EFFECTS OF EWE LATE GESTATIONAL SUPPLEMENTATION OF RUMEN UNDEGRADABLE PROTEIN, VITAMIN E, ZINC, AND CHLORTETRACYCLINE ON EWE PRODUCTIVITY AND POSTWEANING MANAGEMENT OF LAMBS ON FEEDLOT PERFORMANCE AND TISSUE DEPOSITION

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ABSTRACT

Lamb survival and productivity from birth to weaning and lamb postweaning management harvest are areas that the US sheep industry needs to become more efficient at to remain profitable. Western white-faced ewes were supplemented HIGH (12.5% rumen by-pass protein, 880 IU/kg of supplemental Vitamin E, 176 ppm chelated Zn, and 72.7 mg/kg chlortetracycline) or LOW (7.56% rumen by-pass protein, with no supplemental Vitamin E, chelated Zn, or chlortetracycline) supplements at 0.227 kg·ewe^{-1}·d^{-1} during late gestation. Ewes of different age and body condition scores were individually supplemented for 29 d prior to expected lambing. Thereafter, each ewe was mass fed the appropriate supplement until lambing. In Experiment 3, approximately 600 ewes were group fed HIGH or LOW supplements over 2 yr. Differences in antibody transfer from ewe to lamb were detected in supplemented ewes of different age ($P <$ 0.10); however, lamb production was not different ($P > 0.10$) for all 3 experiments. To investigate lamb post-weaning management, terminally sired lambs (n = 72) were randomly assigned to 1 of 4 backgrounding treatments. Lamb backgrounding treatments were: ad libitum access to 80% alfalfa: 20% barley pellets (PELLET); cool season grass paddock grazing (GRASS); remain with ewe flock on fall dormant range (LATE WEAN); wean for 96 h and returned to ewe flock on dormant range (RANGE). Background treatments were applied for 29 d. Thereafter, lambs were finished on a corn based diet. Lamb BW and ultrasound measurements were taken at weaning, after background treatment, after feedlot step-up and at the conclusion of the finishing period. Pen intake was measured. Lambs backgrounded on PELLET were heavier ($P < 0.10$) than all other treatments after the backgrounding period and at the end of the feedlot period. Lambs backgrounded on PELLET had the greatest intakes and ADG ($P < 0.10$) during the feedlot period. At beginning and end of the feedlot period, PELLET and GRASS lambs had larger ($P < 0.05$) LM areas than RANGE and LATE WEAN treated lambs. Under the condition of the studies, late gestational supplements did not improve ewe productivity and backgrounding treatments on dormant range diminished feedlot productivity.

CHAPTER 1

LITERATURE REVIEW

Lamb Production

Domesticated sheep possess the ability to rear multiple offspring per reproductive event. Yet, American lamb producers averaged only 1.15 lambs produced per ewe in 2005 (NASS, 2005). Improving lamb production per ewe is a complex interaction of lambing rate, lamb survival, and lamb growth.

To improve net lamb production, an operation must increase the number of lambs born per ewe and lambs successfully reared to weaning. Improvements in lambing rates can be accomplished through genetic selection and/or flock management. However, an increase in number of lambs born per ewes does not always result in a similar increase in lambs reared per ewe. Rowland (1992) reported that 85 % of perinatal lamb loss was attributed to ewes that gave birth to more than one lamb. Similarly, Shelton and Willingham (2003) reported that lamb death loss of twins was twice as high single born lambs. Improvements in yearly lamb production must come through increased lambing rate and lamb survival.

Rate and Timing of Lamb Loss

Identification of the most critical timing of lamb loss is imperative for progress. Safford and Hoversland (1960) studied large shed lambing operations for 3 yr and found 23.5% lamb loss. The average timing of death was 6 d of age. Of the lambs lost, 56%

occurred in the first 3 d and 73% occurred by d 7 post lambing. Similarly, a survey of Montana sheep operations, by Kott and Thomas (1987), found an average of 20% yearly lamb loss and 50% of losses occurred prior to 1 mo of age. Rowland (1992) reported that perinatal lamb loss from four Colorado operations ranged from 8.2 to 12.2% during the first 3 wk post lambing. In addition, Rowland et al. (1992) commented that most of the lamb deaths in the study occurred within 24 h of parturition. In the Mid-Western regions of the US, lamb losses range from 5 to 25% with the average producer having lamb losses around 20% (Rook et al., 1990). Rook et al., (1990) reported that 65% of lambs lost were lost during the first wk of life. In the Southwestern regions of the nation, producers typically lamb on the range with minimal human interaction. Willingham et al. (1986) reported that in a Texas based range lambing operation, lamb losses averaged 14% and 73% of the losses occurred in the first 2 wk post lambing. Haughey (1981) reported that in Australian range lambing operations, lamb losses averaged 20 to 25% with nearly all lamb loss occurred within 3 d of birth. Redden et al. (2006) reported the neonatal lamb loss was 6% on a New Mexico range lambing operation. Regardless of the area or flock, lamb survival during the first week of life is problematic. Therefore, producers must seek out methods of management to improve lamb survival during the first wk post lambing.

Causes of Lamb Loss

Neonatal diarrhea, starvation, and pneumonia appear to account for most lamb deaths as reported by a study at the US sheep experiment station (Gates, 1977). These

three diseases will be covered in more detail. However, numerous other events can lead to lamb deaths; including, but not limited to dystocia, stillborns and enterotoxemia.

Neonatal diarrhea is characterized by progressive dehydration and death, with *Escherichia coli*, rotavirus, and *Cryptosporidium parvum* being the most prevalent enteropathogens (Kahn, 2005). Scours was the leading cause of lamb loss at 46% of lambs lost in a study conducted at the US sheep experiment station (Gates, 1977). Safford and Hoversland (1960) reported that dysentery (scours) caused 11.8% lamb loss. Moreover, 85% of the scour related deaths were within 4 d of birth.

Starvation was the cause of 20% of lambs lost in a study at the US sheep experiment station (Gates, 1977). Rook et al. (1990) reported that starvation was the leading cause at 50% of all Michigan postpartum lamb losses and 75% of starvation losses were in the first wk of life. Similarly, reports state that almost half of the lambs that perish in the UK are lost due to severe chilling or hypothermia (Henderson, 1990), which can be prevented with proper nutrition and management. Safford and Hoversland (1960) reported that the average age of lambs that died of starvation was 6 d post birth and 27% of those died prior to 3 d of age. Harsh weather conditions can rapidly reduce a young lamb's internal temperature (Alexander, 1961) and could also depress the lambs desire to nurse. Lambs that have exhausted most of their energy reserves will parish without human intervention. Accurate determination of acute lamb starvation can be accomplished with a proper necropsy examination; however, chronic starvation is more difficult because it may lead to the progression of many other diseases.

Pneumonia was reported as the third leading cause of lamb loss by the US sheep experiment station study at 8% of lambs lost (Gates, 1977). However, pneumonia was found to be the leading cause of death by Safford and Hoversland (1960) at 16% of lambs' autopsied. Similarly, Rook (1990) reported that 17% of all death loss could be attributed to pneumonia and 85% of pneumonia losses occurred before 3 wk of age. The cause of pneumonia in lambs is complex and is the result of interactions between infectious microorganisms and lamb passive immunity. Pneumonia often occurs when the lambs' metabolic or immunologic systems are dysfunctional and passive mucosal immunity no longer inhibit commonly prevalent pathogens to proliferate.

Neonatal Lamb Energy

The most important event for a young lamb's livelihood is the proper intake of colostrum. A lamb's thermoregulatory system is only partially functional at birth and does not become fully functional until the lamb is about 3 d old (Henderson, 1990). Brown fat stores are available to lambs; given that their dam was fed properly during late gestation (Alexander, 1978). This energy reserve will only last the lamb a couple of hours in harsh weather conditions. Therefore, a lamb needs to consume the high energy, high fat colostrum shortly after birth, due to the metabolic energy that it provides the lamb (Henderson, 1990). Lambs exposed to severe cold stress at 1 h post parturition, especially twin born lambs, need early colostrum intake for the induction of non-shivering thermogenesis (Hamadeh et al., 2000). The stress of chilling reduces passive immunity and is linked to the reduction in the lamb's resistance to disease such as neonatal diarrhea and pneumonia (Gates, 1990).

Ewe/Lamb Immunology

In ruminants, the placenta morphology is a specific type of placentation that acts as a barrier to the transfer of immunoglobulins from ewe to lamb (O'Doherty and Crosby, 1997). Lambs are therefore reliant on the successful transfer of colostral immunoglobulins to provide them with humoral immunity in the early days and weeks of life. The primary immunoglobulin secreted in colostrum is IgG (Smith et al., 1975). Concentrations of IgG in colostrum decrease rapidly after parturition (Al-Sabbagh 1995). Once the lamb is 24 h old, transport of IgG across the intestinal epithelium is virtually complete (Parker and Nicol, 1990). To effectively fight off the host of microorganisms that the lamb will encounter after birth, it is estimated that a lamb must consume one liter of colostrum within 24 h of birth (Henderson, 1990). Complication may arise in multiple births when ewes do not produce enough colostrum for all of her progeny. Delayed colostrum consumption postpartum negatively affects lamb serum antibody levels and lamb growth and survival (Khalaf et al., 1979).

