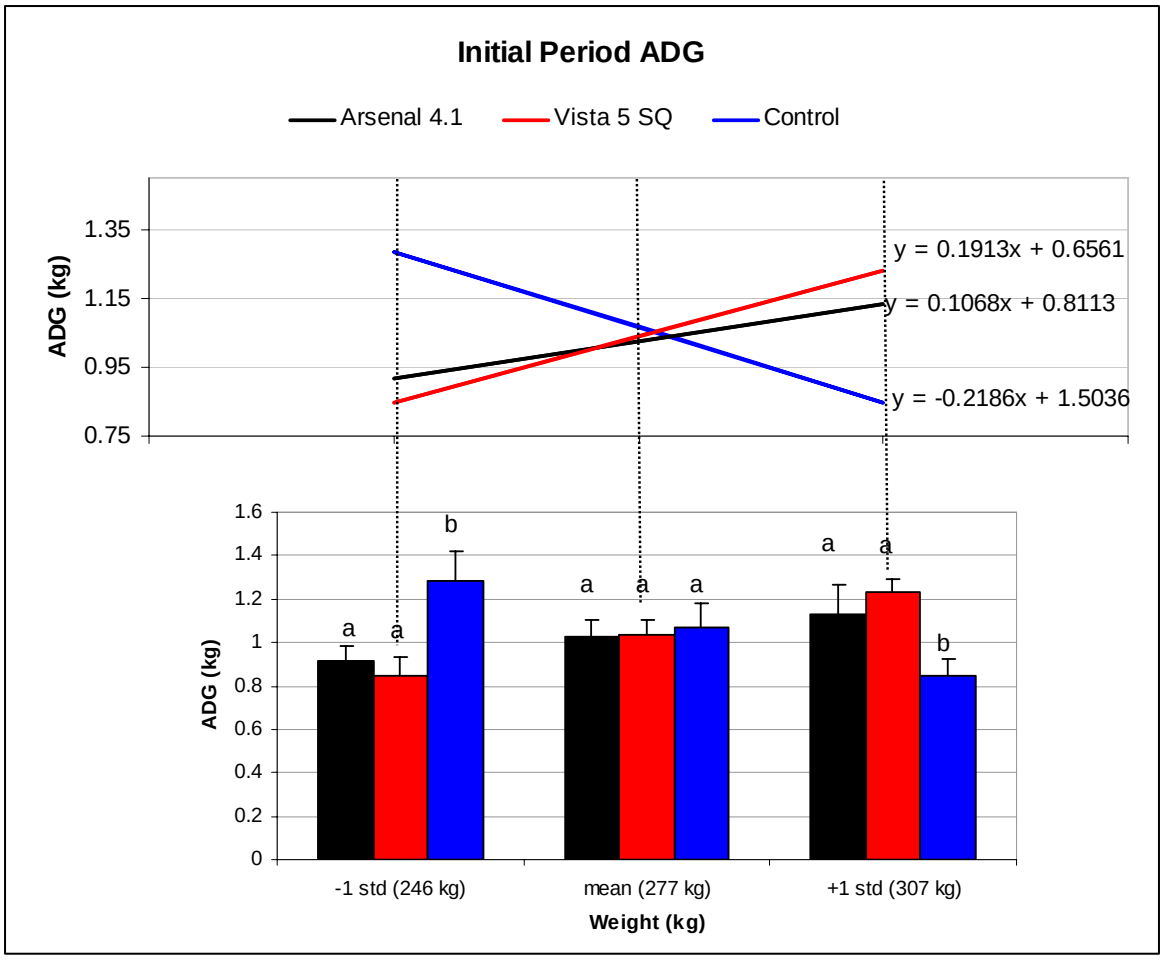


**Figure 31.** Initial period (d 0 to 42) average daily gain of steers vaccinated with Arsenal 4.1, Vista SQ, or physiological saline (Control) compared at initial body weights of -1 SD from mean initial BW, at the mean initial BW, or +1 SD from the mean initial BW.

* Initial body weight X treatment interaction ($P < 0.01$). Treatment comparisons are depicted above, where within weight class, different superscripts differ ($P < 0.05$).

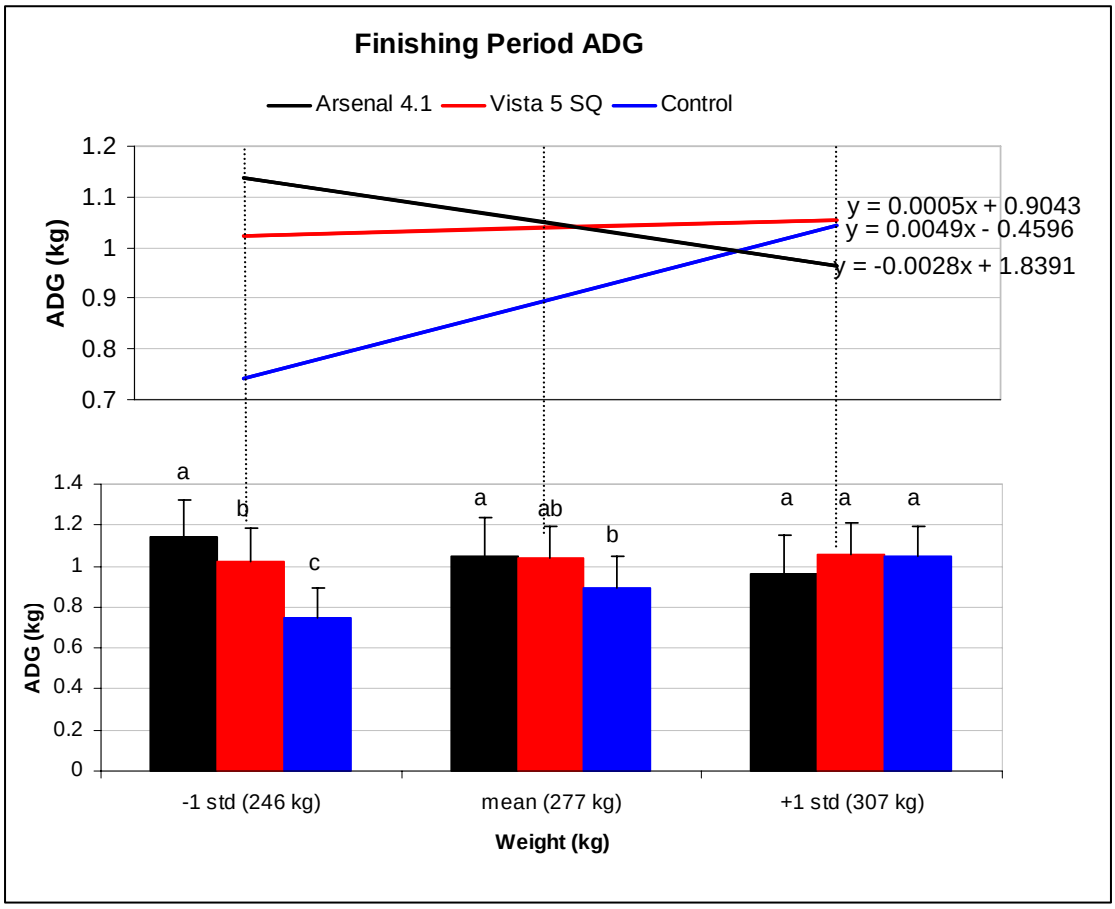


**Figure 32.** Finishing period average daily gain of steers vaccinated with Arsenal 4.1, Vista SQ, or physiological saline (Control) compared at initial body weights of -1 SD from mean initial BW, at the mean initial BW, or +1 SD from the mean initial BW.

* Initial body weight X treatment interaction ($P < 0.01$). Treatment comparisons are depicted above, where within weight class, different superscripts differ ($P < 0.05$).

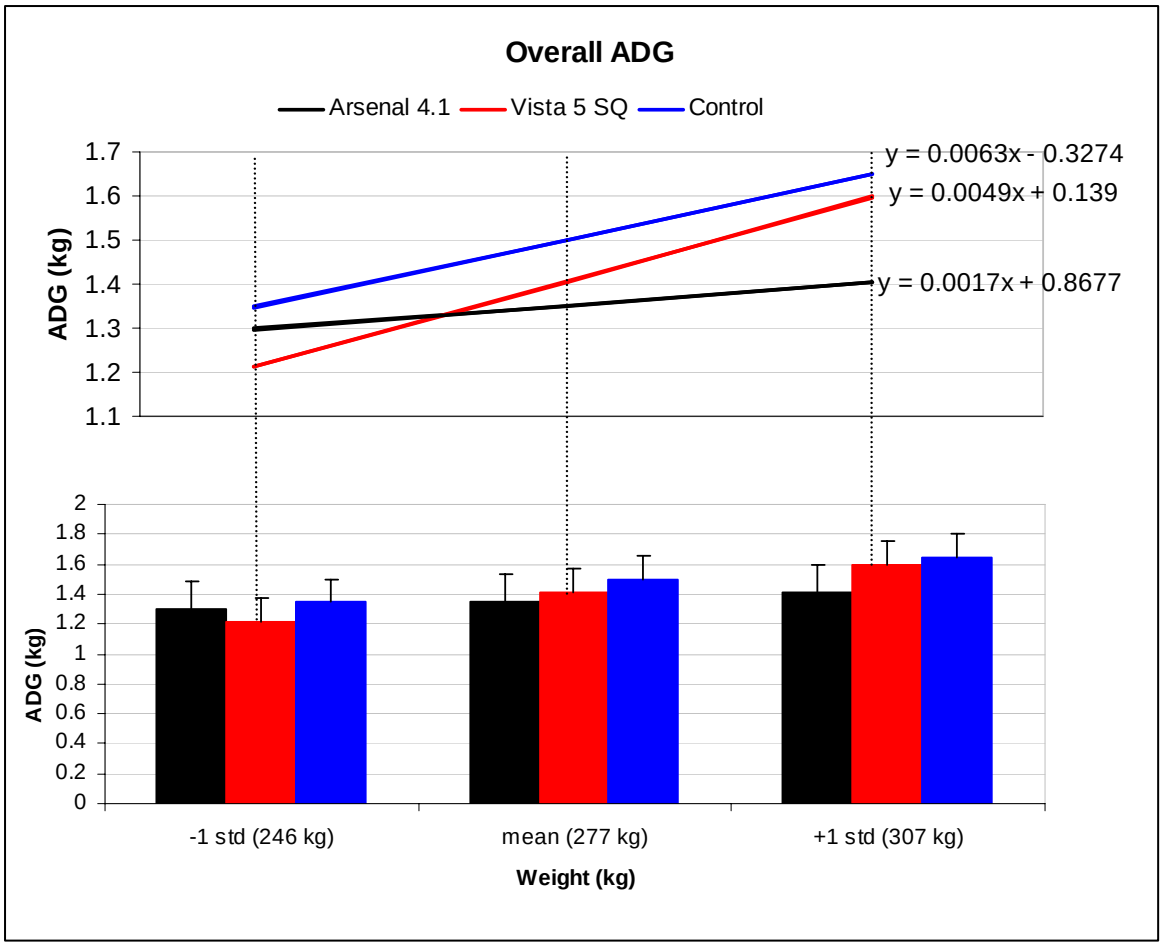


**Figure 33.** Overall average daily gain of steers vaccinated with Arsenal 4.1, Vista SQ, or physiological saline (Control) compared at initial body weights of -1 SD from mean initial BW, at the mean initial BW, or +1 SD from the mean initial BW.

* No treatment differences were found (P = 0.20) and no treatment by weight interactions occurred (P = 0.48).

When overall ADG was evaluated, no treatment differences existed ($P = 0.20$) and no treatment by initial body weight interactions occurred ($P = 0.48$) (Figure 33).

**Ultrasound measurements.** Animal body composition of phase one was measured through the use of ultrasonography. Because animals were measured only at day 0 and day 49, a change in the measured values was calculated as the response variable. For the change in ribeye area, no treatment differences were detected (Table 11). Intramuscular fat deposition did not significantly differ due to treatment either (Table 12). No treatment by initial weight interactions occurred for the change in rib-eye area or the intramuscular fat deposition.

We did find a difference ($P < 0.01$) in the change in fat thickness over the 12$^{th}$ rib due to treatment (Figure 34). An interaction ($P < 0.01$) between initial weight and treatment also existed. For lightweight cattle (-1 SD), administration of Vista™ 5 SQ resulted in a greater ($P < 0.01$) increase in fat cover over the 12$^{th}$ rib than application of either Arsenal 4.1 or control treatments, which were similar ($P = 0.76$). At mean initial BW, cattle receiving Vista™ 5 SQ had a greater ($P < 0.01$) fat thickness increase than the animals in the control group, while animals receiving Arsenal 4.1® had fat thickness change intermediate ($P > 0.10$) to the other treatment groups. When compared at heavy initial BW, cattle receiving Arsenal 4.1® and Vista™ 5 SQ had similar amounts of fat accretion ($P = 0.56$), while those receiving the control treatment tended to have a lesser amount ($P = 0.09$) of fat thickness change.

**Titer response.** Both treatment ($P < 0.01$) and the treatment by day interaction ($P < 0.01$) affected BVD Type 1 titer count (Figure 35). Initial body weight was not a significant covariate with titer response for BVD Type 1, Type 2, or IBR ($P = 0.83$, 0.92, and 0.11 respectively). As animals were confirmed seronegative to BVD Type 1, BVD Type 2, and IBR prior to the initiation of the project, therefore on d 0, no treatment differences existed as were

**Table 11.** Change in rib-eye area ($cm^2$) over 42 d in steers vaccinated with Arsenal 4.1, Vista SQ, or physiological saline (Control).

| | Initial Weight | | | | | |
|---|---|---|---|---|---|---|
| Treatment | -1 Std | SE | Mean | SE | 1 Std | SE |
| Arsenal 4.1 | -0.009 | 0.09 | -0.05 | 0.1 | -0.1 | 0.15 |
| Control | 0.38 | 0.13 | 0.23 | 0.1 | 0.07 | 0.14 |
| Vista SQ | 0.51 | 0.1 | 0.50 | 0.1 | 0.48 | 0.09 |

**Table 12.** Change in intramuscular fat deposition (%) over 42 d in steers vaccinated with Arsenal 4.1, Vista SQ, or physiological saline (Control).

| | Initial Weight | | | | | |
|---|---|---|---|---|---|---|
| Treatment | -1 Std | SE | Mean | SE | 1 Std | SE |
| Arsenal 4.1 | 0.03 | 0.01 | 0.06 | 0.01 | 0.08 | 0.01 |
| Control | 0.03 | 0.01 | 0.05 | 0.01 | 0.08 | 0.01 |
| Vista SQ | 0.06 | 0.01 | 0.07 | 0.01 | 0.08 | 0.01 |

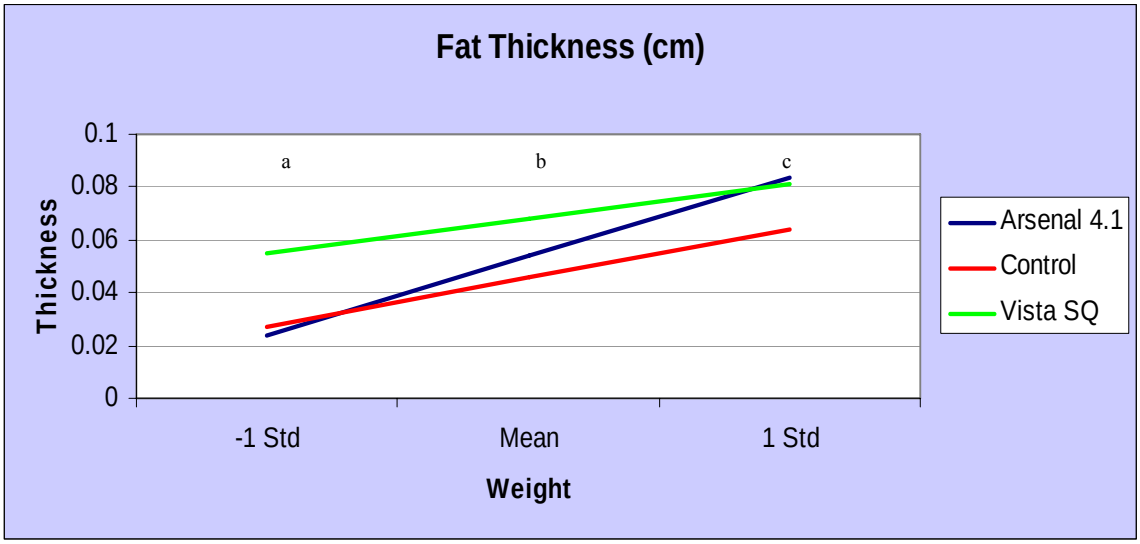


**Figure 34.** Change in 12th rib fat thickness (cm) over 42 d in steers vaccinated with Arsenal 4.1, Vista SQ, or physiological saline (Control) when compared at initial body weights of -1 SD from mean initial BW, at the mean initial BW, or +1 SD from the mean initial BW.

[a]: Vista SQ greater than Arsenal 4.1 or Control, $P < 0.01$; Arsenal 4.1 and Control similar ($P = 0.68$).
[b]: Vista SQ greater than Control, $P < 0.01$; Arsenal intermediate and not different from either Control or Vista ($P > 0.2$).
[c]: Arsenal 4.1 and Vista SQ similar ($P = .52$) and greater than control ($P < 0.01$).

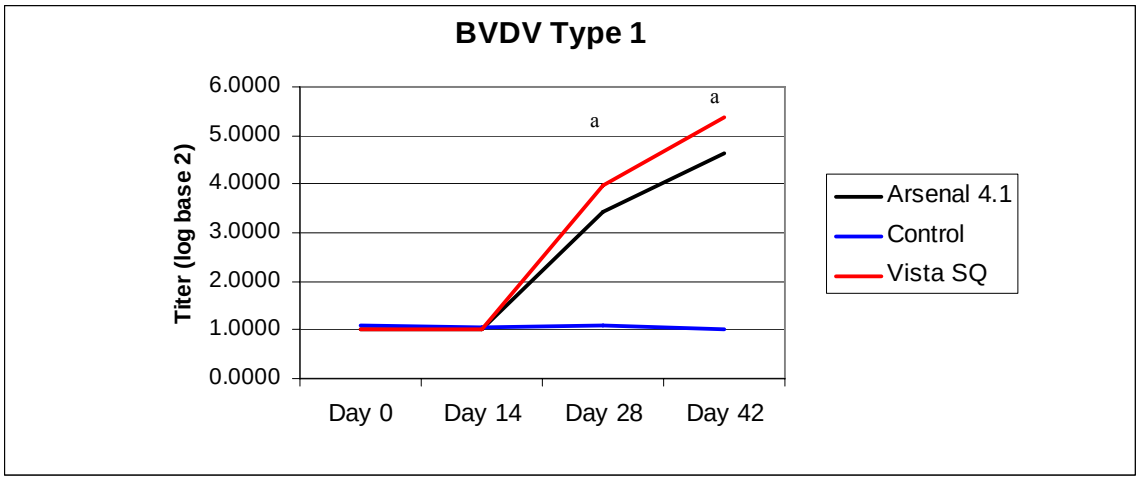


**Figure 35.** Serum neutralizing antibody titer response ($log_2$) to inoculation with BVD type 1 in steers vaccinated with Arsenal 4.1, Vista SQ, or physiological saline (Control) over 42 d.

[a]: Treatment X day interaction, $P < 0.01$. All treatments differ, $P < 0.01$.

expected. No measurable increase in BVD Type 1 titer had occurred by d 14. By d 28 vaccinates had measurable antibodies to BVD Type 1. On both d 28 and 42, Vista™ 5 SQ had the highest ($P < 0.01$) titer counts followed by Arsenal 4.1®., with control treated steers exhibiting no measurable titer to BVD Type 1. On both d 28 and 42, all treatment groups were significantly different ($P < 0.01$) from each other.

Treatment ($P < 0.01$) and the treatment by day interaction ($P < 0.01$) also affected BVD Type 2 titer count (Figure 36). As with BVD Type 1, no animals had measurable antibody production to BVD Type 2 through d 14. By d 28, animals that had received a vaccine had measurable antibody production. Animals that had received Vista™ 5 SQ had the greatest ($P < 0.01$) increase in titer counts followed by the cattle that had received the Arsenal 4.1® vaccine. On d 42, animals in the Vista™ 5 SQ category had the greatest ($P < 0.01$) titer counts to BVD Type 2; the $\log_2$ titer for Arsenal 4.1® treated calves was approximately 40% of that for Vista™ 5 SQ treated calves. On d 28 and 42, all treatment groups were different ($P < 0.01$) from each other. Treatment ($P < 0.01$) and the treatment by day interaction ($P < 0.01$) influenced production of antibody against IBR (Figure 37). On d 0, no animals had measurable antibody against IBR. At d 14, animals that had received Arsenal 4.1® had higher ($P < 0.01$) titer counts than those that had received Vista™ 5 SQ, which in turn had greater ($P < 0.01$) antibody production than animals receiving the control treatment. These separations persisted at d 28 and d 42.

**Carcass data.** Hot carcass weight was influenced ($P < 0.01$) by treatment. Animals receiving Vista™ 5 SQ had heavier ($P < 0.01$) hot carcass weights than those receiving either Arsenal 4.1® or control treatments. Hot carcass weights for animals receiving either Arsenal 4.1® or control treatments were not significantly different ($P = 0.27$). Rib-eye area was not

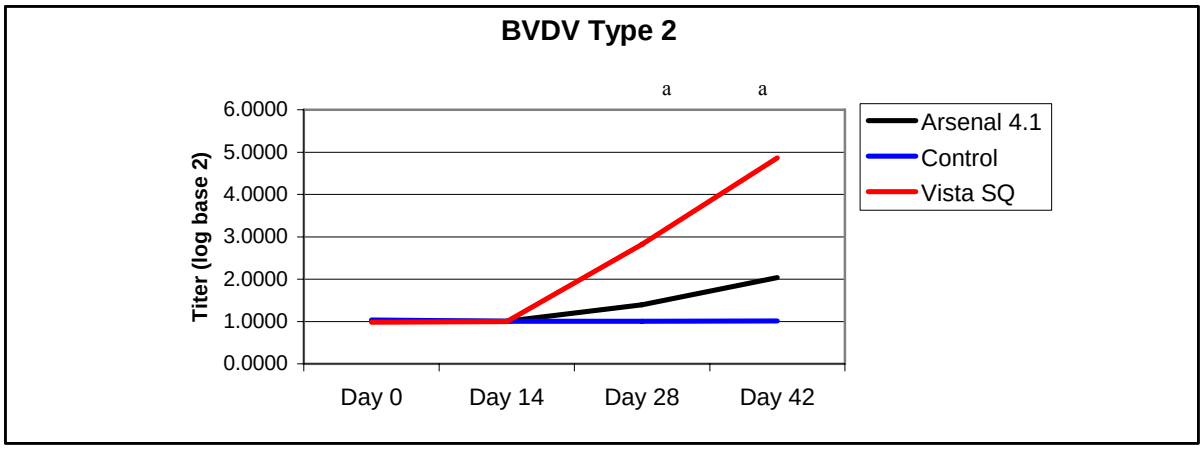


**Figure 36.** Serum neutralizing antibody titer response ($log_2$) to inoculation with BVD type 2 in steers vaccinated with Arsenal 4.1, Vista SQ, or physiological saline (Control) over 42 d.

[a]: Treatment X day interaction, $P < 0.01$. All treatments differ, $P < 0.01$.

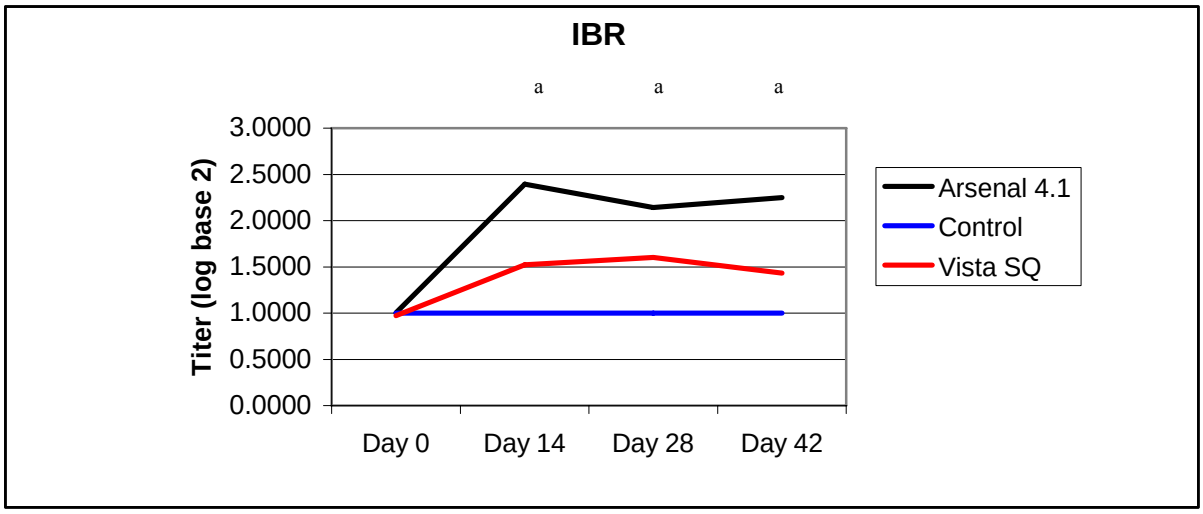


**Figure 37.** Serum neutralizing antibody titer response ($log_2$) to inoculation with IBR in steers vaccinated with Arsenal 4.1, Vista SQ, or physiological saline (Control) over 42 d.

[a]: Treatment X day interaction, $P < 0.01$. All treatments differ, $P < 0.01$.

affected by treatment, day, or the treatment by day interaction ($P > 0.40$). The kidney, pelvic, and heart fat measurement was also not affected by treatment, kill day, or the treatment by kill day interaction ($P > 0.18$). Furthermore, YG was not affected by treatment, kill day, or the treatment by kill day interaction ($P > 0.17$). Marbling score was affected by treatment ($P < 0.01$). Kill day and treatment by kill day was not significant ($P = 1.00$). Animals in the Arsenal 4.1® treatment group had lower ($P < 0.01$) marbling scores than those in the control or Vista™ 5 SQ treatment groups. Marbling scores for animals in the control and Vista™ 5 SQ treatment groups were similar ($P = 0.11$). No treatment, kill day, or treatment by kill day effects were found ($P > 0.20$).

**Shear data.** No treatment ($P = 0.15$) nor treatment by day of aging interaction ($P = 0.92$) differences occurred for the tenderness data (Table 13). Day of aging had a large ($P < 0.01$) impact on tenderness. Steaks aged for either 14 or 21 d had lower ($P < 0.01$) tenderness scores than those aged for 0 d. No differences ($P = 0.33$) were seen between the 14 and 21 d aging period.