Energy restriction during gestation can have large impacts on the health of subsequent offspring, including intrauterine growth retardation (Wu et al., 2006). Improper ewe nutrition from mid to late pregnancy can reduce mammary development, alter colostrum quality, reduce colostrum quantity, and reduce offspring birth weight, which all may have negative implications for lamb health and survival during the early postnatal period (Swanson et al. 2008).

In summary, sheep producers are dependent upon the successful rearing of healthy lambs each year to remain profitable. Production losses are greatest during the

first few weeks after parturition. Proper ewe nutrient intake during gestation can improve lamb vigor and immunological transfer to support a successful reproductive event.

Ewe Nutrition

Montana range ewe operations typically lamb in the spring to take advantage of spring and summer forage production. However, for ewes to lamb in the spring, they must maintain pregnancy throughout the winter. Typically, winter forage cannot support the nutritional needs of the ewe during late gestation and early lactation (NRC, 2007). Supplementation of harvested feed is a common approach during gestation and lactation to provide energy, protein, vitamins, and/or minerals above what is available in dormant forage (Clanton and Zimmerman, 1970). What, when, and how much to supplement for optimal productivity has been a topic of animal science research for many years.

Protein

Western range ewes can rarely consume enough dormant range forages during the winter to meet their protein needs. Early research by Van Horn (1959) showed that 12% CP supplements fed at 0.15 kg/d/ewe improved ewe weight statis throughout the winter and overall ewe production of lamb over no supplementation. In addition, Van Horn (1959) reported that supplements higher in protein concentration or supplements fed at higher quantities would increase ewe BW at lambing but did not improve ewe production of lamb above 12% CP at 0.15 kg per d. Similarly, but more recently, winter supplementation of protein high in rumen degradable intake protein (DIP) has been shown to improve ewe status throughout the winter, however, overall productivity was

similar between supplemented and control ewes (Hoaglund et al. 1992; Padula et al., 1992). Late Gestation

Eighty percent of the fetal growth occurs during the last 2 months of pregnancy, leading to a significant increase in nutrient requirements of the ewe (Bell, 1995). There is also a large increase in ewe's net protein requirement for udder development and colostrum production in the last 2 weeks of gestation (Mellor and Murray, 1985). However, during the last two weeks of gestation for multiparous ewes, voluntary feed intake declines (Orr and Treacher, 1984). Inadequate feed intake during late gestation has been attributed to a reduction in birth weight, mammary development, and milk production (Mellor and Murray, 1985). Late gestation supplementation provides nutrients to a ewe that can no longer consume enough low quality forages to meet her requirements.

Late gestation and early lactation supplementation of 20% CP pellets at 454 g/d (0.53 Mcal/kg) to ewes improved lamb survival (Burfening and Kott, 1993). Ramsey et al. (2000) reported higher lamb survival from range ewes supplemented 150 g/d of a 26% CP pellet during late gestation. Hatfield et al. (1995) reported higher 28, 42, 59, and 120 d lamb BW when ewes were fed 14.9% compared to 11.3% CP diets during late gestation and early lactation. In contrast, Ocak et al. (2005) reported increased lamb birth BW, increased lambing difficulty scores and decreased lamb survival when ewes were fed a diet 1.4 times the protein requirement compared to ewes fed at maintenance.

Ruminally Undegradable Protein

Once the rumen protein requirements of the rumen microflora have been met, providing the host ruminally undegradable intake protein (UIP) will supply additional amino acids to the small intestine (Keery, 1993). Hoaglund et al. (1992) reported that ewe supplementation of protein high in UIP during mid gestation improved ewe weight stasis over ewes supplemented with protein high in ruminally degradable intake protein (DIP). However, Hoaglund et al. (1992) reported that mid-gestation UIP protein supplementation had no effect on lamb survival or lamb BW. In contrast, Bohn et al. (1994) reported that protein supplementation high in UIP improved lamb survival and lamb 90 d BW over control and DIP protein supplementation.

In beef cattle, UIP protein supplementation during gestation had no effect on cow weight change or subsequent calf production (Alderton et al. 2000; Sletmoen-Olson et al. 2000). However, late gestational supplementation of UIP to first calf heifers has been shown to improve rebreeding success post parturition (Wiley et al. 1991; Patterson et al. 2003; Engel et al. 2008).

Late gestation supplementation of UIP has been reported to reduce ewe weight and condition loss during late gestation (30 g/d UIP, Ramsey et al., 2000; 58g/d UIP, Roeder et al., 2000). However, Annett et al. (2008) found no difference in ewe weight stasis when UIP (55 g/d) protein was supplemented during late gestation.

O'Doherty and Crosby (1997) supplemented increasing amounts of dietary protein and reported no difference in IgG concentration but higher colostrum production from ewes. In addition, lambs born to ewes fed more protein during late pregnancy

absorbed more IgGs than did lambs born to ewes fed less protein (O'Doherty and Crosby, 1997). Conversely, Roeder et al. (2000) reported that UIP supplementation increased concentrations of colostral IgG concentrations but did not affect total colostral IgG production due to low levels of colostrum produced by UIP supplemented ewes. Annett et al. (2005) reported no difference in colostrum production or IgG concentration from ewes fed either UIP or DIP. Annett et al. (2008) reported that fish oil supplementation decreased colostrum production and supplementation of UIP in addition to fish oil returned colostrum production to normal levels.

Total ewe milk production and milk constituents were not reported to be different between UIP and DIP supplemented ewes (Ramsey et al. 2000; Roeder et al. 2000). Roeder et al. (2000) reported higher milk protein for supplemented ewes than control ewes, whereas, Ramsey et al. (2000) found no change in milk profile with either protein supplement vs. control ewes.

Lamb production from ewes supplemented with increasing levels of UIP during late gestation has been reported to be improved via higher lamb survival (Annett et al. 2005). Moreover, late gestation supplementation of fish oil decreases colostrum output and decreases lamb survival. Supplementation of UIP has also been shown to return colostrum production and lamb survival rates to normal levels (Annett et al. 2008). Ramsey et al. (2000) reported that late gestation supplementation of UIP or DIP to nulliparous range ewes had no effect on lamb growth and DIP supplementation to multiparous range ewes increased lamb d 50 and 150 BW over UIP supplementation.

Roeder et al. (2000) reported that lamb birth BW was similar between UIP and DIP late gestation supplemented ewes.

In summary, late gestational supplementation of protein has the potential to improved ewe weight stasis, immunological transfer, and lamb performance. In addition, supplementation of protein with higher concentrations of UIP has shown mixed results for ewe weight stasis, immunological transfer, and lamb performance.

Zinc

Lab animal studies in the 1930s first showed that Zn is essential for growth and survival of animals (Todd et al., 1934). Low Zn intake during all or part of gestation has resulted in dystocia of the rat (Apgar, 1976) and pig (Hoekstra et al., 1967), and reduced viability of offspring in the rat (Apgar, 1968), pig (Hoekstra et al., 1967), and sheep (Apgar and Fitzgerald, 1985). Depression in growth can be explained by the fact that, Zn is incorporated in numerous enzymes that are involved in vitamin A synthesis, CO_2 transport, protein metabolism, degradation of collagen fibrils, carbohydrate metabolism, free radical destruction, erythrocyte membrane stability, and essential fatty acid metabolism (Underwood and Suttle, 1999). In addition, Zn is essential in the formation of Zn fingers within DNA-binding protein (Berg, 1990) that influences transcription and cell replication (Chesters, 1992).

Zinc is known to play a central role in the immune system. Zinc deficiencies can lead to increased susceptibility to a variety of pathogens through damaged epidermal, gastrointestinal, and pulmonary cells (Shankar and Prasad, 1998), allowing routes of entry for pathogens. Zinc deficiencies also adversely affect other mediators of rat

nonspecific immunity, such as neutrophils, monocytes, macrophages, natural killer cell, and complement activity (Shankar and Prasad, 1998). Mice fed Zn deficient diets for 2 weeks had reduced numbers of T and B lymphocytes in peripheral blood and spleen tissues, which in turn depressed T and B cell function (Fraker et al., 1986). Additionally, even marginally Zn deficient mice had substantially suppressed peripheral blood lymphoid cell concentrations (Fraker et al., 1986).

Spears et al. (1991) reported that supplemental Zn showed a positive antibody response to bovine herpes vaccine compared to cattle not Zn supplemented. However, Hatfield et al. (2002) reported that Zn supplemented to ewes (140 mg/d) reduced the humoral response to a killed parainfluenza type 3 (PI_3) virus. Authors speculated that Zn supplemented to a diet high in Zn was antagonistic to other minerals, which are also needed for an optimal immune response. Bremner et al. (1976) reported that lambs receiving 420 mg Zn/kg diet had reduced liver Cu concentrations.

In beef feedlot research, Zn supplementation has shown inconsistent results for enhancing or having no effect on animal health (Duff and Galyean, 2007) and productivity (Spears 1989; Nunnery et al., 2008). Lambs supplemented with organic Zn-methionine had higher cellulose and ADF digestibility, improved Zn absorption, higher ADG and G:F than control or inorganic $ZnSO_4$ supplemented lambs (Garg et al., 2008). Similarly, Hatfield et al. (1992) reported improvements in lamb feedlot gains with organic Zn supplementation. Furthermore, ewes supplemented with organic forms of Zn had higher concentrations of liver Zn than inorganic forms of Zn (Hatfield et al., 2001b).