Underlying morbidity (which we were not able to measure) may have affected the performance and efficiency of steers in this trial. However, any effects on ADG that may have been seen during the early portions of the study were not seen when the trial was taken to completion. As most research from confined feeding experiments have indicated, a weight loss associated with early morbidity is usually compensated within a short period (Gaylean et al., 1999; Pinchak et al., 2004). The lighter animals who had been vaccinated had reduced gains below that of those who had not received a vaccination, possibly due to underlying morbidity issues. Those lightweight animals then compensated throughout the feeding period, so that no differences in ADG could be seen when the entire feeding period was evaluated.

**Table 13.** Warner-Bratzler shear force values in steers vaccinated with Arsenal 4.1, Vista SQ, or physiological saline (Control) and whose subsequent steaks were aged for 0, 14, or 21 d.

| | Vaccine Treatment | | | | Day of Aging | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Arsenal 4.1 | Control | Vista SQ | SE | 0 | 14 | 21 | SE |
| WBSF, kg | 3.08 | 2.77 | 2.97 | 0.1 | 3.41 | 2.79 | 2.63 | 0.1 |

[a] : Treatment effect, P = 0.15
[b] : Day of aging effect, P < 0.01
[c] : Treatment x Day of Aging effect, P = 0.92

Findings of the ultrasonography measurements are consistent with intake and gain data. The lack of change in rib-eye area based on treatment differences suggests that the treatments did not alter lean tissue deposition. In this experiment, differences in ADG among treatments by initial weight class were reflected in differences among change in subcutaneous fat thickness. This may suggest alterations in nutrient partitioning or efficiency of energy retention during the early stages of the feeding period.

In this study, both vaccines significantly increased titers for BVDV Type 1 and Type 2. No significant differences could be seen between vaccines for BVDV Type 1. However, treatment differences did exist for BVDV Type 2 ($P < 0.05$). These results are consistent with expectations, as Vista™ 5 SQ vaccine has BVD Type 2 antigen while Arsenal 4.1® does not, relying instead upon cross-reacting antibodies generated in response to the BVD Type 1 antigen.

While overall average daily gains were not different, setbacks in weight increases early on, led to treatment differences in hot carcass weights. Lower marbling scores for the Arsenal 4.1® treated animals cannot be explained. More research is needed, to help understand if this is due to the vaccine, or just an artifact of this data set.

## Conclusions

Different vaccines may have different economic consequences depending upon the sector of the beef industry in which they are used. Across the entire trial, the vaccines performed equally. While in the early periods, performance differences existed, the differences disappeared by the end of the trial. As both vaccines stimulated adequate antibody production, differences in early weight gains and the length of time and/or phase of ownership may be a driver in the decision as to which vaccine should be used. As no clear differences in tenderness values of

carcass characteristics were found, it is our belief that both vaccines adequately stimulated the immune system without causing decreases in the profitability of the animal.

# CHAPTER V

# EFFECTS OF SUPPLEMENTAL COPPER AND SELENIUM ON PERFORMANCE OF CALVES ENTERING THE TEXAS A&M UNIVERSITY RANCH TO RAIL PROGRAM

## Introduction

A calf encounters significant stressors during the weaning, shipping, and commingling stages of his life. Upon entry into a feedyard, the animal's immune system is challenged with a variety of pathogens which serve to threaten if not weaken the animal. Often, the physical and pathological stressors seen at this time suppress the immune function of the calf resulting in economic losses associated with production losses.

While the actual mineral requirements of stressed calves do not seem to be greater than those of unstressed calves (Cole, 1993), pre-weaning nutritional deficiencies may interact with the pathological stressors to further hinder the immune function of the animal. In an effort to mitigate these deficiencies, receiving diets are often fortified with minerals. Gaylean and Hubbert (1995) reported that feed intake by lightweight stressed calves is low shortly after entering the feedyard. Low feed intake results in lowered nutrient intake, thereby, making correction of nutritional deficiencies difficult (Gaylean et al., 1999).

The trace minerals selenium and copper have been associated with impaired performance of cattle entering feedlots (Xin et al., 1991; Reffet et al., 1988). Copper deficiency has been shown to reduce growth rate (Gengelbach et al., 1994; Kegley and Spears, 1994) and immune function of calves (Gengelbach et al., 1997). Whereas selenium supplementation has been associated with increased serum antibody titers (IgG) in growing beef cattle, thus enhancing immune response to illness (Droke and Loerch, 1989; Nicholson et al., 1991 Swecker et al., 1989, 2008).

The objectives of the present study were to determine: 1) the effects of mineral supplements on incidence of bovine respiratory disease, 2) the response of animals supplemented with a mineral to treatment against the disease, and 3) if treatment with a mineral supplement affected feedlot performance in steers enrolled in the Texas Ranch to Rail program.

## Materials and Methods

**Animals.** Three hundred and fifty-two animals representing 88 ranches were used for this experiment. The calves were part of one year of the Texas A&M University ranch to rail program and entered the King Ranch Feedyard, Kingsville, Texas, during the third week of October, 1994. Cattle used for this trial originated from Texas. Prior to feedyard arrival, producers completed questionnaires as to the cattle background management. Upon arrival, cattle were assigned a Texas A&M University ear tag, implanted, weighed, given an anthelminic, bled, vaccinated both with a respiratory and a clostridial vaccine, and treated with the appropriate mineral treatment. Cattle were fed to a common fat thickness endpoint utilizing a diet common to the commercial feedlot. Carcass data including hot carcass weights, KPH fat thickness, marbling scores, and USDA yield grade (calculated) were collected by trained Texas A&M University personnel 48 h post slaughter at a commercial abbatoir (Sam Kane Beef Packing, Corpus Christi, TX).

**Experimental treatments.** Four animals from each ranch were randomly assigned to this project and randomly assigned to one of 4 treatments: control, copper, selenium, and copper/selenium mixture. Animals in the control group **(CON)** received no treatment. Those in the copper treatment **(CU)** were orally administered a Copasure bolus (Schering-Plough Animal Health, Kenilworth, NJ) containing 25 mg of copper oxide needles. Calves in the selenium treatment **(SE)** group received a subcutaneous injection of 3 ml of MU-SE (Schering-Plough

Animal Health, Kenilworth, NJ) containing 10.95 mg sodium selenite and 50 mg Vitamin E. The animals in mixture **(MIX)** treatment group received both an oral administration of a Copasure bolus as well as a subcutaneous injection of MU-SE.

Initial blood samples were drawn into evacuated blood tubes prior to administration of the treatments to determine initial mineral status. Samples were sent to the Texas A&M University Veterinary Medical Diagnostic Laboratory for analysis of copper, selenium, and zinc levels. Initial mineral status was assigned to a 4-point scale as deficient, borderline, adequate or high as described in Mineral Levels in Animal Health, 1994 (Pulls, 1994).

**Interactions with pre-feedlot practices.** Ranches consigning cattle to the program were asked to fill out questionnaires asking about vaccination practices, weaning periods, backgrounding periods, and nutrition of calves prior to entry into the Ranch to Rail Program. Vaccination practices were grouped based on type of vaccine given: clostridials, bovine respiratory disease, or other. Bovine respiratory disease was further broken into the categories of modified-live virus vaccine, killed vaccine, or altered vaccine. Vaccinations were also grouped as pre-weaning and post-weaning prior to entry into the feedlot. Period from weaning to entry into the feedlot was also categorized in this data set. Categories were Bac14 (< 21 d prior to feedlot entry), Bac 21 (< 45 d but > 21 d) and Bac 45 (> 45 d). All animals in this study received at least one vaccination prior to entry into the feedlot. Nutrition practices were grouped into one of six categories: None (Nothing given); Past + Supp (Pasture plus a supplement); Dry + Hay (Drylot plus hay); Dry + Hay + Supp (Drylot plus Hay plus a supplement); Drylot + TMR (Drylot plus total mixed ration).

**Statistical analysis.** Data were analyzed using the MIXED procedures of SAS (Release 8.1, SAS Inst. Inc., Cary, NC). The model included the fixed effects of treatment, mineral status,

and treatment x mineral status, with Ranch included as a random effect. Treatment means were computed with the LSMEANS option. When an *F*-test was significant ($P < 0.05$), individual treatment means were separated with pairwise t-tests among all means.

## Results and Discussion

**Mineral status of calves.** Results for incoming mineral status of the calves at feedyard arrival are shown in Table 14. In regard to serum copper levels, only 3 calves were classified as deficient, 304 were determined to be marginal, and 43 were classified as adequate. No calves were found to have high levels of circulating copper. In regard to selenium status classification, 8 were deficient, 171 were marginal, and 171 were adequate. The numbers of animals determined to be deficient, marginal, adequate, or high for circulating zinc levels were 6, 18, 314, and 12, respectively.

**Production responses.** No significant interactions were found between treatment and initial mineral status. Therefore, only main effects of the treatments are discussed for production responses (summarized in Table 15). Final body weight was not significantly altered by supplementation with either copper, selenium, or a combination of copper and selenium. Least squares means of final body weights were 539.46, 529.83, 543.91, 536.52 kg for the Con, Cu, Mix, and Se treatment categories, respectively. Average daily gains were not affected by treatment. Average daily gains ranged from 1.35 kg/day for the CU group to 1.42 kg/day for the

**Table 14**. Mineral status percentages of incoming ranch to rail calves.

| | Mineral (%) | | |
|---|---|---|---|
| | Cu | Se | Zn |
| Deficient | 0.86 | 2.28 | 1.72 |
| Marginal | 86.86 | 48.86 | 5.14 |
| Adequate | 12.28 | 48.86 | 89.71 |
| High | 0 | 0 | 3.43 |
| Total | 100 | 100 | 100 |

**Table 15**. Effects of supplemental copper and selenium on feedlot performance of growing beef animals.

| | Treatment [1] | | | | | | Initial Mineral Status Interaction (P-value) [3] | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | Con | Cu | Mix | Sel | P-value | SE[2] | 1 | 2 | 3 |
| Initial BW, kg | 264.25 | 259.85 | 270.39 | 259.27 | 0.82 | 11.23 | 0.47 | 0.23 | 0.34 |
| Final BW, kg | 539.46 | 529.83 | 543.91 | 536.52 | 0.97 | 12.40 | 0.13 | 0.48 | 0.72 |
| ADG, kg | 1.39 | 1.35 | 1.42 | 1.39 | 0.95 | 0.06 | 0.81 | 0.55 | 0.41 |
| Total COG ($ / lb) [4] | 0.52 | 0.54 | 0.52 | 0.52 | 0.88 | 0.02 | 0.74 | 0.58 | 0.51 |
| Medicine Cost ($) [4] | 23.52 | 22.51 | 21.00 | 20.72 | 0.43 | 6.75 | 0.09 | 0.42 | 0.73 |
| Gross Return ($) [4] | 467.45 | 452.51 | 480.40 | 460.00 | 0.84 | 29.00 | 0.55 | 0.78 | 0.57 |
| Net Return ($) [4,5] | 74.29 | 63.06 | 77.74 | 72.40 | 0.82 | 23.60 | 0.23 | 0.88 | 0.60 |

[1] Con = control (no mineral supplementation); Cu = copper; Mix = copper and selenium; and Sel = selenium

[2] Pooled SE of treatment means

[3] Interactions: 1) Treatment x Initial copper status; 2)

[4] US Dollars

[5] Gross Return minus initial value of animal as determined by trained personnel

Mix group. Total cost of gain and medicine costs were not significantly different among treatments. Costs of gain were $0.52 USD for the Con, Mix, and Sel treatment groups. Cost of gain increased to $0.54 USD for the Cu group. Average medicine cost ranged from $20.72 to $23.53 USD for the treatment groups. Neither gross nor net returns were affected by treatment ($P > 0.05$).

**Carcass results.** Carcass traits were measured when animals were harvested at the completion of the feeding period. Several treatment by initial mineral status interactions ($P < 0.05$) occurred. Treatment by initial copper interaction was observed for dressing percentage (Figures 38). A treatment by initial selenium interaction occurred for percentage of kidney, pelvic, and heart fat (Figure 39). As we were not able to find similar interactions within the literature, we cannot determine whether these can be replicated or are just an artifact of this particular data set.

Interestingly we found that a treatment by initial zinc interaction occurred for hot carcass weight, dressing percentage, and rib-eye area (REA)(Figures 40,41,42). In all three instances, animals in the Mix group had lower levels when serum zinc was high at initial feedlot entry. Pulls, 1994, reported that high levels of zinc may cause calves to be more susceptible to pneumonia. While we did not see an increase in morbidity in these cattle, we suspect that animals in the Mix group could have had pneumonia but showed no outward clinical signs.