Hatfield et al. (1995) reported that late gestation and early lactation supplementation of Zn methionine increased ewe gestational DMI, d 28 milk production, and lamb weaning BW. However, Zn supplementation did not affect ewe weight change (Hatfield et al., 1995). Similarly, late gestation and early lactation Zn supplementation of range cow/calf pairs improved calf weaning BW but did not affect cow weight change (Maryland et al. 1980). Neither, experiment supplemented Zn during gestation or lactation independent of the other, so it is unclear whether Zn affected animal production was affected by pre or postpartum supplementation.

In summary, reports of Zn supplementation above recommended requirements to enhance indices of immunity and increase productivity have been inconsistent. This could be due to a lack of environmental stress required to immunologically challenge the animals or bioavailability of the source of supplemental Zn. In addition, late gestation Zn supplementation has not been proven to improve lamb production independent of early lactation Zn supplementation.

Vitamin E

Vitamin E is a collective name for a series of 8 tocopherols, which are fat-soluble vitamins known for their antioxidant properties (Burton and Ingold, 1989). Of these, α-tocopherol has the highest bioavailability. For the remainder of this paper, α-tocopherol will be referred to as vitamin E. Vitamin E becomes very important during the immune response when macrophages and neutrophils produce large quantities of superoxide and hydrogen peroxide to hydrolyze foreign organisms (Badwey and Karnovsky, 1980). Additional immune responses attributed to vitamin E included enhanced humoral

immunity via elevated immunoglobulin G (IgG), enhanced phagocytosis by polymorphonuclear cells, and enhanced cell-mediated immunity (Tengerdy, 1990).

Hatfield et al. (2002) reported serum α-tocopherol tended to be higher in vitamin E supplemented (330 IU/d) than control ewes. Similarly, Daniels et al. (2000) and Bohn et al. (1995) supplemented 400 and 300 IU/d of vitamin E to gestating ewes and measured increased serum α-tocopherol concentrations in the ewes and their lambs. Gentry et al. (1992) gave two vitamin E injections (1500 IU) to ewes and increased ewe serum, lamb serum, and colostrum α-tocopherol concentrations; however differences were only detected in one of two yr. Hatfield et al. (2001a) orally supplemented 400 IU of vitamin E to lambs after birth and increased serum α-tocopherol concentrations. Njeru et al. (1994) found that supplementation of increasing levels of vitamin E (0, 15, 30, and 60 IU) to ewes in late gestation and early lactation linearly increased lamb serum vitamin E concentrations. Njeru et al. (1994) and Bohn et al. (1995) reported that neonatal lamb serum vitamin E was not different between vitamin E treated groups; however, after colostrum consumption serum vitamin E concentrations was greater in lambs born to vitamin E treated ewes, indicating inefficient placental transfer.

Colostral and lamb serum IgG titers were increased with two 1500 IU injections of vitamin E (Gentry et al., 1992); however, Gentry et al. (1992) only reported differences in one of two yr. Daniels et al. (2000) and Bohn et al. (1995) found that d 3 postpartum lamb serum and colostrum IgG titers were not different between vitamin E supplemented (400 IU/d) and control ewes. Gentry et al. (1992) also found that lambs given an injection of vitamin E (900 IU) on the d of parturition increased d 3 serum IgG

titers. In contrast, Reffett et al. (1988) and Hatfield et al. (2001a) reported no difference in serum IgG titers of lambs given an oral vitamin E supplement (20 mg/kg diet and 400 IU, respectively).

Daniels et al. (2000) reported that anti-PI_3 titers were higher in lambs born to ewes vaccinated for PI_3 but vitamin E supplementation (400 IU/d) to the ewe had no effect on transfer of the anti-PI_3 titers to the lambs. In contrast, lambs supplemented with vitamin E responded with higher antibody titers following PI_3 challenge than did control lambs (Reffett et al., 1988; 20 mg/kg of diet). Rittacco et al. (1986) also found that lamb antibody titers to *Brucella ovis* increased with oral vitamin E supplementation of 3,000 mg/d.

Kott et al. (1998) and Thomas et al. (1995) found that oral supplementation of vitamin E to ewes during late gestation improved lamb survival. Kott et al. (1998) attributed treatment response to lamb's ability to combat the early season environmental stressors. Kott et al. (1983) gave monthly injections of vitamin E (272 IU) throughout gestation and increased lamb survival over ewes that did not receive vitamin E injections. Similarly, Ali et al. (2004) reported that weekly vitamin E injections (900 IU) during late gestation improved lamb survival from multiple birthing ewes in 1 of 2 experimental years. Oral vitamin E supplementation during late gestation has been reported to have no effect on lamb survival (Gentry et al., 1992; Daniels et al. 2000; Williamson et al., 2004; Dafoe et al. 2008). Lamb supplementation of vitamin E has also shown to have no effect on lamb survival (Gentry et al., 1992; Hatfield et al. 2001; Williamson et al., 2004). In a

review, Hatfield et al. (2000) stated that advantages of lamb survival may not be seen in conditions of low environmental and pathogenic stress.

Late gestational supplementation of ewes with vitamin E has been found to improve lamb body weight at 30 and 90 d of age (Gentry et al. 1992; two 1500 IU/injections) and ADG (Ali et al. 2004; four 900 IU/injections). Furthermore, vitamin E supplementation to young (1 and 2 yr) and old (6 and 7 yr) ewes improved lamb gains; however, vitamin E supplementation to 3 to 5 year old ewes had no effect on lamb body weight gain (Ali et al., 2004). Kott et al. (1983), Kott et al. (1998), Daniels et al. (2000), and Dafoe et al. (2008) all reported no difference in lamb gains born to ewes supplemented with vitamin E. However, these authors did not investigate the impact of vitamin E supplementation within age groups as did Ali and co-workers.

In summary, vitamin E plays a vital role in antioxidant protection and immune system modulation. Vitamin E supplementation during late gestation has the potential to improve indices of immune transfer from ewe to lamb, lamb survival, and lamb growth, given events of stress increase ewe and lamb requirements above dietary vitamin E.

Chlortetracycline

Tetracyclines were discovered in the 1940s and are a family of antibiotics that inhibit bacterial protein synthesis by preventing the attachment of aminoacyl-tRNA to the ribosomal receptor site (Chopra and Roberts, 2001). They are broad-spectrum agents that act on a wide range of gram-positive and gram-negative bacteria. The antimicrobial properties of these agents and the absence of major adverse side effects have led to their extensive use in the therapy of human and animal infections. Furthermore, tetracyclines

are added at subtherapeutic levels to animal feeds to act as growth promoters (Chopra and Roberts, 2001).

Subtheraputic levels of oral antibiotics can enhance feedlot performance in beef cattle (Hays, 1991). However, Baldwin et al. (2000) stated that the mechanism by which these compounds alter beef cattle performance has not been clearly delineated. Traditionally, the beneficial effects of chlortetracycline (CTC) were thought to occur when animals were exposed to negative environmental influences. However, Baldwin et al. (2000) reported that CTC improved metabolic status of feedlot steers by reducing the mass of metabolically active intestinal tract tissue. Chlortetracycline added to feedlot lamb rations has improved lamb ADG, feed intake, and feed efficiency (Bridges et al. 1953; Calhoun and Shelton, 1973; Ternus et al., 1971).

In swine, CTC fed during late gestation and lactation improved feed efficiency, reduced lactational weight loss, tended to improve survival rates of piglets, and improved subsequent conception rate (Maxwell et al., 1994). In addition, CTC has been recommended as a late gestational supplement to suppress pathogens that manifest during late gestation, mainly abortion causing pathogens (SID, 1996). However, to our knowledge no literature exists that has evaluated the effects of lamb production from ewes supplemented CTC during late gestation.

Ewe Status

Ewe Condition

Yearly ewe production of lamb can be quite variable and much of the variation may be attributed to age and condition of the ewe. Russel et al. (1969) developed a subjective method of assessing ewe body condition (BCS) based on the amount of tissue (lean muscle or adipose tissue) she has deposited. This value ranges from 1 to 5 in half score increments, with 1 being emaciated and 5 being obese. Al-Sabbagh et al. (1995) found that ewe prolificacy was greater for 2.5 than 3.5 BCS ewes and lambs weaned per ewe exposed were greater for 3 than 3.5 BCS ewes. However, IgG, lamb birth wt, and lamb weaning wt were not different between 2.5, 3.0, and 3.5 body conditioned ewes (Al-Sabbagh et al., 1995). In contrast, Thomas et al. (1988) showed that range ewes of 3.5 BCS had higher lamb birth weights than 2.5 BCS ewes.

Ewe Age

Across numerous breeds, Dickerson and Glimp (1975) reported that fertility, lambs born per ewe, and lambs weaned per ewe follow a curvilinear pattern. Low production was reported in yearling and 2 yr old ewes. Maximum production occurred in ewes that ranged from 4 to 7 yr of age. Thereafter, ewe production of lamb after 7 yr of age was diminished. Seven yr old ewes have been reported to have the highest lamb birth BW; however, weaning BW and lamb survival was lower in 7 yr old ewes than 3 to 6 yr old ewes (Al-Sabbagh et al., 1995). Similarly, Ali et al. (2004) reported that 6 to 7 yr old

ewes had lower lamb weaning weights and ADG from birth to weaning than 1 to 5 yr old ewe.

In summary, age and body condition affect the productivity of ewes and could affect the effectiveness of supplemental feed additive developed to improve ewe productivity. Supplemental feed additives, such as UIP, vitamin E, Zn, and CTC, have inconsistently been reported to improve ewe productivity. Therefore, research is warranted to investigate the effects of supplemental UIP, vitamin E, Zn, and CTC fed during late gestation to ewes of differing age and body condition.

CHAPTER 2

MATERIALS AND METHODS

Ewes were selected from the ewe flock at Red Bluff Research Ranch (Montana State University Agricultural Experiment Station) near Norris, Montana. Ranch elevations range from 1402 to 1889 m, and annual precipitation ranges from 35.5 to 43.1 cm (Harris et al., 1989). Vegetation is a typical foothill bunchgrass type. Bluebunch wheatgrass (Agropyron spicatum) and Idaho fescue (Festuca idahoensis) are the major grasses. Rubber rabbitbrush (Chrysothamnus nauseosus), fringed sagewort (Artemisia frigida), lupine (Lupinus spp.), milkvetch (Astragalus spp.) and western yarrow (Achillea millefolium) are commonly occurring shrubs and forbs (Harris et al., 1989).

Ewe breeds consisted of Rambouillet, Targhee, and Columbia. In 2006 and 2007, ewes were single sire mated from mid-November to mid-December followed by group mating to black faced rams (Suffolk/Hampshire) from mid-December 6 to late-December. After breeding, ewes were herded on the native rangelands. While grazing native range, ewes received 0.15 $kg \cdot ewe^{-1} \cdot d^{-1}$ of a range protein supplement (14% CP). Ewes were sheared one month before anticipated lambing. After shearing, ewes were group fed a target intake of 1 $kg \cdot ewe^{-1} \cdot d^{-1}$ of long stem alfalfa hay and 1 $kg \cdot ewe^{-1} \cdot d^{-1}$ of long stem barley hay (Table 2.1). After shearing, ewes received a Clostridium perfringens type C & D vaccine (Bar-Vac CDT; Boehringer Ingelheim Vetmedica, Inc. St. Joseph, MO) and treated for internal (Valbazen; Phizer Animal Health, Exton, PA)

and external parasites (Permectrin; Boehringer Ingelheim Vetmedica, Inc. St. Joseph, MO).

Ewes were observed 24 h per d during lambing season. When ewes were observed to be in labor, they were monitored until parturition. Immediately after birth, ewes and lambs were placed in jugs (1.5 m^2) for 12-36 h to allow maternal bonding. Within three hours of birth, lamb sex and birth weight were recorded. Lamb umbilical cords were clipped and dipped in iodine. At 24-36 h post parturition lambs were ear tagged and tail docked. Columbia and black-faced sire rams lambs were castrated. Ewe and lamb(s) were moved to single and twin mixing pens, respectively, at 12 to 36 h of age. For one wk ($\pm$ 2 d), ewes and lambs remained in mixing pens with ad libitum access to bunk fed long stem alfalfa hay (Table 2.1) and water. After 7 d in mixing pens, ewe and lambs were moved to larger paddocks and fed alfalfa hay (Table 2.1) ad libitum until late-May. On May 23rd and 20th in 2007 and 2008, respectively, all ewes and lambs were moved out of lambing paddocks and herded as one contiguous flock on native range, this date was referred to as turnout. On August 23rd and 28th, 2007 and 2008, respectively, all lambs were weaned.

Treatments

Isocaloric (64% TDN) and isonitrogenous (25% CP) pelleted supplements were fed to ewes at 454 g every other day. The **HIGH** supplement treatment contained 12.5% UIP, 880 IU/kg of supplemental vitamin E, 176 ppm chelated Zn (Availa-Zn 100; Zinpro, Eden Prairie, MN), and 352 mg/kg chlortetracycline (Aureomycin; Alpharma,

Bridgewater, NJ). The **LOW** supplement treatment contained 7.56% UIP, no supplemental vitamin E, no chelated Zn, and no chlortetracycline (Table 2.1). In 2007 and 2008, supplements were fed from until individual lambing events.

Table 2.1. Chemical composition of long stem hays and supplements fed to ewes during late gestation.

	Hay[1]			Supplements[2]	
	Grass	Alfalfa	Barley	HIGH	LOW
DM, %	87.7	87.34	85.6	90.1	90.0
CP, %	9.39	14.7	13.9	25.0	25.0
UIP, %				12.5	7.56
ADF, %	37.6	37.5	33.2	7.45	12.21
TDN, %	59.7	58.2	64.7	64.0	64.4
Sulfur, %	0.14	0.27	0.17	0.42	0.52
Phosphorus, %	0.22	0.21	0.22	0.75	0.75
Potassium, %	1.97	2.61	2	0.84	1.1
Magnesium, %	0.22	0.27	0.14	0.24	0.36
Calcium, %	0.68	1.45	0.42	1.50	1.49
Sodium, %	0.01	0.06	0.15	0.91	0.91
Iron, ppm	84.	417	71	130	136
Manganese, ppm	58	40	34	158	150
Copper, ppm	6	20	5	10	8
Zinc, ppm	12	13	17	343	166
Selenium, ppm				0.3	0.3
Vitamin E, additional IU/kg				880	0
Chlortetracycline, mg/kg	0	0	0	352	0

[1] Chemical analysis conducted by Midwest Laboratory Inc. (Omaha, NE).
[2] Ewes were fed supplemental treatments at 0.227 $kg \cdot ewe^{-1} \cdot d^{-1}$ for at a least 30 d prior to lambing in Experiment 1, 2, & 3.

Experiment 1

Fifty two Targhee ewes were moved March 8, 2007 (2 days prior to initiation of 29 d of supplement treatment) from the range flock at Montana State University's Red Bluff Research Ranch (latitude 45˚35' N, longitude 111˚38' W, altitude 1450 m) to the Montana State University Fort Ellis Research Farm (latitude 45˚ 38' N, longitude 110˚ 58' W, altitude 1505 m). Ewes were housed in a 3721 m^2 pen with ad libitum access to

long stemmed grass hay (Table 2.1) and water. March 9, 2007 ewes were held off feed and water for 12 h to obtain a shrunk weight. Body condition scores (BCS; Russel et al, 1969) were assigned to each ewe by an experienced technician. Ewes were drenched with an anthelmintic (Valbazen; Pfizer Animal Health, Exton, PA) prior to initiating treatment.

Fifty two ewes were assigned randomly to a 2 X 2 factorial arrangement of treatments. Ewes were assigned to either the HIGH or LOW supplemental treatments. Additionally, half were selected from the **6 yr old** Targhee population and half were selected from the **3 yr old** Targhee population of ewes managed at the Red Bluff Research Ranch. Treatment combinations were 1) High 6 yr old, 2) High 3 yr old, 3) Low 6 yr old, and 4) Low 3 yr old with 13 ewes/treatment. The 3 yr old ewe BCS average was 2.3 with a mediam value of 2.0 and ranged from 1.5 to 2.5. The 6 yr old ewe BCS average was 2.1 with a median value of 2.0 and ranged from 1.5 to 3. For 29 days ewes were individually supplemented (March 10 to April 7 2007) in pens (1.5 m^2) every other day at 454 g/ewe. April 9, 2007 ewe 12 h shrunk BWs were obtained and then ewes were returned to Red Bluff approximately 5 d before anticipated lambing date. Ewes were group fed their respective supplement throughout lambing. Upon parturition each ewe was removed from the lambing drop lot and removed from supplemental treatment.

Data Collection

Ewe/Lamb Production Data

Lamb BW was recorded at birth, turnout (May 23, 2007, 32 ± 6 d of age; May 20, 2008, 27 ± 6 d of age), and weaning (August 23, 2007, 117 ± 6 d of age; August 28, 2008, 127 ± 6 d of age). Ewe BW and BCS was recorded at turnout and weaning. Ewe performance was calculated as kilograms of lambs/ewe. Lambs that died were included in the analysis as 0 kg BW.

Parainfluenza Type 3 (Experiment 1 & 2)

In Experiment 1 and 2, ewes were bled via jugular puncture using red topped vaccutainers, and treated with an intranasal injection of bovine rhinotracheitis-parainfluenza$_3$ vaccine (PI_3; Pfizer Animal Health, NY, NY) 2 d prior to initiation of supplement treatment (March 8, 2007). On March 22, 2007 an additional intranasal treatment of PI_3 was administered. Following the individual feeding period, ewes were again bled via jugular puncture with red topped vaccutainers. Three d post lambing, lambs were bled via jugular puncture using red topped vaccutainer. Blood samples were centrifuged for 20 min at 1000 x g. Serum was decanted into 10 mL plastic tubes and stored at -20ºC. Lamb serum was analyzed for anti-PI_3 titers at the Montana Veterinary Diagnostic Laboratory by the hema-absorption method using an end point titer assay as described by Daniels et al. (2000) modified for a 96 well plate. Dilutions at 1:4 were made by adding 0.1 mL of serum to 0.3 mL of Eagle's MEM. These dilutions were incubated for 30 min at 56ºC in a water bath. After removing from the water bath, a

small amount of Kaolin was added to each sample. Samples were well shaken, left standing for 10 min at room temperature, and then slowly centrifuged @ 1500 rpm for 15 min. Dilutions of 1:8 through 1:512 were made by serially diluting 0.025 mL of each sample and adding 0.025 of Eagle's MEM to a 96 well U-bottom plate. This was repeated until all dilutions were completed and the last 0.025 mL of sample was discarded. Virus stock was prepared by serially diluting 0.05 mL of virus with 0.05 mL of PBS, similar to sera dilutions. Next, 0.025 mL PI_3 stock virus at dilution previously described were added to respective test well. Wells were gently mixed and left standing at room temperature for 1 h. Washed red blood cells were added at 0.05 mL per well. Tubes were covered with plastic wrap and refrigerated overnight. Samples were observed for hema-absorption. The last dilution of cultured PI_3 virus giving visible positive hema-absorption was recorded as the end point titer. A greater dilution giving positive hema-absorption equates to a greater amount of anti-PI_3 antibody in the sample.