No differences in the initial mineral status or the mineral treatment main effects were seen for any of the carcass traits (Table 16). USDA yield grade had a tendency for differences among treatments. Animals in the CON group had the highest yield grades at 2.25 followed by MIX, SE, and CU respectively. Least squares means for hot carcass weights were 337.3, 325.46, 339.44, and 336.76 kg for the CON, CU, MIX, and SE treatment groups. Mean dressing

**Table 16**. Effects of supplemental copper and selenium on carcass characteristics of finishing beef animals.

| | Treatment | | | | | | Initial Mineral Status Interaction (P-value) [3] | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | Con | Cu | Mix | Sel | P-value | SE[2] | 1 | 2 | 3 |
| HCW, kg | 337.3 | 325.46 | 339.44 | 336.76 | 0.27 | 13.06 | 0.91 | 0.99 | 0.04 |
| Dressing percent | 62.73 | 61.52 | 62.51 | 61.98 | 0.21 | 2.20 | 0.01 | 0.98 | 0.01 |
| LM area, $cm^2$ | 86.75 | 87.32 | 91.34 | 88.05 | 0.21 | 5.18 | 0.51 | 0.29 | 0.04 |
| KPH, % | 2.2 | 2.15 | 2.28 | 2.16 | 0.73 | 0.18 | 0.23 | 0.04 | 0.84 |
| USDA yield grade | 2.25 | 1.97 | 2.09 | 2 | 0.1 | 0.20 | 0.28 | 0.61 | 0.40 |

[1] Con = control (no mineral supplementation); Cu = copper; Mix = copper; selenium; and Sel = selenium

[2] Pooled SE of treatment means

[3] Interactions: 1) Treatment x Initial copper status; 2) Treatment x initial selenium status; 3) Treatment x initial zinc status

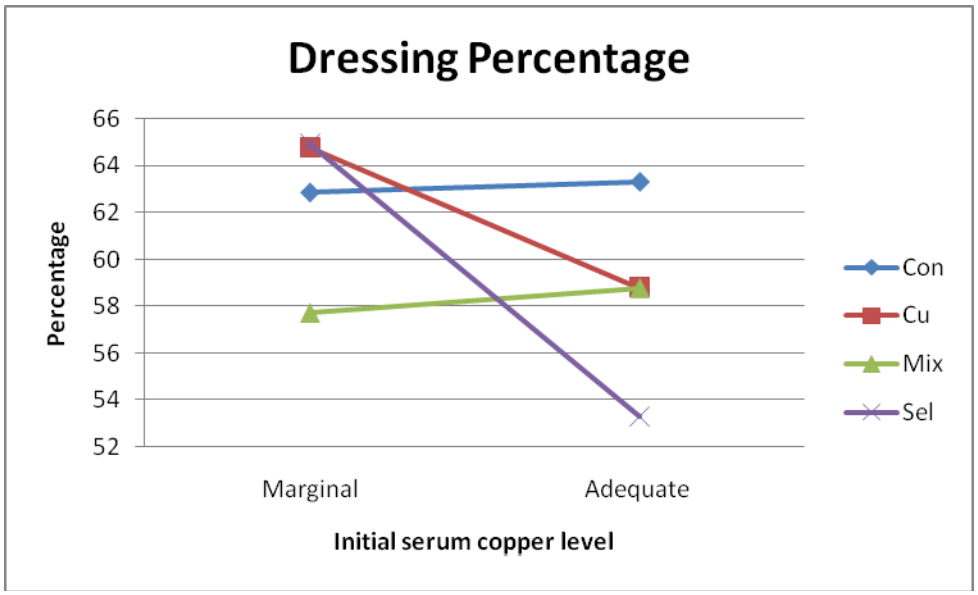


**Figure 38**. Dressing percentage for incoming beef calves to the ranch to rail program at varying initial serum copper levels.
* Treatments include: **Con** (Controls – no supplementation); **Cu** (Copper – animals supplemented with Copasure bolus, Schering-Plough Animal Health, Kenilworth, NJ); **Se** (animals injected with MU-SE, Schering-Plough Animal Health, Kenilworth, NJ); and **Mix** (animals treated with both the Cu and Se treatments).

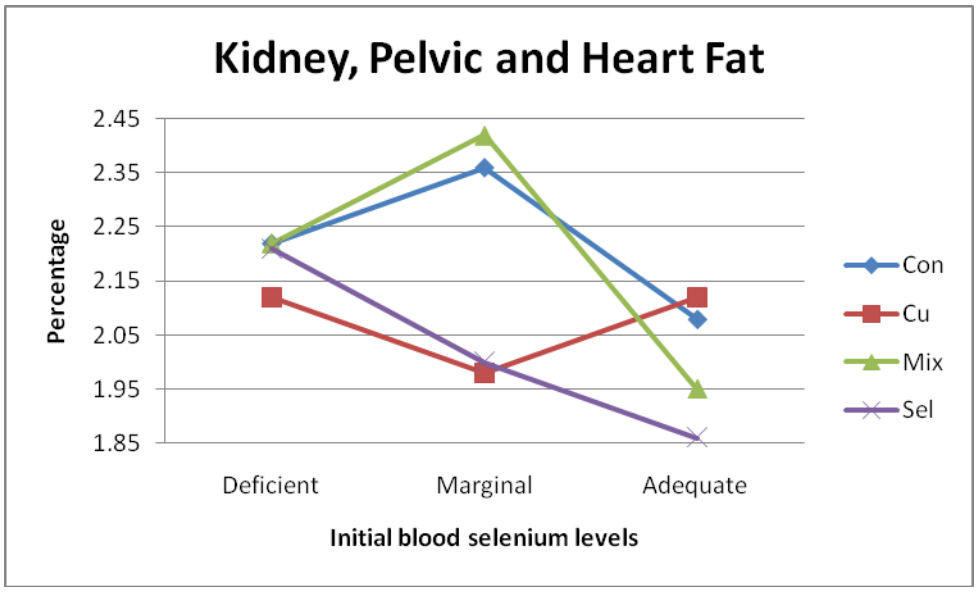


**Figure 39.** Kidney, pelvic, and heart fat percentage of beef calves in the ranch to rail program at varying initial serum selenium levels.

* Treatments include: **Con** (Controls – no supplementation); **Cu** (Copper – animals supplemented with Copasure bolus, Schering-Plough Animal Health, Kenilworth, NJ); **Sel** (animals injected with MU-SE, Schering-Plough Animal Health, Kenilworth, NJ); and **Mix** (animals treated with both the Cu and Sel treatments).

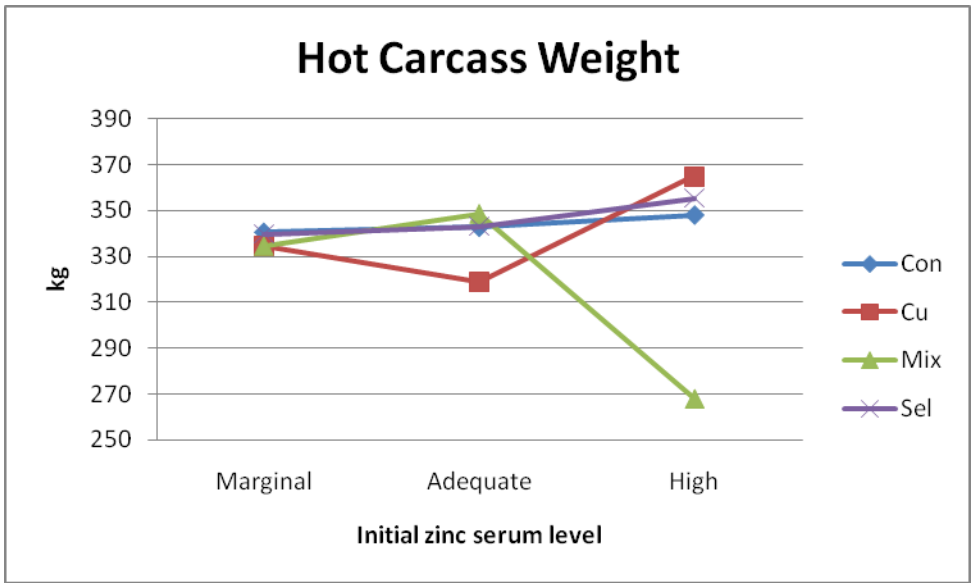


**Figure 40.** Hot carcass weights of beef calves in the ranch to rail program at varying initial zinc serum levels.

* Treatments include: **Con** (Controls – no supplementation); **Cu** (Copper – animals supplemented with Copasure bolus, Schering-Plough Animal Health, Kenilworth, NJ); **Sel** (animals injected with MU-SE, Schering-Plough Animal Health, Kenilworth, NJ); and **Mix** (animals treated with both the Cu and Sel treatments).

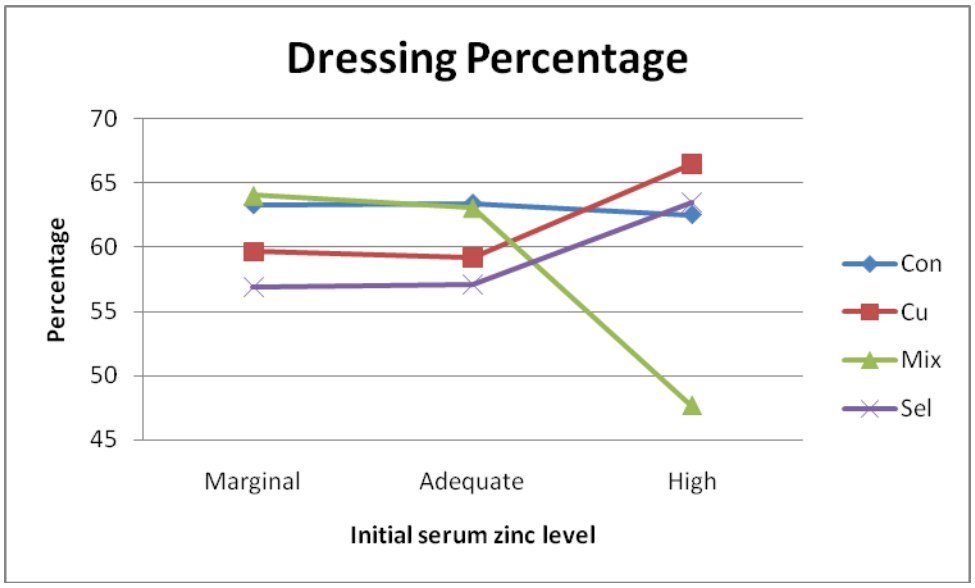


**Figure 41.** Dressing percentages of beef calves in the ranch to rail program at varying initial zinc serum levels.

* Treatments include: **Con** (Controls – no supplementation); **Cu** (Copper – animals supplemented with Copasure bolus, Schering-Plough Animal Health, Kenilworth, NJ); **Sel** (animals injected with MU-SE, Schering-Plough Animal Health, Kenilworth, NJ); and **Mix** (animals treated with both the Cu and Sel treatments).

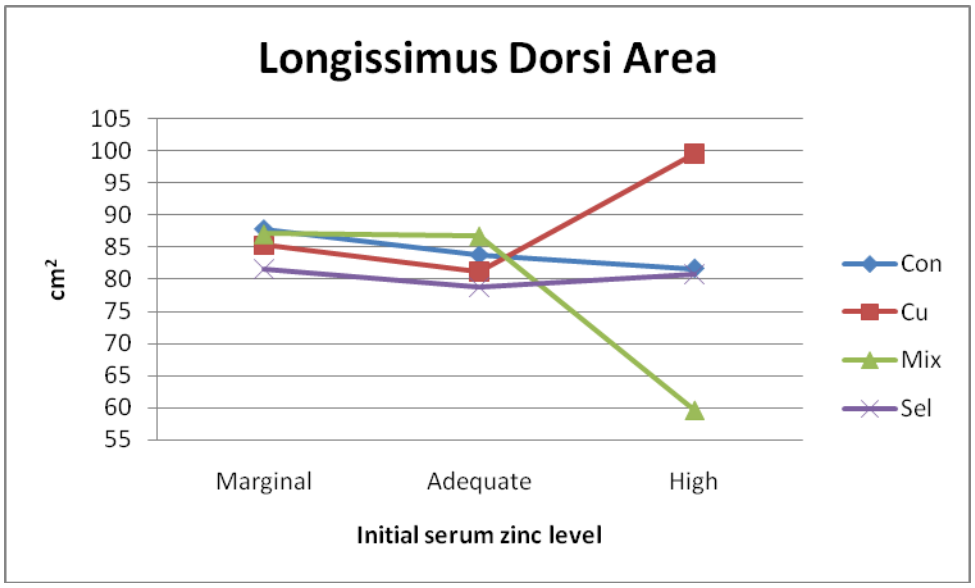


**Figure 42.** Longissimus dorsi area ($cm^2$) of beef calves in the ranch to rail program at varying initial zinc serum levels.

* Treatments include: **Con** (Controls – no supplementation); **Cu** (Copper – animals supplemented with Copasure bolus, Schering-Plough Animal Health, Kenilworth, NJ); **Sel** (animals injected with MU-SE, Schering-Plough Animal Health, Kenilworth, NJ); and **Mix** (animals treated with both the Cu and Sel treatments).

percentages ranged from 61.5% to 62.7%. REA of the groups had means from 86.75 to 91.3 $cm^2$.

**Interactions with pre-feedlot practices.** Ranches consigning cattle to the program were asked to fill out questionnaires asking about vaccination practices, weaning periods, backgrounding periods, and nutrition of calves prior to entry into the Ranch to Rail Program. Vaccination practices were grouped based on type of vaccine given: clostridials, bovine respiratory disease, or other. Bovine respiratory disease was further broken into the categories of modified-live virus vaccine, killed vaccine, or altered vaccine. Vaccinations were also grouped as pre-weaning and post-weaning prior to entry into the feedlot. Period from weaning to entry into the feedlot was also categorized in this data set. Categories were Bac14 (< 21 d prior to feedlot entry), Bac 21 (< 45 d but > 21 d) and Bac 45 (> 45 d). All animals in this study received at least one vaccination prior to entry into the feedlot. Nutrition practices were grouped into one of six categories: None (Nothing given); Past + Supp (Pasture plus a supplement); Dry + Hay (Drylot plus hay); Dry + Hay + Supp (Drylot plus Hay plus a supplement); Drylot + TMR (Drylot plus total mixed ration).