This method of vaccine administration and serum anti-PI_3 titer analysis is similar to Reffett et al. (1988). Although the vaccine mainly stimulates mucosal immunity, it also stimulates a humoral response. This vaccine was used because PI_3 titers are not common in sheep and assays were available for the specific titer.

Intake (Experiment 1 & 2)

On March 14, 2007, chromic oxide boli (Sheep Chrome; Captec; Armidale, New South Wales, Australia) were administered to ewes. Five d were allowed for the release rate of the chromic oxide bolus to equalize. Fecal collections were then taken every other d for 6 d. Fecal samples were frozen at -20ºC for later analysis.

After thawing, fecal samples were composited over time by ewe and dried at 60 º C for 24 h. Fecal samples were then ground through a 1-mm screen in a Wiley mill. Dry matter was then determined on fecal samples following a 12 h drying at 100 º C.

Fecal samples were then prepared for chromium analysis using a modified version of the method described by Williams et al. (1962). Duplicate fecal 1.0 g samples were ashed in a silica basin for 90 min at 600º C. Samples were digested in 3 mL of phosphoric acid-manganese sulfate solution and 4.5% (wt/vol) potassium bromate solution until effervescence ceased or a light purple color appeared. Samples were brought to volume in a 100 mL volumetric flask with deionized water and mixed thoroughly. Chromium concentration was determined by atomic absorption spectroscopy using air/acetylene flame. Daily fecal output (FO) was estimated by dividing the concentration of fecal chromium into the quantity of chromium released daily from the bolus (0.195 g Cr_2O_3 / day; supplied by manufacturer).

Grass hay and supplement samples (Table 2.1) were ground through a 1-mm screen in a Wiley mill. Dry matter was then determined on feed samples following a 12 h deehydration at 100 º C. Hay, supplement, and fecal samples were analyzed for indigestible acid detergent fiber (IADF) using the procedure described by Bohnert et al. (2002). Duplicate samples (0.5 g) of hay, supplement, and feces were weighed into Ankom filter bags (F57; Ankom Co., Fairport, NY). Samples were then incubated for 96 h in the rumen of a cannulated cow consuming low-quality forage ad libitum. The sample bags were then removed from the rumen, rinsed with warm (39°C) tap water until the rinse water was clear, and analyzed for ADF as described by (Goering and Van Soest,

1970) using procedures modified for use in an Ankom 200 Fiber Analyzer (Ankom Co., Fairport, NY). Ewe dry matter digestibility was calculated by the dividing the IADF fraction of the hay by the IADF fraction of the feces. Hay intake was estimated by dividing FO by dry matter digestibility.

Fecal output = daily chromium release rate / fecal chromium %

Dry matter digestibility = (IADF of hay / IADF of feces)

Hay intake = fecal output / dry matter digestibility

Milk Collection and Analysis (Experiment 1 & 2)

Within two hours of birth, colostrum samples were taken from ewes, placed in a 100 mL container, and frozen for later analysis. Three and 10 d post lambing, ewes and lambs were separated for a two hour period. At the beginning and end of this period, ewes were hand milked following an intravenous injection of oxytocin (20 USP units of oxytocin principle). Milk volume was recorded from the second milking and a milk sample was collected in a 100 mL container and frozen for later analysis. Milk protein, fat, lactose, total solids, and nonfat solids were determined by infrared (MilkoScan FT120, Foss America, Eden Prairie, MN) analysis at the FDA-certified Montana Livestock Diagnostic Laboratory in Bozeman, MT. Somatic cell count (SCC) was determined in the same lab on a Soma-Scope MKII counter (Delta Instruments, Norwood, MA). Colostral immunoglobulin G concentration was measured by radioimmunoassay at the New Mexico State University Endocrinology Lab in Las Cruces, NM as described by Richards et al. (1999).

Experiment 2

Forty Targhee and Rambouillet ewes were assigned randomly to a 2 X 2 factorial arrangement of treatments. Ewes were assigned to either the HIGH or LOW supplemental treatments. Additionally, half were selected from the **GOOD** BCS population of ewes and half were randomly selected from the **POOR** BCS population of ewes. Treatment combinations were 1) High GOOD, 2) High POOR, 3) Low GOOD, and 4) Low POOR with 10 ewes/treatment. The GOOD conditioned ewes averaged 3.0 BCS with a median score of 3.0 and ranged from 2.5 to 3.5. The POOR conditioned ewes averaged 1.7 BCS with a median score of 2.0 and ranged from 1.5 to 2. Supplementation and data were collected the same as in experiment 1.

Experiment 3

Ewes (606 and 657 ewes in 2007 and 2008, respectively) at the Red Bluff Research Ranch were randomly divided into two groups and assigned to either the HIGH or LOW supplemental treatment. In 2007 and 2008, ewes were group fed supplemental treatments from March 10th throughout lambing. Upon parturition each ewe was removed from the lambing drop lot and removed from supplemental treatment. Only production data was collected from ewes in experiment 3.

Statistical Analysis

In experiment 1 & 2, ewe was the experimental unit. In experiment 3, pen was the experimental unit. Experiment 1 & 2 model included effects of supplement, age

(experiment 1) or condition (experiment 2), and treatment X age/condition. End point PI_3 titer dilutions were transformed with a log base 10 transformation. Data were analyzed using PROC GLM procedures of SAS (SAS Inst. Inc., Cary, NC) and are presented as least squares means with differences considered significant at $P < 0.10$. Birthday was added as a covariate for lamb turnout and weaning BW to account for differences in age of lamb.

CHAPTER 3

RESULTS

Experiment 1

Ewe Intake and Digestion

No supplement by age interactions were detected ($P > 0.33$) for DMD, DMI, and DMI as a percent of ewe initial BW (Table 3.1). Dry matter intake and DMD did not differ ($P > 0.13$) between ewes consuming the HIGH and LOW supplements. Three year old ewes had greater ($P < 0.01$) ewe DMI and DMI as a percent of ewe BW than six year old ewes.

Table 3.1. Least square means of fecal output, DMD, and DMI of 3 and 6 yr old ewes fed 227 g·ewe^{-1}·d^{-1} of either a HIGH or LOW supplement the last 30 d of gestation in experiment 1[1,2]

	Treatments							
	3 yr old		6 yr old			S x A[4]	3 vs 6 yr old	HIGH vs LOW
	HIGH	LOW	HIGH	LOW	SEM[3]	*P*-value	*P*-value	*P*-value
Fecal output, kg	0.89	1.00	0.87	0.90	0.06	0.58	0.29	0.29
DMD, %	46.5[a]	45.9[a]	40.8[b]	38.2[c]	1.05	0.33	<0.01	0.13
DMI, kg	1.65[a]	1.82[a]	1.43[b]	1.41[b]	0.11	0.41	<0.01	0.51
DMI:BW[5], %	2.58[a]	2.84[a]	2.07[b]	2.07[b]	0.16	0.40	<0.01	0.41

[a,b]Within row, means without a common superscript differ, $P < 0.10$
[1]HIGH = 12.5% UIP, 880 IU/kg supplemental vitamin E, 176 mg/kg chelated-Zn, and 352 mg/kg chlortetracycline.
[2]LOW = 7.56% UIP, no supplemental vitamin E, no chelated Zn, and no chlortetracycline.
[3]n=50
[4]S x A = Interaction between type of supplement (S) and age of ewe (A).
[5]DMI:BW = DMI divided by ewe initial BW

Immunological Data

No effects of age, supplement, or age x supplement were detected for colostrum IgG or ewe anti-PI_3 titer concentrations ($P > 0.15$; Table 3.2). However, an age x

supplement interaction ($P < 0.01$) was detected for lamb anti-PI_3 titers. Lambs born to 3 yr old ewes on HIGH supplement and 6 yr old ewes on LOW supplement had greater ($P < 0.05$) anti-PI_3 antibody titers than lambs born to 3 yr old ewes on LOW supplement and 6 yr old ewes on the HIGH supplement. Lamb anti-PI_3 titers from 6 yr old ewes on HIGH supplement was not different ($P > 0.16$) from all other treatments.

Table 3.2. Least square means of log based 10 transformations of ewe pre-lambing and d 3 postpartum lamb serum anti-parainfluenza type 3 (PI_3) titer dilutions, and colostral IgG concentrations taken from 3 and 6 yr old ewes fed 227 $g \cdot ewe^{-1} \cdot d^{-1}$ of either a HIGH or LOW supplement the last 30 d of gestation in experiment 1[1,2]

	Treatments							
	3 yr old		6 yr old			S x A[4]	3 vs 6 yr old	HIGH vs LOW
	HIGH	LOW	HIGH	LOW	SEM[3]	*P*-value	*P*-value	*P*-value
Ewe serum anti-PI_3 titers[5]	0.95	0.76	0.67	0.76	0.14	0.34	0.34	0.75
Lamb serum anti-PI_3 titers[5]	1.25[a]	0.87[b]	1.07[ab]	1.29[a]	0.11	<0.01		
IgG, mg/mL	54.1	56.8	45.9	50.8	5.49	0.83	0.15	0.43

[a,b]Within row, means without a common superscript differ, $P < 0.10$
[1] HIGH = 12.5% UIP, 880 IU/kg supplemental vitamin E, 176 mg/kg chelated Zn, and 352 mg/kg chlortetracycline
[2] LOW = 7.56% UIP, no supplemental vitamin E, no chelated Zn, and no chlortetracycline
[3]n=35
[4]S x A = Interaction between type of supplement (S) and age of ewe (A)
[5]Analyzed using end point titer assay. The last culture PI_3 virus to medium dilution giving visible positive hema-absorption was recorded as the end point titer. A greater dilution giving positive hema-absoprtion equates to a greater amount of anti-PI_3 antibody in the sample.

Milk Production and Composition

On d 3, supplement x age interactions were not detected ($P > 0.15$; Table 3.3) for two hour milk production, milk fat concentrations, milk lactose concentrations, milk total solids concentration, and somatic cell counts. In addition, ewe age and type of supplement did not affect ($P > 0.11$) these variables.

Supplement x age interactions were detected ($P < 0.07$) for milk protein concentrations and milk non-fat solid concentrations. Milk concentrations of protein and non-fat solids were greater ($P < 0.10$) in 6 yr old ewes fed the LOW supplement than all other treatments. Age and supplement treatments had no effect ($P > 0.11$) on two hour milk production, milk fat concentration, milk lactose concentration, milk total solid concentrations, and somatic cell counts (Table 3.3).

On d 10, a supplement x age interaction was detected (P = 0.06) for concentrations of milk solid non-fat (Table 3.3). Interactions were not detected ($P > 0.14$) for any of the other milk variables. Six yr old ewes on the LOW supplement had greater ($P < 0.01$) solid non-fat concentrations than 3 yr old HIGH and LOW supplemented ewes. Six year old ewes on the HIGH supplement had greater ($P = 0.04$) solid non-fat concentrations than 3 yr old ewes on the LOW supplement. Ewes supplemented the LOW supplement had greater ($P = 0.07$) two hour milk production than ewes fed the HIGH supplement. Three yr old ewes had greater ($P = 0.02$) milk protein concentrations than the six yr old ewes. Day 10 milk fat, lactose, solids, and somatic cells were similar ($P > 0.23$) for age and supplemental treatments.

Supplement x age interactions were not detected (P > 0.16) for change in milk production, milk profile, and somatic cell counts from d 3 to 10 (Table 3.3). Supplement and age treatment differences were also not detected (P > 0.20) for milk production, milk profile, and somatic cell counts.

Table 3.3. Least square means of milk volume and composition from 3 and 6 year old ewes fed 227 g·ewe^{-1}·d^{-1} of either a HIGH or LOW supplement the last 30 d of gestation in experiment 1[1,2]

	Treatments							
	3 yr old		6 yr old			S x A[4]	3 vs 6 yr old	HIGH vs LOW
d 3	HIGH	LOW	HIGH	LOW	SEM[3]	*P*-value	*P*-value	*P*-value
2 hr milk production, mL	190	210	174	230	26.2	0.48	0.95	0.14
Fat, %	11.5[a]	9.85[b]	11.6[a]	11.0[ab]	0.71	0.43	0.36	0.12
Protein, %	5.55[a]	5.31[a]	5.61[a]	6.07[b]	0.19	0.07		
Lactose, %	4.29	4.24	4.25	4.34	0.09	0.45	0.76	0.81
Total solids, %	22.5[a]	20.6[b]	22.6[a]	22.6[a]	0.68	0.15	0.11	0.14
Solids non-fat, %	10.9[a]	10.6[a]	10.9[a]	11.4[b]	0.18	0.03		
SSC[5]	5.25[a]	5.34[ab]	5.74[b]	5.41[ab]	0.18	0.24	0.16	0.49
d 10								
2 hr milk production, mL	155[a]	191[ab]	165[ab]	217[b]	25.5	0.73	0.47	0.07
Fat, %	9.78	9.13	10.3	10.1	0.75	0.80	0.31	0.52
Protein, %	5.03[a]	4.84[a]	5.15[ab]	5.34[b]	0.13	0.14	0.02	0.98
Lactose, %	4.63	4.72	4.72	4.70	0.09	0.57	0.72	0.73
Total solids, %	20.7	19.9	21.0	21.3	0.75	0.45	0.23	0.74
Solids non-fat, %	10.8[ac]	10.7[a]	10.9[bc]	11.2[b]	0.09	0.06		
SSC[5]	5.23	5.19	5.57	5.37	0.19	0.73	0.17	0.49
d 3 – 10								
2 hr milk production, mL	34.6	28.3	39.4	13.5	26.3	0.70	0.84	0.52
Fat, %	1.70	0.73	1.66	0.99	0.85	0.85	0.88	0.30
Protein, %	0.51	0.47	0.43	0.72	0.22	0.41	0.68	0.54
Lactose, %	-0.35	-0.47	-0.47	-0.36	0.15	0.41	0.96	0.95
Total solids, %	1.85	0.69	2.08	1.31	0.80	0.79	0.58	0.20
Solids non-fat, %	0.17	-0.06	-0.06	0.29	0.19	0.16	0.65	0.63
SSC[5]	0.00	0.15	0.03	0.04	0.22	0.72	0.82	0.69

[a,b] Within row, means without a common superscript differ, $P < 0.10$

[1]HIGH = 12.5% UIP, 880 IU/kg supplemental vitamin E, 176 mg/kg chelated Zn, and 352 mg/kg chlortetracycline.

[2]LOW = 7.56% UIP, no supplemental vitamin E, no chelated Zn, and no chlortetracycline

[3]n=43

[4]S x A = Interaction between type of supplement (S) and age of ewe (A)

[5]SSC = log transformation of somatic cell counts

Ewe Weight and BCS

Supplement x age interactions were not detected ($P > 0.26$) for any of the ewe BW or BCS variables. Initial shrunk BW was greater ($P < 0.01$) for 6 yr old than 3 yr old ewes (Table 3.4). However, HIGH supplemented ewes lost more BW ($P = 0.07$) than LOW supplemented ewes from supplementation to turnout. No differences ($P > 0.14$) were detected in ewe BW change from supplementation to weaning.

Initial body condition scores (BCS) did not differ ($P > 0.44$) among treatments at the start of the experiment (3.4). No differences ($P > 0.18$) were measured for BCS change after the individual supplementation period. Body condition scores did not differ ($P > 0.26$) between the HIGH and LOW supplemented ewes at turn out. However, 3 yr old ewes lost more BCS ($P = 0.08$) than 6 yr old ewes at turn out. No differences ($P > 0.11$) in ewe BCS change were detected among treatments at weaning. However, there was a tendency ($P = 0.11$) for 3 yr old ewes to gain BCS while 6 yr old ewes maintained or lost a slight amount of condition.

Table 3.4. Least square means of 3 and 6 yr old ewe BW and BCS changes when fed 227 g·ewe^{-1}·d^{-1} of either a HIGH or LOW supplement the last 30 d gestation in experiment 1[1,2]

	Treatments							
	3 yr old		6 yr old			S x A[5]	3 vs 6 yr old	HIGH vs LOW
Dates[3]	HIGH	LOW	HIGH	LOW	SEM[4]	*P*-value	*P*-value	*P*-value
Initial weight:	64.7[a]	64.3[a]	70.2[b]	70.3[b]	1.86	0.89	<0.01	0.96
	Ewe weight change, kg							
Pre-lambing	2.44	1.94	1.55	2.86	1.01	0.34	0.99	0.67
Turnout	-7.64[a]	-5.61[ab]	-6.12[ab]	-4.03[b]	1.21	0.98	0.16	0.07
Weaning	-3.80[a]	0.41[b]	-3.17[ab]	-2.07[ab]	1.92	0.38	0.60	0.14
Initial BCS	2.27	2.32	2.17	2.2	0.12	0.87	0.44	0.55
	Ewe BCS change[6]							
Pre-lambing	-0.15	-0.14	0.00	0.05	0.13	0.90	0.18	0.79
Turnout	-0.19[a]	-0.09[ab]	0.21[b]	0.00[ab]	0.15	0.26	0.08	0.70
Weaning	0.12[ab]	0.3[a]	-0.08[b]	0.00[ab]	0.17	0.74	0.11	0.39

[a,b] Within row, means without a common superscript differ, $P < 0.10$

[1]HIGH = 12.5% UIP, 880 IU/kg supplemental vitamin E, 176 mg/kg chelated Zn, and 352 mg/kg chlortetracycline.

[2]LOW = 7.56% UIP, no supplemental vitamin E, no chelated Zn, and no chlortetracycline.