No mineral treatment by vaccination practice interactions were seen in this data set. In addition, no mineral treatment by backgrounding period or mineral treatment by nutrition interactions were observed. The main effects of the practices associated with the questionnaires are discussed in the companion paper to this. Therefore, we will not discuss the main effects here.

Results of the initial selenium levels are fairly consistent with findings of Dargatz and Ross (1996) who reported that in the Southeast 29% of cattle not supplemented with a trace mineral supplement were severely deficient in selenium; 32% were marginally deficient, 31% were

adequate, and 8% had highly adequate levels. Our results tended to have more animals clustered in the marginally deficient or adequate ranges than they found.

It could be said that it is disappointing that we found no performance differences among mineral treatments. However, the lack of differences is consistent with findings of other researchers. Wright et al. (2000) found no production differences when they supplemented 0.3 mg Se/kg DM, and their average daily gains (ADG) for the supplemented cattle (0.98 kg/d) were slightly less from the gain we observed. Ward et al. (1997) reported that supplementation with 5 mg Cu had no effect on ADG in steers fed corn-silage based diets regardless of Mo or S addition. Gaylean et al. (1995) also did not show differences between ADG of steers fed receiving diets supplemented with Cu lysine or CuO. Nicholson et al. (1991) concluded that no differences were found in pattern of weight gains of calves fed low selenium or selenium supplemented diets regardless of initial selenium status of the calves.

For immune functions based on supplementation, Wright et al. (2000) found no differences in antibody titers to Bovine herpes virus-1 and Bovine viral diarrhea based on mineral treatment. Furthermore, Reffett et al. (1986) reported that in stressed calves, selenium injection had no effect on antibody titers to infectious bovine rhinotracheitis virus or parainfluenza type-3 viruses. Dill et al. (1990) reported that humoral immune response did not increase with 3.25 mL of injectable ZnO suspension, Cu (2 mL of Moly-Cu), or Se (1 mL of Mu-Se / 90.8 kg BW) + Cu in steers fed diets deficient in these minerals. While we did not measure antibody titers, our lack of differences in medicine costs and gains likely indicate, as they found, that immune performance was probably not altered by treatment. Our results agree with the results of Beck et al. (2001) and Stanton et al. (2001) who reported that trace mineral supplementation treatment had no influence on morbidity or mortality rates.

The interesting thing that we did find in this study is that steers entering the feedlot with high levels of circulating zinc had decreased carcass weights, dressing percentages, and rib-eye areas when supplemented with both copper and selenium. While it can only be hypothesized that the high levels of zinc caused animals to be susceptible to pneumonia, we cannot understand how supplementing copper and selenium added to this effect. At this time, we do not understand why this interaction occurred. More research needs to be done in this area to understand the inter-relationship between high levels of zinc and supplementation with both selenium and zinc or if these results can be repeated.

## Conclusions

Selenium and copper supplementation did not enhance ADG or carcass characteristics by correcting a possible deficient state in trace mineral levels. No differences in morbidity or mortality were observed based on the treatments given in this study. These results are in agreement with supplementation of these micronutrients to animals with adequate status is not likely physiologically beneficial to the animal or economically beneficial to the producer.

# CHAPTER VI
# EVALUATION OF MANAGEMENT PRACTICES AT THE COW/CALF LEVEL ON FEEDLOT PERFORMANCE AND CARCASS TRAITS: RESULTS OF THE TEXAS A&M RANCH TO RAIL PROGRAM

## Introduction

Marketing practices in the US beef cattle industry can result in varying periods of stress, nutritional deficiencies, and exposure to infectious agents when calves are commingled from various sources, transported to distant sites, and changes in diet, feed intake, or both are abrupt (Step et al., 2008). These periods of stress result in increased morbidity and mortality which result in substantial losses for the US beef feeding industry.

Morbidity and mortality in feedlots are highly attributable to the bovine respiratory disease complex (BRD). Duff and Galyean (2007) reported that limited data and practical experiences have provided evidence that the effects of BRD on beef cattle morbidity and mortality can be decreased through pretransport preventative health programs commonly referred to as preconditioning, which may include vaccination for various infectious agents, anthelmintic treatments, exposure to feed bunks and troughs, and delayed shipment for 3 to 6 wk after weaning. In general, preconditioning programs ensure that animals have been weaned for a certain amount of time (usually 30 to 45 d), vaccinated (clostridial and viral vaccines), treated with an anthelmintic, castrated, dehorned, and accustomed to feed bunks and water troughs.

Preconditioning programs are designed to prepare a weaned calf for the "stresses" that may occur when it (1) is commingled with cattle from other sources and unknown health status; (2) is placed in an environment that maximizes exposure to infectious pathogens; (3) has a compromised immune system and cannot adequately protect itself against pathogens; (4) is

placed in environmental conditions that contribute to stress (temperature changes, dust, transportation, crowding, new feed and water delivery methods etc.)(Step et al., 2008). However, much debate occurs because of limited data, as to the feedlot performance of calves that have experienced different preconditioning programs. To provide meaningful data to this issue Texas Ranch to Rail data were evaluated with objectives to: (1) determine which kinds of preconditioning practices were being used; (2) answer if specific ranch-level regimens could result in performance differences for cattle in the feeding phase; (3) determine if management decisions at the cow/calf level can influence carcass characteristics after the feeding period.

## Materials and Methods

Cattle (n = 12,063) were entered in the Texas A&M University Ranch to Rail Program from 1995 to 2001. Due to incomplete data, we were only able to use 7,614 animals sent from 247 ranches during the years of 1996 to 2000 (2,193 were not included due to missing background sheets; 2,045 were not included because of missing carcass data; 211 were not included because missing both background and carcass information). The number of steers per ranch ranged from 1 to 132. Steers included a variety of genetic types typical in the southwestern United States. Weight of steers entering the feedlot ranged from 149 to 481 kg, with the vast majority falling between 191 and 362 kg.

Producers were allowed to send their cattle to a feedyard in the panhandle of Texas (north) or to a south Texas feedyard (south). Cattle sent north, were fed at Swisher County Cattle Feeders, Tulia, Texas. Cattle sent south were fed at either Hondo Creek Cattle Co. in Edroy, Texas or at the King Ranch Feedyard, Kingsville, Texas. Producers were asked to fill out background information and include it with the cattle at time of receiving. Background surveys asked for: name of ranch, location of ranch, date of calf birth, date of weaning, any internal parasite control

given, any external parasite given, any implant given, any vaccine administered, and what nutritional program was used. Survey data were entered into an excel spreadsheet as standardized value based on responses to survey. For example, when asked what pre-weaning shot was given a producer may respond with a particular brand name or give a generic term such as a clostridial. When a particular brand was referenced, a drop down list in excel linked the answer to a series of pre-determined generic values. Generic values consisted of things such as: clostridial, viral, modified-live, killed, altered, etc.

Cattle were received at the feedlot on a single day in mid-November each year. Cattle were managed according to standard procedures in place at the respective feedlot; however, management practices were not identical across years or feedlots. Cattle were diagnosed as morbid based on subjective visual appraisal by the feedlot staff. Upon arrival, all steers individually weighed, identified, administered a growth-promoting implant, and given preventative pharmaceuticals based on the judgment of feedlot management. Calves were assigned an initial market value by a trained USDA feeder calf grader upon entry into the feedyard based on weight, frame and muscle score, and current medical conditions. These values were used in calculations for net returns. Steers were processed for secondary application of implants in January or February each year.

Individual intake was not evaluated as animals were fed as groups; however, intake was calculated as total pounds fed per day divided by total of animals within each pen. Cattle were harvested at a commercial facility within a 200 mile radius of the feedyard. Hot carcass weight (**HCW**) was collected at slaughter and longissimus muscle area, fat thickness, kidney, pelvic and heart fat (KPH), calculated yield grade, and USDA marbling score and quality grade were evaluated by independent data collection services following chilling.

**Statistical analysis.** **S**eparate analyses were conducted to evaluate different treatment classifications on the feedlot and carcass traits. Treatment classifications included (1) morbidity, (2) backgrounding period, (3) nutritional strategy, (4) clostridial versus viral vaccine, (5) type of viral vaccine given, and (6) other types of vaccines given. For all dependent variable analyses, the Mixed procedure of SAS (SAS Inst. Inc., Cary, NC) was utilized with ranch nested within year as a random term. Individual steer was considered the experimental unit for all analyses.

To study impacts of morbidity, steers were categorized as either **healthy** (receiving no treatment) or **sick** (receiving at least one medical treatment). The effect of morbidity on ADG, days on feed, HCW, fat thickness, longissimus muscle area, calculated yield grade, total medicine cost, gross income, and net return was evaluated. The FREQ procedure of SAS (SAS Inst. Inc., Cary, NC) was used to determine number of animals per treatment group. A Chi-square test was utilized to evaluate the categorical distribution of USDA quality grade.

In evaluation of backgrounding effects, steers were grouped according to the amount of time from weaning to shipping to the feedyard. Treatment groups included: **none** (animals were weaned the day of shipping); **1-14** (animals were weaned for no more than 14 days prior to shipping); **15-21** (animals were weaned for no less than 14 d and no more than 21 d prior to shipping); and **22-45** (weaning to shipping time was greater than 21d and less than 45). Analysis was conducted as noted for the morbidity analysis. This analysis included backgrounding period, morbidity (yes/no) and the backgrounding by morbidity interaction as fixed effects.

For the nutritional strategy evaluation, calves were grouped depending upon the type of nutritional strategy that was provided on the incoming information sheet. Nutritional strategies included: pasture only (**pasture)**; pasture plus a supplement (**Past + Supp)**; drylot plus hay (**Dry + Hay)**; drylot plus hay plus a supplement (**Dry + Hay + Supp)**; drylot plus total mixed ration

(**Drylot + TMR**); and background feeding information not available (**Not Reported**). Nutritional strategy and morbidity were included in the model as fixed effects.

For the clostridial versus viral vaccination strategies calves were grouped as whether or not they had a clostridial vaccination and whether or not they had a viral vaccination prior to entry into the feedlot. All vaccines were characterized based on the Compendium of Veterinary Products (Bayer Animal Health, 2006). Clostridial (yes/no), viral (yes/no), and the clostridial by viral interaction were included in the model as fixed effects. There was a lack of balance across vaccination classifications as 5,338 steers were reported as having both vaccines, and only 180 steers were reported as not receiving either. Due to the fact that so many had received both vaccinations, we cannot fairly compare the main effects. Therefore, the interaction of the two effects received the main focus.

Of steers receiving a viral vaccine, the vaccine was characterized as either killed vaccine (**Kill)**, modified-live virus vaccine (**MLV)**, altered vaccine (**Alt)**, or the combination of any two. No animals received a combination of shots that resulted in the combination of a Kill and an Alt. The statistical analysis was performed in the same manner as the morbidity analysis. However, type of vaccine, morbidity (yes/no), and type of vaccine by morbidity interaction were included as fixed effects in the model.

Another analysis was performed using other vaccines as the treatment categories. Treatments included: *lepto-spirosis* (**lepto)**, *haemophilus somnus* (**somnus)** and *lepto-spirosis plus haemophilis somnus* (**lepto + somnus)**. Animals receiving these vaccines also had been vaccinated with some type of clostridial vaccine. The fixed effects of other vaccine treatment, morbidity (yes/no) and the interaction were included in the model.

Simple linear correlations were calculated through PROC CORR of SAS (SAS Inst. Inc., Cary, NC) among response variables.

## Results and Discussion

**Morbidity.** During the feeding period, 18% (1,399) of the 7,614 steers showed signs of morbidity. This percentage falls within published reports of morbidity rates (Waggoner et al., 2007). Our data set did not allow us to determine how many times each calf was pulled and treated for morbidity. When morbidity was analyzed as a treatment variable, significant differences were found for many traits. Final body weights were significantly affected by morbidity and were 8 kg lighter for calves that had been treated for an illness at least once during the feeding period. Days on feed was also significantly increased by morbidity, and calves that were morbid averaged 6 days longer in the feeding period. Average daily gains tended (P = 0.8) to be affected by morbidity. Calves that were morbid gained .4 kg/d less than calves that did not get sick. Hot carcass weights, dressing percentages, KPH, and yield grades were significantly different for healthy and treated steers. A strong tendency ($P = 0.02$) occurred for difference in fat thickness. Sick calves had significantly lower hot carcass weights, dressing percentages, and yield grades than healthy animals. Differences ($P < 0.01$) existed for all of the financial measurements that were analyzed. Medicine costs averaged $25.60 per animal that was treated due to illness, and healthy animals returned an additional $58.81 in gross returns over sick calves.

Morbidity had a tendency ($P = .10$) to have an effect on quality grade; 42% of the healthy animals had choice carcasses while only 31% of the sick animals graded choice. If the animal was treated at least once, there was a 44.61% chance that its carcass would not grade choice.

However, it the animal remained healthy throughout the feeding period, the probability of it not grading choice decreased to 32.61%.

In a similar Ranch to Rail program, 22% of steers received medical treatment for morbidity (Waggoner et al., 2007). Our 18% morbidity rate is less than their number and less than the 23.9% rate reported by USDA-APHIS (2001). However, it is higher than 8% rate reported by Edwards (1996) for Midwestern feedlots from 1979 to 1994. We believe that our lower morbidity results could be due in part to ranch management and producer education. We expect that producers enrolling in this program tended to be more progressive in their management and therefore the resulting calves may have less morbidity when reaching the feedlot, and the Ranch to Rail Program has had a producer education component.