[3]Initial, pre-lambing, turnout, and weaning ewe BW and BCS were taken -44, -9, 32, and 117 d, respectively, relative to average lambing (April 22, 2007)

[4]n=46

[5]S x A = Interaction between type of supplement (S) and age of ewe (A).

[6]Ewe BCS was evaluated by trained technician (1=emaciated; 5= obese)

Lamb Production

No supplement X age or age effects were detected ($P > 0.18$) for lamb birth, turnout, or weaning weight of single or twin bearing ewes (Table 3.5). Birth weight of single lambs born to LOW supplemented ewes was greater ($P = 0.10$) than single lambs born to HIGH supplemented ewes. In contrast birth weight of twin lambs born to HIGH supplemented ewes was greater ($P = 0.07$) than birth weight of twin lambs born to LOW supplemented ewes. No supplement or age differences were detected ($P > 0.26$) for turn out or weaning weights of lambs born to single or twin bearing ewes.

Table 3.5. Least square means of lamb BW born to 3 and 6 yr old ewes fed 227 g·ewe^{-1}·d^{-1} of either a HIGH or LOW supplement during the last 30 d of gestation in experiment 1[1,2]

	Treatments							
	3 yr old		6 yr old			S x A[5]	3 vs 6 yr old	HIGH vs LOW
Dates[3]	HIGH	LOW	HIGH	LOW	SEM[4]	*P*-value	*P*-value	*P*-value
Single-born								
Birth BW, kg	5.40	5.76	5.40	6.17	0.35	0.50	0.51	0.10
Turnout BW, kg	15.2	14.7	13.5	13.5	1.50	0.84	0.31	0.86
Weaning BW, kg	31.7	31.7	31.2	32.5	4.76	0.86	0.99	0.87
Twin-born								
Birth BW, kg	9.43	8.53	9.71	8.89	0.53	0.93	0.42	0.07
Turnout BW, kg	19.5	18.5	17.9	22.7	2.90	0.18	0.58	0.44
Weaning BW, kg	43.9	48.8	34.3	54.0	12.7	0.42	0.82	0.26

[1]HIGH = 12.5% UIP, 880 IU/kg supplemental vitamin E, 176 mg/kg chelated Zn, and 352 mg/kg chlortetracycline
[2]LOW = 7.56% UIP, no supplemental vitamin E, no chelated Zn, and no chlortetracycline
[3]Birth BW were taken within 12 h of birth. Turnout and weaning BW were taken 32 and 117 d relative to average lambing (April 22, 2007).
[4]n=29 for single-born lambs and n=16 for twin-born lambs
[5]S x A = Interaction between type of supplement (S) and age of ewe (A)

Experiment 2

Ewe Intake and Digestion

No BCS, supplement type, or supplement x condition interactions were detected ($P > 0.11$) for ewe intake or DMD of grass hay. Dry matter intake as a percent of initial BW was not different (P > 0.68) among treatments. There was a tendency ($P = 0.11$) for GOOD condition ewes to have greater DMD coefficients than POOR condition ewes (Table 3.6).

Table 3.6. Least square means of fecal output, DMD, and DMI of GOOD and POOR BCS ewes fed 227 g·ewe^{-1}·d^{-1} of either a HIGH or LOW supplement the last 30 d of gestation in experiment 2[1,2,3,4]

	Treatments							
	GOOD		POOR			S x C[6]	GOOD vs POOR	HIGH vs LOW
	HIGH	LOW	HIGH	LOW	SEM[5]	*P*-value	*P*-value	*P*-value
Fecal Output, kg	0.87	0.86	0.82	0.89	0.08	0.53	0.88	0.53
DMD, %	46.4	45.1	43.8	43.6	1.32	0.67	0.11	0.54
DMI, kg	1.60	1.53	1.42	1.53	0.13	0.47	0.47	0.85
DMI:BW[7], %	2.37	2.36	2.32	2.47	0.19	0.68	0.87	0.70

[a,b] Within row, means without a common superscript letter differ, $P < 0.10$

[1] GOOD = average body condition score = 3; range of 2.5 to 3.5

[2] POOR = average body condition score = 1.7; range of 1.5 to 2

[3] HIGH = 12.5% UIP, 880 IU/kg supplemental vitamin E, 176 ppm chelated Zn, and 352 mg/kg chlortetracycline.

[4] LOW = 7.56% UIP, no supplemental vitamin E, no chelated Zn, and no chlortetracycline.

[5] n=36

[6] S X C = Interaction between type of supplement (S) and condition of ewe (C).

[7] DMI:BW = DMI divided by initial ewe BW

Immunological Data

No BCS, supplement type, or supplement x condition interactions were detected ($P > 0.31$) for colostrum IgG concentrations (Table 3.7). In addition, ewe and lamb anti-PI_3 titers did not differ ($P > 0.31$) among treatments.

Table 3.7. Least square means of log based 10 transformations of ewe pre-lambing and d 3 postpartum lamb serum anti-parainfluenza type 3 (PI_3) titer dilutions and IgG concentrations taken from GOOD and POOR BCS ewes fed 227 $g \cdot ewe^{-1} \cdot d^{-1}$ of either a HIGH or LOW supplement the last 30 d of gestation in experiment 2[1,2,3,4]

	Treatments							
	GOOD		POOR			S x C[6]	GOOD vs POOR	HIGH vs LOW
	HIGH	LOW	HIGH	LOW	SEM[5]	*P*-value	*P*-value	*P*-value
Ewe serum anti-PI_3 titers[7]	1.00	0.76	0.71	0.87	0.18	0.26	0.57	0.81
Lamb serum anti-PI_3 titers[7]	1.28	0.94	0.93	1.01	0.23	0.31	0.51	0.54
IgG, mg/mL	57.7	53.3	59.6	54.6	5.63	0.95	0.78	0.41

[1]GOOD = average body condition score = 3; range of 2.5 to 3.5
[2]POOR = average body condition score = 1.7; range of 1.5 to 2
[3]HIGH = 12.5% UIP, 880 IU/kg supplemental vitamin E, 176 mg/kg chelated Zn, and 352 mg/kg chlortetracycline
[4]LOW = 7.56% UIP, no supplemental vitamin E, no chelated Zn, and no chlortetracycline
[5]n=25
[6]S X C = Interaction between type of supplement (S) and condition of ewe (C)
[7]Analyzed using end point titer assay. The last culture PI_3 virus to medium dilution giving visible positive hema-absorption was recorded as the end point titer. A greater dilution giving positive hema-absoprtion equates to a greater amount of anti-PI_3 antibody in the sample.

Milk Production

On d 3, supplement X condition interactions were not detected ($P > 0.12$) for two hour milk production, concentration of milk fat, protein, lactose, total solids, and solids non-fat (Table 3.8). Concentration of milk fat and lactose was greater ($P < 0.10$) in GOOD than POOR conditioned ewes. Ewes on the HIGH supplement had less (P = 0.03) somatic cell counts than did LOW supplemented ewes.

On d 10, supplement x condition interactions were detected ($P < 0.06$) for concentrations of milk protein and solids non-fat (Table 3.8). Supplement x condition interactions were not detected (P > 0.039) for d 10 two hour milk production or milk concentrations of fat, lactose, total solids, or somatic cells. Ewes in GOOD condition on

the HIGH supplement had greater (P < 0.07) milk protein and solids non-fat concentrations than ewes in GOOD condition on the LOW supplement. Protein and solids non-fat concentrations did not differ (P > 0.13) between HIGH and LOW ewes in POOR condition. Ewes in GOOD condition had greater (P = 0.02) two hour milk production than ewes in POOR condition.

Supplement x condition interactions were not detected (*P* > 0.22) for d 3 to 10 change in two hour milk production, concentration of milk fat, protein, lactose, total solids, and solids non-fat (Table 3.8). Change in somatic cell count from d 3 to 10 was lower (P = 0.06) in HIGH than LOW supplemented ewes. All other supplement and condition treatment effects were similar (P > 0.24) for milk production and milk profile.

Table 3.8. Least square means of milk volume and composition from GOOD and POOR conditioned ewes fed 227 g·ewe^{-1}·d^{-1} of either a HIGH or LOW supplement the last 30 d gestation in experiment 2[1,2,3,4]