Our results are consistent with several studies, who reported reduced ADG in steers receiving medical treatment during the feeding period (Van Donkersgoed et al., 1993; McNeil et al., 1996; Wittum et al., 1996; Gardner et al., 1999; Waggoner et al., 2007). Waggoner et al. (2007) hypothesized that lower ADG among the clinically ill cattle likely resulted from alterations in nutrient portioning and suppressed intake. As we did not measure individual intake in this study, we can only speculate that this may have occurred for the cattle in this program as well.

Hot carcass weight, fat thickness, and calculated yield grade were different for healthy and treated steers. These results are consistent with findings of Gardner et al. (1999) who reported greater fat thickness and yield grades for steers that were not treated for respiratory disease. However, these finding disagree with the findings of Waggoner et al. (2007). They found no significant differences for hot carcass weight, fat thickness, and calculated yield grade for healthy and treated steers. We did find an agreement with the Waggoner et al. (2007) results in that we did not find a difference in longissimus muscle area due to morbidity.

We did see that net returns were decreased by $52.32 when an animal became sick (Table 17). This value is similar to those presented by Fulton et al. (2002). Calves treated for BRD once returned $40.64 less, those receiving two medical treatments returned $58.35 less, and those receiving 3 or more treatments returned $291.93 less than calves that were not treated.

USDA quality grade distribution differed significantly ($P < 0.01$) among morbidity categories (Table 18). Yield grade was also significantly different which contrasts the findings of Waggoner et al. (2007) who found no differences in calculated yield grade. We believe that we may have been able to find significant differences due to sample size. To the best of our knowledge, this is the largest data set of this kind.

**Backgrounding period.** When backgrounding period was analyzed, it was found that pre-feedlot backgrounding period affected several aspects of feedlot performance (Table 19). Calves backgrounded for more than 21 days were 8.24 kg heavier than calves from any other backgrounding period at feedlot entry. These calves also had the heaviest final body weights. Days on feed had a tendency ($P = 0.09$) to be affected by backgrounding period. Calves backgrounded for less than 14 days had the least amount of days on feed at 189 d. Backgrounding period also significantly altered average daily gains. Least squares means of average daily gains were 1.28, 1.35, 1.32, and 1.38 kg/d for the periods of not backgrounded, 1-13 d, 14-20, and 21-45, respectively. Backgrounding period caused a difference ($P = 0.04$) in percentage morbidity. Morbidity for animals backgrounded for more than 21 d prior to feedlot entry was 18.45%; while morbidity for animals not backgrounded was 24.93%.

**Table 17.** The influence of morbidity on production and carcass traits of Texas A&M ranch to rail calves.

| | Morbidity at feedyard | | | |
|---|---|---|---|---|
| Item | No | Yes | SE | P-Value |
| Number of calves | 6215 | 1399 | ------- | ------- |
| Performance | | | | |
| Initial BW, kg | 270.26 | 269.42 | 4.96 | 0.82 |
| Final BW, kg | 536.41 | 528.41 | 4.95 | <0.01 |
| Days on Feed | 191 | 197 | 1.45 | <0.01 |
| ADG, kg/d | 1.33 | 1.28 | 0.02 | 0.04 |
| Carcass | | | | |
| HCW, kg | 345.25 | 334.74 | 3.86 | <0.01 |
| Dressing Percent | 63.91 | 63.24 | 0.22 | 0.01 |
| LM area, $cm^2$ | 84.62 | 85.59 | 1.16 | 0.49 |
| Fat Thickness, cm | 1.06 | 0.93 | 0.05 | 0.02 |
| KPH, % | 2.33 | 2.15 | 0.05 | <0.01 |
| USDA yield grade | 2.38 | 2.14 | 0.08 | <0.01 |
| Financial | | | | |
| Total COG ($ / lb) | 0.52 | 0.58 | 0.01 | <0.01 |
| Medicine Cost ($) | 0 | 25.6 | 0.89 | <0.01 |
| Gross Return ($) | 574.51 | 515.7 | 15.58 | <0.01 |
| Net Return ($) [1] | 138.46 | 86.14 | 10.95 | <0.01 |

[1] Gross Return minus initial value of animal as determined by trained personnel

**Table 18.** Influence of morbidity on quality grade of steers in the Texas A&M ranch to rail program.

| | Morbidity Category [1] | |
|---|---|---|
| Item | Healthy | Sick |
| Number of steers | 6052 | 1354 |
| USDA quality grade | ----------%---------- | |
| Prime | 0.38 | 0.07 |
| Choice | 42.3 | 30.8 |
| Select | 52.5 | 61.08 |
| Standard | 4.28 | 7.9 |
| Dark Cutter | 0.51 | 0.15 |
| Hard Bone | 0.03 | 0 |

[1] Number of medical treatments per head:
healthy = no treatment; sick = at least one treatment

**Table 19.** The effects of backgrounding period on feedlot production and carcass traits of Texas A&M ranch to rail calves.

| | Number of Days backgrounded prior to Shipping [1] | | | | | |
|---|---|---|---|---|---|---|
| Item | None | 1-14 | 15-21 | > 21 | SE | P-Value |
| Number of Steers | 127 | 432 | 1011 | 3538 | -------- | -------- |
| Performance | | | | | | |
| Initial BW, kg | 267.28 | 267.22 | 267.03 | 275.52 | 5.7 | 0.03 |
| Final BW, kg | 531.53 | 530.86 | 525.68 | 539.82 | 6.2 | <0.01 |
| Days on Feed | 201 | 189 | 198 | 192 | 6.58 | 0.09 |
| ADG, kg/d | 1.28 | 1.35 | 1.32 | 1.38 | 0.02 | <0.01 |
| Percent Morbidity | 24.93 | 22.72 | 22.79 | 18.45 | 3.91 | 0.04 |
| Carcass | | | | | | |
| HCW, kg | 338.73 | 336.81 | 333.02 | 342.98 | 4.8 | <0.01 |
| Dressing Percent | 63.55 | 63.6 | 63.25 | 63.34 | 0.25 | 0.32 |
| LM area, $cm^2$ | 84.83 | 84.08 | 84.07 | 85.36 | 1.3 | 0.31 |
| Fat Thickness, cm | 0.96 | 1.14 | 1.05 | 1.08 | 0.06 | <0.01 |
| KPH, % | 2.34 | 2.2 | 2.15 | 2.15 | 0.04 | <0.01 |
| USDA yield grade | 2.18 | 2.54 | 2.45 | 2.5 | 0.09 | <0.01 |
| Financial | | | | | | |
| Total COG, $ / lb | 0.55 | 0.55 | 0.55 | 0.55 | 0.01 | 0.91 |
| Medicine Cost, $ / head | 10.11 | 12.14 | 11.2 | 10.16 | 1.6 | <0.01 |
| Gross Return, $ / head | 562.92 | 424.81 | 425.9 | 463.02 | 18.53 | <0.01 |
| Net Return, $ / head [2] | 127.06 | 48.71 | 26.24 | 65.16 | 14.4 | <0.01 |

[1] Treatment groups: **none** (animals were weaned the day of shipping); **0-14** (animals were weaned for no more than 14 days prior to shipping); **14-21** (animals were weaned for no less than 14 d and no more than 21 d prior to shipping); and **21-45** (weaning to shipping time was greater than 21d and less than 45).

[2] Gross Return minus initial value of animal as determined by trained personnel

Carcass traits were also altered by backgrounding period prior to feedlot entry. Hot carcass weights were heaviest for calves backgrounded for more than 21 d at 342.98 kg; however, these weights are similar to carcass weights of calves not backgrounded at 338.73 kg. Dressing percentage and rib-eye area were not influenced by backgrounding period. Animals backgrounded for no more than 14 days had the highest ($P < 0.01$) fat thickness measurements; this was followed by animals in the 21-45 group, then the 14-20 group, and finally by those not vaccinated. Calves not backgrounded had lower ($P < 0.01$) yield grades than calves backgrounded. Quality grade was influenced by backgrounding period and morbidity. Interaction results are shown in Table 20.

Total cost of gain per animal was not different among backgrounding periods. Net returns were significantly different among the groups when looking at main effects. Since the interaction of backgrounding period and morbidity was significant ($P = 0.03$) we are reporting the net returns across the combinations in Figure 43. In calves that were healthy, net returns were greatest for calves that were not backgrounded. However, when sickness was encountered in the feedyard, non-backgrounded calves returned $28.74 less than calves backgrounded for more than 21 days.

Of the 5,108 head entered into the program with complete backgrounding information, 69% (3,538) were backgrounded for more than 21 days; whereas, only 2.5% (127) were not vaccinated at all. This could mean that for the backgrounding information, results could be skewed. As we did not have control over backgrounding period, we have to analyze the data as it is. Therefore, the results presented here are the best results that we can provide with the data set given.

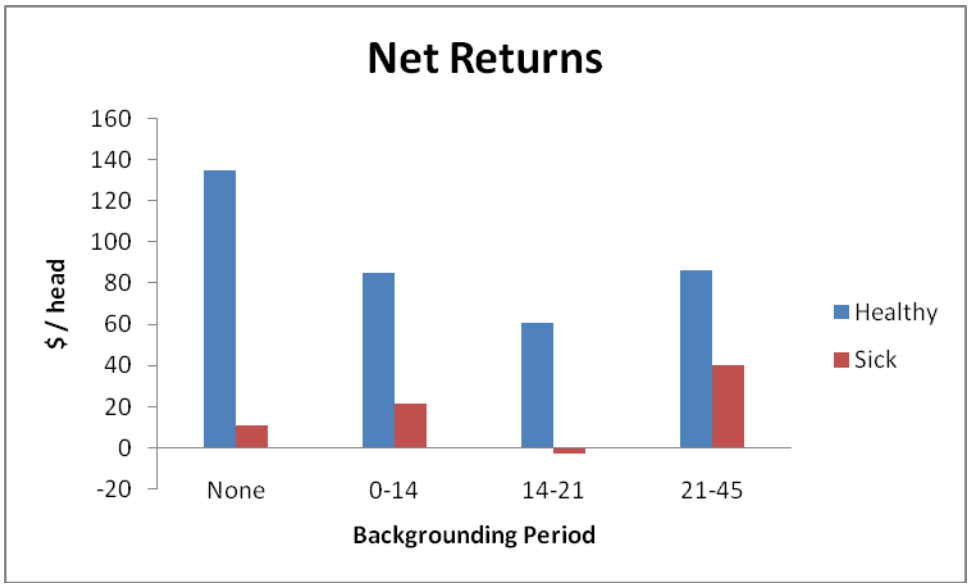


**Figure 43.** Feedlot net returns of calves in the Texas A&M ranch to rail program. [1]

[1] Interaction between backgrounding period and morbidity status of calf significant ($P < 0.01$).

**Table 20.** Effect of pre-feedlot backgrounding period on carcass quality of Texas A&M ranch to rail steers.

| | Backgrounding Period [1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Healthy | | | | Sick | | | |
| Item | None | 0-13 | 14-20 | 21-45 | None | 0-13 | 14-20 | 21-45 |
| Number of steers | 95 | 343 | 797 | 2965 | 12 | 89 | 214 | 573 |
| USDA quality grade | ----------%---------- | | | | ----------%---------- | | | |
| Prime | 1.05 | 0.29 | 0.25 | 0.37 | 0 | 0 | 0 | 0.17 |
| Choice | 55.79 | 35.28 | 33.12 | 46.48 | 33.33 | 26.97 | 26.64 | 33.86 |
| Select | 38.95 | 59.18 | 59.72 | 48.60 | 50.00 | 64.04 | 59.81 | 56.72 |
| Standard | 4.21 | 4.37 | 6.02 | 3.98 | 16.67 | 8.99 | 12.62 | 9.25 |
| Dark Cutter | 0 | 0.87 | 0.88 | 0.54 | 0 | 0 | 0.93 | 0 |
| Hard Bone | 0 | 0 | 0 | 0.03 | 0 | 0 | 0 | 0 |

[1] Treatment groups: **none** (animals were weaned the day of shipping); **0-14** (animals were weaned for no more than 14 days prior to shipping); **14-21** (animals were weaned for no less than 14 d and no more than 21 d prior to shipping); and **21-45** (weaning to shipping time was greater than 21d and less than 45).

Step et al. (2008) reported the effects of different weaning protocols on feedlot performance during a 42 d receiving period. They showed that on arrival, calves weaned for 45 d prior to feedlot entry and receiving a vaccination had higher ($P < 0.01$) body weights than calves weaned upon arrival. Our results agree with their findings. Calves weaned for greater than 21 d were significantly ($P < 0.03$) heavier at feedlot entry than calves not weaned prior to feedlot entry. This effect for increased body weights disappeared within 42 d after entry to the feedlot for the Step et al. (2008) project. Our results, however, indicate that the differences in body weights remained throughout the feeding period. Calves weaned for greater than 21 d were significantly heavier at the end of the study than those having been weaned for 14 to 21 d. However, finishing weights in the animals in the 21-45 d group were similar to those weaned for less than 14 d.

We were able to show that percentage morbidity was influenced by number of days backgrounded prior to shipping. Animals weaned more than 21 d prior to entry into the feedlot were less morbid than those weaned at time of shipping. Fulton et al. (2002) showed that the timing of vaccine administration in the herds with the lowest morbidity rates was alike: herd 1 received an MLV vaccine with the 4 viruses (IBR, BVD1a, PI3, and BRSV) approximately 7 and 3 wk before delivery; herd 2 received a MLV vaccine with the same 4 viruses approximately 7 wk before delivery; and herd 12 received a killed-virus vaccine with the same 4 viruses plus a *M. haemolytica* approximately 6 and 4 wk before delivery. This is also in agreement with the findings of Step et al. (2008) if we assume their morbidity rates follow through the end of the feeding period. Because of the interaction of net returns and morbidity, we found that in healthy calves, net returns were greatest for animals being weaned on the truck. However, when sickness occurred, animals backgrounded for more than 21d had the highest net returns.

Depending upon a feedlot manager's aversion to risk and ability to manage sick cattle, premium differences may occur depending upon length of backgrounding period.

Dhuyvetter et al. (2005) were able to put a value on these premiums offered by the feedlot. They suggested that based on a 45 d postweaning preconditioning program, cow/calf producers can realize a $14.00 increase in returns compared with the sale of calves at weaning that are not preconditioned. The differential in price between our returns and the premium paid by feedlot suggest that the majority of feedlots are working on the imperfect knowledge of where most of their cattle come from. USDA-APHIS (2000) reported that only 32.4% of all feedlots surveyed, received information about the previous history of the calves "always or most of the time". Duff and Galyean (2007) suggest that perhaps improved information flow regarding the background of the cattle will result from the greater national emphasis on individual animal identification and trace-back, which might stimulate the demand for preconditioned calves; thus it may decrease the difference between the net returns we found and the premiums paid to producers. It is possible that other market factors are also influencing the premiums paid. Time of year, economic status, and price of corn may all effect price differences paid for backgrounded cattle. King et al. (2006) reported that price premiums for calves in intensive certified health programs ranged from $2.74 per 45.45 kg to $7.91 per 45.45 kg from 1995 to 2004.

**Pre-feedlot nutrition.** Producers were asked to describe their nutritional strategies prior to sending the calves to the feedyard. Almost 3,000 cattle were reported to have been allowed to graze forage while being supplemented with some type of supplement (Table 21). We did not have pre-feedlot feeding information on 2,194 animals.

Pre-feedlot nutrition tended ($P = 0.07$) to have an effect on initial body weight. Calves held in a drylot, receiving hay and a supplement were lightest at the initiation of the feeding period.

**Table 21.** Effect of nutrition on production and carcass characteristics of beef steers in the Texas A&M ranch to rail program.

| | Weaning Period Feeds [1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Item | Pasture | Past + Supp | Dry + Hay | Dry+ Hay + Supp | Drylot + TMR | Not Reported | SEM | P-Value |
| Number of Steers | 603 | 2994 | 273 | 1311 | 239 | 2194 | -------- | -------- |
| Performance | | | | | | | | |
| Initial BW, kg | 277.80 | 280.99 | 288.77 | 268.39 | 276.95 | 277.14 | 10.50 | 0.07 |
| Final BW, kg | 538.23 | 534.50 | 529.64 | 528.17 | 530.59 | 538.98 | 10.90 | 0.47 |
| Days on Feed | 192 | 194 | 186 | 196 | 195 | 196 | 7.46 | 0.86 |
| ADG, kg/d | 1.35 | 1.33 | 1.28 | 1.31 | 1.31 | 1.33 | 0.04 | 0.76 |
| Percent Morbidity | 15.74 | 16.37 | 17.33 | 16.31 | 23.99 | 34.70 | 7.09 | <0.01 |
| Carcass | | | | | | | | |
| HCW, kg | 350.23 | 347.17 | 337.32 | 342.79 | 343.52 | 350.92 | 5.49 | 0.16 |
| Dressing Percent | 64.32 | 64.23 | 63.32 | 64.18 | 64.20 | 64.80 | 0.43 | <0.01 |
| LM area, $cm^2$ | 88.10 | 87.28 | 91.77 | 86.97 | 85.62 | 89.20 | 1.61 | 0.04 |
| Fat Thickness, cm | 0.95 | 1.02 | 0.88 | 1.08 | 1.09 | 1.17 | 0.07 | <0.01 |
| KPH, % | 2.06 | 2.08 | 2.22 | 2.11 | 2.13 | 2.11 | 0.06 | 0.42 |
| USDA yield grade | 2.36 | 2.42 | 1.93 | 2.45 | 2.47 | 2.24 | 0.17 | 0.01 |
| Financial | | | | | | | | |
| Total COG, $ / lb | 0.54 | 0.55 | 0.53 | 0.54 | 0.54 | 0.64 | 0.02 | <0.01 |
| Medicine Cost, $ / head | 12.58 | 11.19 | 9.06 | 11.63 | 7.91 | 11.89 | 3.84 | 0.75 |
| Gross Return, $ / head | 510.90 | 502.76 | 484.88 | 493.52 | 517.77 | 383.54 | 23.37 | <0.01 |
| Net Return, $ / head [2] | 114.75 | 90.63 | 78.24 | 96.64 | 69.55 | 21.40 | 23.70 | <0.01 |

[1] Feeding strategies were: Pasture (Pasture only); Past + Supp (Pasture plus a supplement); Dry + Hay (Drylot plus hay); Dry + Hay + Supp (Drylot plus Hay plus a supplement); Drylot + TMR (Drylot plus total mixed ration); Not Reported (Background feeding information not available)

[2] Gross Return minus initial value of animal as determined by trained personnel.

Least squares means for the initial body weights ranged from 268.39 kg for the dry + hay + supp category, to 288.77 kg for the dry + hay group. No differences were seen in the final body weights, days on feed, or average daily gains. Percentage morbidity was significantly influenced by pre-feedlot feeding strategies. Calves grazing only pasture prior to entry had a 15.74% morbidity rate while those held in a drylot and fed a total mixed ration (TMR) had a 24% morbidity rate. Calves from producers not reporting their feeding strategies had the highest morbidity rates at 34.7%.

Several carcass traits were influenced by pre-feedlot feeding strategies. Dressing percentage, fat thickness, and yield grades were significantly different among treatment groups. Cattle receiving hay in a drylot had the lowest yield grades. Yield grades were highest for calves held in a drylot and received a TMR. Calves that only grazed pasture returned an additional $45.20 in profit over calves that were held in a drylot and fed a total mixed ration prior to entry into the feedlot. Calves of producers not reporting their feeding strategies, had the lowest net returns of the treatment groups. Hot carcass weight and KPH were not affected by pre-feedlot nutrition.

Few research projects set out to determine the difference in the pre-feedlot nutrition programs. Most research programs assume that if calves are pre-conditioned for a certain amount of time and vaccinated that calves will have similar results in the feedlot. Our results contradict this assumption. We found that calves coming from a pasture only program had increased net returns in the feedlot over that of calves placed on drylot during the pre-conditioning program. This is most likely due to the difference in morbidity seen between the two groups. A sensitivity analysis by Macartney et al. (2003) indicated that morbidity rate had a great influence on profitability. Calves backgrounded on pasture only had much lower morbidity

rates at 15.74% than that of drylot fed calves (24%). This agrees with the findings of St. Louis et al. (2003) who found that pre-conditioning calves on ryegrass pastures resulted in greater ADG and decreased feed costs compared with preconditioning in a drylot. They, like us, were not able to determine whether the improved performance on grass was a result of decreased morbidity or other factors.

**Viral and clostridial vaccines.** All calves received at least two injections prior to entry into the program. The type of vaccine given in these injections varied greatly. Some producers gave as many as 8 injections prior to sending their calves to the feedlot ; 88.6% of the cattle received at least a clostridial vaccine while 86% received at least a viral vaccine to bovine respiratory disease, and 70.1% (5,338) received both a clostridial vaccine and a viral vaccination prior to entry into the feedlot (Table 22). Receipt of either a clostridial or a viral vaccine did not influence weight of the calves at feedlot entry or exit. The feedlot production parameters of days on feed, average daily gains, and percent morbidity were also not significantly altered by receipt of either a clostridial or viral vaccine. No carcass characteristics differed ($P < 0.10$) due to receipt of vaccination prior to entry into the feedyard. However, medicine cost was significantly different for calves that received a viral vaccine over that of calves not receiving a vaccination. Mean medicine costs for calves receiving a viral vaccine was $10.52 per head while the mean for those not receiving a vaccination was $12.71 per head. Total cost of gain and net returns were not influenced by receipt of a viral or clostridial vaccine prior to entry into the feedlot.

A previous study of the cow-calf segment revealed that approximately 60% of producers vaccinated calves for clostridial diseases before weaning (NAHMS, 1994). We found that 89% of producers enrolling in this program vaccinated for clostridial diseases. As the majority of producers enrolled in this program are concerned about how their cattle perform in the feedlot,

**Table 22.** Production and carcass responses of steers in the Texas A&M ranch to rail program to clostridial and viral vaccines given prior to feedlot entry [1].

| | Clostridial | | | Viral | | | Interaction |
|---|---|---|---|---|---|---|---|
| Item | No | Yes | SE | No | Yes | SE | P-Value |
| Number of Steers | 864 | 6750 | | 1059 | 6555 | --- | --- |
| Performance | | | | | | | |
| Initial BW, kg | 280.75 | 274.56 | 6.05 | 276.67 | 278.63 | 5.65 | 0.37 |
| Final BW, kg | 532.96 | 531.80 | 6.96 | 529.97 | 534.79 | 6.51 | 0.82 |
| Days on Feed | 188 | 193 | 7.42 | 187 | 195 | 7.38 | 0.48 |
| ADG, kg/d | 1.31 | 1.32 | 0.02 | 1.30 | 1.32 | 0.02 | 0.86 |
| Percent Morbidity | 14.96 | 18.67 | 5.70 | 16.48 | 17.15 | 1.90 | 0.80 |
| Carcass | | | | | | | |
| HCW, kg | 343.52 | 341.40 | 4.15 | 341.68 | 343.24 | 3.80 | 0.96 |
| Dressing Percent | 64.17 | 64.00 | 0.27 | 64.36 | 63.82 | 0.20 | 0.03 |
| LM area, $cm^2$ | 87.46 | 88.11 | 1.20 | 87.58 | 87.99 | 1.15 | 0.77 |
| Fat Thickness, cm | 1.01 | 1.01 | 0.05 | 1.03 | 1.00 | 0.05 | 0.58 |
| KPH, % | 2.07 | 2.06 | 0.04 | 2.07 | 2.06 | 0.04 | 0.50 |
| USDA yield grade | 2.33 | 2.28 | 0.10 | 2.31 | 2.29 | 0.09 | 0.95 |
| Financial | | | | | | | |
| Total COG, $ / lb | 0.56 | 0.57 | 0.01 | 0.56 | 0.57 | 0.01 | 0.54 |
| Medicine Cost, $ / head | 11.89 | 11.34 | 1.24 | 12.71 | 10.52 | 1.12 | 0.06 |
| Gross Return, $ / head | 467.23 | 457.89 | 19.90 | 472.92 | 452.20 | 18.64 | 0.96 |
| Net Return, $ / head [2] | 55.46 | 68.97 | 15.12 | 68.35 | 56.09 | 14.16 | 0.58 |

[1] Additional viral and clostridial vaccinations given at feedlot entry.
[2] Gross Return minus initial value of animal as determined by trained personnel.

we believe that they may not be a true representative sample the proportion of producers vaccinating for clostridials. The producers in this program are trying to improve their management practices, and may therefore, have already implemented the policy of giving clostridial vaccines to their calves prior to shipping.

We were not able to find in this study differences in production or carcass data with clostridial and viral vaccine as treatment. This is surprising. Macartney et al. (2003) showed that in 1999 and 2000, animals that were vaccinated had decreased morbidity rates of 7.1 and 5.4% respectively. We found that, while not significantly different, animals receiving a clostridial or viral vaccine prior to feedlot entry actually had higher morbidity rates. We cannot explain this. However, as all animals received both a clostridial and a viral vaccination at feedlot entry it could be possible that vaccination at feedlot arrival was able to protect the cattle from disease no matter the vaccination sequence prior to feedlot entry.

**Type of viral vaccine.** When we evaluated calves that had received a viral vaccine for the type of vaccine that they received, we found no differences ($P < 0.01$) among the parameters that we measured (Table 23). There was a tendency ($P = 0.11$) for average daily gains to be influenced by type of viral vaccine given prior to feedlot entry. Calves receiving only a killed vaccine had the highest ADG at 1.48 kg/d while those receiving both a killed and a MLV had the lowest at 1.36 kg/d. Least squares means of type of viral vaccine for feedlot entry body weights ranged from 271.31 to 295.23 kg. Feedlot morbidity was not influenced by type of viral vaccine given prior to feedlot entry. Those calves in the Kill treatment group had morbidity rates of 12.4% while those in the Kill + MLV group had rates of 25.13%. Net returns were not significantly different among treatment groups. However, animals that received only a killed vaccine prior to feedlot entry returned $80.13 while those receiving a combination of killed and a

**Table 23.** Effect of various types of viral vaccines on carcass traits and production responses of beef calves in the Texas A&M ranch to rail program.

| | Viral Vaccine [1] | | | | | | |
|---|---|---|---|---|---|---|---|
| Item | Alt | Kill | MLV | Alt + MLV | Kill + MLV | SE | P-Value |
| Number of Steers | 1283 | 685 | 3556 | 401 | 321 | -------- | -------- |
| Performance | | | | | | | |
| Initial BW, kg | 276.26 | 271.31 | 281.32 | 278.79 | 295.23 | 13.08 | 0.36 |
| Final BW, kg | 537.17 | 557.74 | 542.61 | 543.53 | 545.51 | 13.94 | 0.14 |
| Days on Feed | 196 | 202 | 193 | 193 | 186 | 5.65 | 0.51 |
| ADG, kg/d | 1.38 | 1.48 | 1.39 | 1.39 | 1.36 | 0.03 | 0.11 |
| Percent Morbidity | 19.27 | 12.4 | 17.65 | 17.86 | 25.13 | 9.01 | 0.69 |
| Carcass | | | | | | | |
| HCW, kg | 344.43 | 357.77 | 346.79 | 344.64 | 352.86 | 8.92 | 0.15 |
| Dressing Percent | 63.94 | 64.13 | 63.81 | 63.44 | 64.34 | 0.59 | 0.49 |
| LM area, $cm^2$ | 86.55 | 88.5 | 87.4 | 88.69 | 92.02 | 2.72 | 0.23 |
| Fat Thickness, cm | 1.04 | 1.2 | 1.07 | 1.01 | 1.07 | 0.12 | 0.25 |
| KPH, % | 2.12 | 2.17 | 2.09 | 2.12 | 1.99 | 0.08 | 0.29 |
| USDA yield grade | 2.38 | 2.56 | 2.38 | 2.3 | 2.19 | 0.13 | 0.54 |
| Financial | | | | | | | |
| Total COG, $ / lb | 0.56 | 0.53 | 0.57 | 0.57 | 0.61 | 0.04 | 0.24 |
| Medicine Cost, $ / head | 11.59 | 8.15 | 10.07 | 11.94 | 7.41 | 4.38 | 0.64 |
| Gross Return, $ / head | 439.94 | 485.98 | 437.6 | 447.66 | 449.55 | 24.36 | 0.4 |
| Net Return, $ / head [2] | 57.62 | 80.13 | 42.88 | 36.5 | 16.97 | 18.56 | 0.15 |

[1] Treatments include: **Kill** (killed vaccine); **MLV** (modified-live virus vaccine); **Alt** (altered vaccine); Alt + MLV (combination of Alt and MLV); Kill + MLV (combination of Kill and MLV).

[2] Gross Return minus initial value of animal as determined by trained personnel.

MLV vaccine returned only $16.97. Medicine cost per animal was lowest for the kill + MLV treatment category.

There was an interaction between morbidity and net returns (Figure 44). When animals remained healthy throughout the feeding period, net returns for animals in the kill+MLV treatment group were significantly lower than those in the kill group. When the animal became sick, returns were greatest for animals in the kill group. Animals in both the kill+MLV group and in the Alt+MLV group were similar for net returns. They were both significantly less than the kill group. Animals in the MLV and Alt only groups were intermediate to these.

Strategies to control respiratory viruses are a key component in preventing BRD (Grooms and Coe, 2002). In most preconditioning programs, it is recommended that cattle receive a viral vaccination prior to feedlot entry. Vaccines and vaccination protocols vary tremendously and are often debated by veterinarians and producers. Grooms and Coe, (2002) reported that frequently these protocols are based on extrapolation of data from unrelated studies or experiences, and there is a lack of critical evaluation and comparison among different vaccination protocols that focus on optimizing immunity in the preconditioned calf.

We evaluated the different vaccination protocols for viral vaccination used in calves prior to entry into the feedlot. No differences existed among the viral vaccinations. These results agree with Grooms and Coe (2002) who report that significant differences in ADG among the nine vaccine groups were not detected during the study. Furthermore, they report that vaccination protocols for BVDV and BHV-1 that include at least one MLV stimulate the highest levels of serum-neutralizing antibodies. We might assume, that as all animals received a MLV when they reached the feedyard, that the animals received their pre-conditioning vaccinations

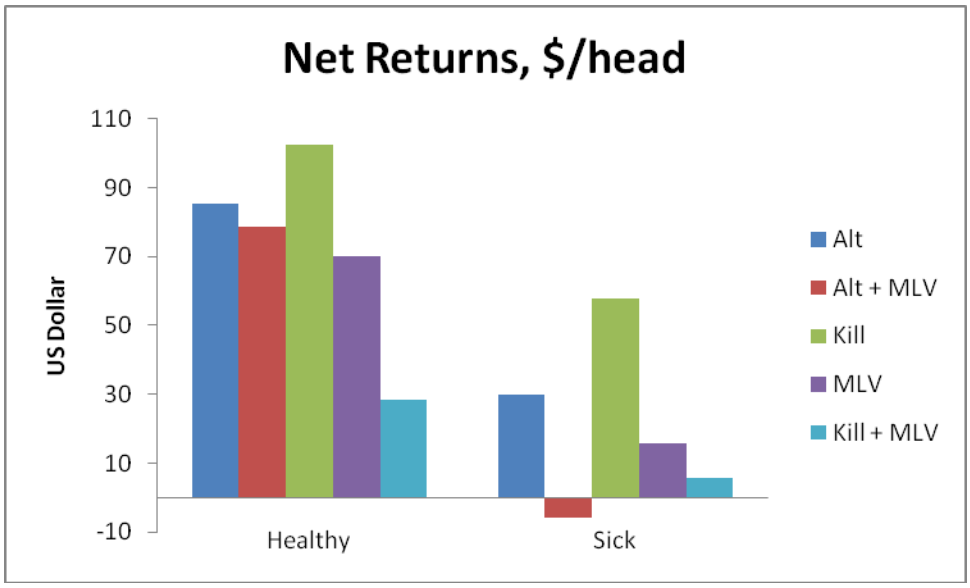


**Figure 44.** Feedlot net returns of various viral vaccination combinations on healthy and sick steers in the Texas A&M ranch to rail program[1].

[1] Treatments include: **Kill** (killed vaccine); **MLV** (modified-live virus vaccine); **Alt** (altered vaccine); Alt + MLV (combination of Alt and MLV); Kill + MLV (combination of Kill and MLV).

plus a booster when arriving at the feedyard. Therefore, all the calves maximized their antibody titer response because of the vaccination at the feedlot and not at the ranch level.

The vaccination regimens differed, particularly in the number of vaccinations and the timing of vaccination administration. Some producers only gave 2 shots while others gave as many as 8 shots. Fulton et al. (2002) reported that a particular vaccine may not be as important as timing of vaccination administration. We were not able to measure timing of vaccine administration. However, if the Fulton et al. (2002) conjecture is correct, it may explain why we found no differences among types of viral vaccinations given. Even if we had the dates of vaccination, we may not be able to differentiate among vaccination strategies as it would be highly confounded with backgrounding period.

**Other vaccinations.** Upon evaluation of other vaccinations (not viral or clostridial) given to animals prior to feedlot entry, we found no differences due to an additional lepto or somnus vaccine (Table 24). For all response variables, no treatment by morbidity interaction occurred due to treatment with a lepto or somnus vaccine.

**Correlations.** Pearson correlations (seen in Table 25) among response variables were highly significant ($P < 0.001$). Hot carcass weights were correlated to ADG at 0.65. Medicine costs were negatively correlated with net returns. ADG and HCW were positively correlated to net returns. Days on feed was correlated with initial weight at -0.62. We did not find the correlations with initial weight as Zinn et al. (2008) found. We were not able to find strong correlations between hot carcass weight, ADG and initial weight. In that study they used shrunk initial weight which may have created some of the differences between the two studies.

**Table 24.** Feedlot production responses of various vaccinations given (other than a viral or clostridial vaccine) to calves in the Texas A&M ranch to rail program.

| | Vaccine [1] | | | | | |
|---|---|---|---|---|---|---|
| Item | Lepto | Somnus | Lepto + Somnus | None | SE | P-Value |
| Number of Steers | 764 | 1980 | 530 | 4340 | ------ | ------ |
| Performance | | | | | | |
| Initial BW, kg | 282.52 | 274.95 | 272.42 | 270.74 | 4.83 | 0.28 |
| Final BW, kg | 539.87 | 543.24 | 540.78 | 540.36 | 5.84 | 0.95 |
| Days on Feed | 193 | 194 | 196 | 195 | 2.88 | 0.90 |
| ADG, kg/d | 1.34 | 1.39 | 1.40 | 1.37 | 0.02 | 0.12 |
| Percent Morbidity | 17.11 | 17.34 | 23.79 | 20.22 | 3.30 | 0.35 |
| Carcass | | | | | | |
| HCW, kg | 344.38 | 347.32 | 344.71 | 344.87 | 3.43 | 0.83 |
| Dressing Percent | 63.67 | 63.71 | 63.71 | 63.42 | 0.20 | 0.80 |
| LM area, $cm^2$ | 86.28 | 87.62 | 88.00 | 88.13 | 0.99 | 0.49 |
| Fat Thickness, cm | 0.99 | 1.09 | 0.97 | 1.03 | 0.05 | 0.08 |
| KPH, % | 2.05 | 2.07 | 2.01 | 2.10 | 0.03 | 0.43 |
| USDA yield grade | 2.37 | 2.39 | 2.23 | 2.25 | 0.08 | 0.28 |
| Financial | | | | | | |
| Total COG, $ / lb | 0.57 | 0.55 | 0.57 | 0.59 | 0.01 | 0.22 |
| Medicine Cost, $ / head | 10.98 | 9.90 | 11.39 | 11.26 | 0.80 | 0.29 |
| Gross Return, $ / head | 464.99 | 460.10 | 463.38 | 438.46 | 15.63 | 0.70 |
| Net Return, $ / head [2] | 54.92 | 66.09 | 67.84 | 51.92 | 11.99 | 0.66 |

[1] This vaccine given in addition to a 7 or 8-way clostridial

[2] Treatments include: Lepto (a clostridial plus *lepto-spirosis*); Somnus (a clostridial plus *Haemophilus somnus*); Lepto+Somnus (a clostridial plus both Lepto and Somnus); none (only receiving a clostridial).

**Table 25.** Correlations among production traits and carcass characteristics of Texas A&M ranch to rail steers.

| | InWt | OutWt | ADG | Dress | HCW | YG | Med |
|---|---|---|---|---|---|---|---|
| InWt | | | | | | | |
| OutWt | 0.43 | | | | | | |
| ADG | 0.09 | 0.74 | | | | | |
| Dress | 0.09 | -0.04 | -0.12 | | | | |
| HCW | 0.45 | 0.93 | 0.65 | 0.34 | | | |
| YG | 0.08 | 0.23 | 0.2 | 0.11 | 0.26 | | |
| Med | -0.08 | -0.04 | -0.07 | -0.14 | -0.11 | -0.09 | |
| Net | 0.08 | 0.46 | 0.55 | 0.25 | 0.53 | 0.13 | -0.26 |

[1] Abbreviations: InWt (initial weight); OutWt (final weight); ADG (average daily gain, kg/d); Dress (dressing percentage); HCW (hot carcass weight, kg); YG (calculated yield grade); Med (medicine cost, $ / head); Net (net return, $/head)

[2] All significant at the $P < 0.0001$ level

## Conclusions

As producers question the profitability of preconditioning programs, it is important to detail how producer management decisions affect feedlot production. These data help to assign value to management decisions at the cow/calf level that effect feedlot returns. Morbidity in the feedyard significantly affects yield grade, quality grade, medicine costs, gross returns and net returns. Morbidity is influenced by the amount of time that a calf is backgrounded prior to entry into the feedlot. Value of backgrounding period is highly dependent upon whether or not the calf gets sick. If the calf remains healthy, calves not backgrounded return the most money. However, if the calf does get sick, then calves that were backgrounded for more than 21 d are most valuable. Therefore, levels of morbidity in the feedyard is highly correlated with how much risk feedlot management is willing to accept.

Cattle backgrounded on pasture only were more profitable to feedlots than calves that are backgrounded in a drylot. In this study, vaccination prior to feedlot entry did not alter production of the cattle in the feedlot as long as the calf receives the vaccination at the feedlot. However, due to the large numbers of animals vaccinated and backgrounded and the relatively few animals not vaccinated or backgrounded, we cannot definitively say that vaccination prior to feedlot entry does not work because of confounding in the data.

Many research trials show that it is possible to induce immunity in cattle with vaccinations prior to feedlot entry. On the basis of disease containment, we must continue to recommend that cattle are vaccinated as early in life as possible. Vaccinating prior to feedlot entry does not cause any disadvantages once the animal reaches the feedlot.

# CHAPTER VII

# DISSERTATION SUMMARY

The segments of the beef industry are intrinsically linked together. Management decisions at one level alter the value of the product at other levels. In this dissertation, we discussed each segment as an individual entity as well as looked at connections between the levels.

Results of the experiments conducted show that vaccination of an animal at a young age is critical to the economic return seen when the animal is harvested at the conclusion of the feedlot experience. While vaccination in itself is critical, type of vaccination is also important. Different vaccines have differential effects on the magnitude and timing of release of various cytokines. These differences may in part be due to differences in the development of the calf's own immune system. We showed that it is possible to vaccinate a calf within the first three days of birth and get an immune response; but that it may be more beneficial to the calf's own immune system development, to wait to vaccinate the calf until it is somewhat older (approximately 3 to 5 months of age).

When vaccinations were given to older cattle, we found that due to size and age differences, animals responded differently to the vaccine. While in the early periods of the feeding phase, performance differences did exist, the differences disappeared by the end of the trial. As the vaccines all stimulated adequate antibody production, differences in early weight gains and the length of time and/or phase of ownership may be a driver in the decision as to which vaccine should be used.

Length of time that a calf is backgrounded also affects the economic value of the calf at the end of the feeding period. Morbidity in the feedyard significantly affects yield grade, quality

grade, medicine costs, gross returns and net returns. Morbidity is directly influenced by the amount of time that a calf is backgrounded prior to entry into the feedlot. Type of backgrounding program also influences profitability of the animal. Cattle backgrounded on pasture only were more profitable to feedlots than calves that are backgrounded in a drylot. This, therefore, affects that value at which the feedlot can pay the producer for the animal.

The data gathered here suggest that strong relationships exist between management decisions and resulting economic returns of the animals. As each segment of the industry is inherently linked to all other segments, it is important for all involved to start to recognize how their decisions impact others.

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