	Treatments							
	GOOD		POOR			S x A[6]	GOOD vs POOR	HIGH vs LOW
d 3	HIGH	LOW	HIGH	LOW	SEM[5]	*P*-value	*P*-value	*P*-value
2 hr milk production, mL	163	182	194	158	30.0	0.31	0.90	0.75
Fat, %	11.1[ab]	11.8[a]	9.34[b]	10.5[ab]	0.96	0.79	0.10	0.28
Protein, %	5.88	4.99	5.56	6.05	0.51	0.15	0.42	0.67
Lactose, %	4.55[a]	4.47[a]	4.39[ab]	4.23[b]	0.10	0.66	0.04	0.21
Total solids, %	22.6	22.4	20.5	22.0	1.25	0.46	0.28	0.53
Solids non-fat, %	11.4[a]	10.5[b]	11.1[ab]	11.4[ab]	0.41	0.12	0.44	0.48
SSC[5]	5.02[a]	5.27[b]	5.14[ab]	5.53[b]	0.16	0.62	0.20	0.03
d 10								
2 hr milk production, mL	166[a]	168[a]	108[b]	134[ab]	18.9	0.51	0.02	0.41
Fat, %	9.38	10.5	10.7	9.48	1.56	0.41	0.90	0.95
Protein, %	5.15[a]	4.48[b]	4.64[ab]	4.93[ab]	0.27	0.06		
Lactose, %	4.77	4.72	4.29	4.75	0.32	0.39	0.44	0.48
Total solids, %	20.43	20.9	21.2	20.4	1.46	0.61	0.91	0.89
Solids non-fat, %	10.9[a]	10.4[b]	10.5[ab]	10.8[ab]	0.26	0.05		
SSC[7]	6.19	2.94	6.09	2.26	3.41	0.50	0.88	0.63
d 3 – 10								
2 hr milk production, mL	18.6[a]	23.8[ab]	86.9[b]	22.5[ab]	30.4	0.22	0.24	0.30
Fat, %	1.67	1.32	-1.39	0.76	1.94	0.45	0.28	0.59
Protein, %	0.73	0.51	0.93	1.03	0.61	0.76	0.49	0.91
Lactose, %	-0.22	-0.25	0.10	-0.44	0.34	0.38	0.82	0.33
Total solids, %	2.15	1.51	-0.74	1.35	2.11	0.45	0.40	0.68
Solids non-fat, %	0.43	0.15	0.62	0.56	0.52	0.81	0.51	0.70
SSC[7]	-0.41[a]	0.05[b]	-0.15[ab]	0.15[b]	0.26	0.66	0.35	0.06

[a,b] Within row, means without a common superscript differ, $P < 0.10$

[1]GOOD = average body condition score = 3; range of 2.5 to 3.5

[2]POOR = average body condition score = 1.7; range of 1.5 to 2

[3]HIGH = 12.5% UIP, 880 IU/kg supplemental vitamin E, 176 mg/kg chelated Zn, and 352 mg/kg chlortetracycline

[4]LOW = 7.56% UIP, no supplemental vitamin E, no chelated Zn, and no chlortetracycline

[5]n=31

[6]S X C = Interaction between type of supplement (S) and condition of ewe (C)

[7]S x A = Interaction between type of supplement (S) and age of ewe (A)

Ewe Weight and BCS

Initial shrunk BW was greater ($P = 0.06$) for GOOD than POOR ewes (Table 3.9). No condition, supplement, or condition X supplement differences were detected ($P > 0.38$) for ewe weight change during the individual supplementation period. No differences were detected ($P > 0.18$) among treatment in ewe weight change from start of supplementation to turn out. No differences ($P > 0.63$) were detected in ewe weight change from supplementation to weaning. Initial body condition scores (BCS) were greater ($P = 0.01$) for GOOD than POOR condition ewes. Supplement X condition interactions existed ($P = 0.09$) for BCS change during the individual supplementation period. HIGH and LOW supplemented GOOD ewes had more ($P < 0.01$) BCS loss than did HIGH and LOW supplemented POOR ewes. Condition and condition X age differences in BCS changes were not detected ($P > 0.16$) at turn out. However, GOOD conditioned ewes lost more BCS ($P < 0.01$) than POOR conditioned ewes at turn out. Similarly, GOOD conditioned ewes lost more BCS ($P < 0.01$) than POOR conditioned ewes at weaning.

Table 3.9. Least square means of ewe BW and BCS change from GOOD and POOR BCS ewes fed 227 g·ewe^{-1}·d^{-1} of either a HIGH or LOW supplement the last 30 d gestation in experiment 2[1,2,3,4]

	Treatments							
	GOOD		POOR			S x C[6]	GOOD vs POOR	HIGH vs LOW
Dates	HIGH	LOW	HIGH	LOW	SEM[5]	*P*-value	*P*-value	*P*-value
Initial weight:	68.6[a]	67.1[a]	62.0[b]	61.9[b]	2.72	0.74	0.06	0.76
	Ewe weight change, kg							
Pre-lambing	0.30	0.05	0.74	0.91	0.79	0.77	0.38	0.95
Turn out	-9.17[a]	-6.80[ab]	-5.44[b]	-7.33[ab]	1.73	0.18	0.31	0.88
Weaning	-6.55	-7.31	-2.20	-4.99	3.16	0.70	0.21	0.50
Initial BCS	3.11[a]	2.95[a]	1.69[b]	1.79[b]	0.08	0.11	<0.01	0.69
	Ewe BCS change, kg							
Pre-lambing	-0.66[a]	-0.50[a]	0.44[b]	0.21[b]	0.12	0.09		
Turn out	-0.67[a]	-0.44[a]	0.25[b]	0.08[b]	0.59	0.16	<0.01	0.84
Weaning	-0.56[a]	-0.33[ac]	0.25[b]	0.00[bc]	0.20	0.19	<0.01	0.94

[a,b] Within row, means without a common superscript differ, $P < 0.10$

[1]GOOD = average body condition score = 3; range of 2.5 to 3.5

[2]POOR = average body condition score = 1.7; range of 1.5 to 2

[3]HIGH = 12.5% UIP, 880 IU/kg supplemental vitamin E, 176 mg/kg chelated Zn, and 352 mg/kg chlortetracycline

[4]LOW = 7.56% UIP, no supplemental vitamin E, no chelated Zn, and no chlortetracycline

[5]n=34

[6]S X C = Interaction between type of supplement (S) and condition of ewe (C)

Lamb Production

No supplement, condition, or supplement x condition effects were detected ($P >$ 0.12) for single- or twin-born lamb birth, turnout, or weaning BW (Table 3.10).

Table 3.10. Least square means of lamb BW born to GOOD and POOR BCS ewes fed 227 g·ewe^{-1}·d^{-1} of either a HIGH or LOW supplement the last 30 d of gestation in experiment 2[1,2,3,4]

	Treatments							
	GOOD		POOR			S x C[7]	GOOD vs POOR	HIGH vs LOW
Dates[5]	HIGH	LOW	HIGH	LOW	SEM[6]	*P*-value	*P*-value	*P*-value
Single-born								
Birth BW, kg	5.40	5.31	4.13	5.22	0.79	0.41	0.28	0.43
Turnout BW, kg	12.9	13.7	11.5	8.8	2.98	0.50	0.19	0.68
Weaning BW, kg	36.4	29.6	30.6	20.2	9.12	0.62	0.29	0.24
Twin-born								
Birth BW, kg	9.34	11.6	8.21	9.48	1.71	0.68	0.15	0.12
Turnout BW, kg	17.1	24.4	18.8	17.5	4.94	0.21	0.40	0.34
Weaning BW, kg	37.3	62.1	43.6	36.9	16.6	0.18	0.37	0.40

[1] GOOD = average body condition score = 3; range of 2.5 to 3.5
[2] POOR = average body condition score = 1.7; range of 1.5 to 2
[3]HIGH = 12.5% UIP, 880 IU/kg supplemental vitamin E, 176 mg/kg chelated Zn, and 352 mg/kg chlortetracycline.
[4]LOW = 7.56% UIP, no supplemental vitamin E, no chelated Zn, and no chlortetracycline.
[5]Birth BW were taken within 12 h of birth. Turnout and weaning BW were taken 32 and 117 d relative to average lambing (April 22, 2007)
[6]n=18, single-born lambs; n=16, twin-born lambs
[7]S x C = Interaction between type of supplement (S) and condition of ewe (C)

Experiment 3

Ewe and Lamb Production

Ewe BW and body condition score at turnout and weaning did not differ (*P* >0.19) between supplemental treatments (Table 3.11). Birth, turnout, and weaning BW did not differ (*P* > 0.31) between single and twin lambs born to ewes consuming either HIGH or LOW supplements (Table 3.12). Percent lambs alive at turnout and weaning BW did not differ (*P* > 0.75) between single and twin lambs born to ewes consuming either HIGH or LOW supplements (Table 3.13).

Table 3.11. Least square means of ewe BW and BCS when fed 227 g·ewe^{-1}·d^{-1} of either HIGH or LOW supplement the last 30 d gestation in experiment 3 (2 pens per treatment)[123]

	Treatments			
Dates3	HIGH	LOW	SEM[4]	*P*-value
Turnout BW, kg	58.2	58.2	0.47	0.95
Weaning BW, kg	61.4	60.9	0.47	0.33
Turnout BCS	2.50	2.35	0.08	0.19
Weaning BCS	2.81	2.75	0.10	0.64

[1]HIGH = 12.5% UIP, 880 IU/ kg supplemental vitamin E, 176 mg/kg chelated Zn, and 352 mg/kg chlortetracycline.
[2]LOW = 7.56% UIP, no supplemental vitamin E, no chelated Zn, and no chlortetracycline.
[3]Turnout BW were taken on 32 and 27 d after average lambing date in 2007 and 2008, respectively. Weaning BW were taken on 117 and 127 d after average lambing in 2007 and 2008, respectively.
[4]n=4

Table 3.12. Least square means of lamb BW born to ewes fed 227 g·ewe^{-1}·d^{-1} of either HIGH or LOW supplemental treatments the last 30 d gestation in experiment 3 (2 pens per treatment)[1,2,3]

n = 4	Treatments			
	HIGH	LOW	SEM[4]	*P*-value
Singles				
Birth BW, kg	5.36	5.41	0.05	0.63
Turnout BW, kg	12.9	12.8	0.80	0.95
Weaning BW, kg	30.1	30.6	1.18	0.80
Twins				
Birth BW, kg	8.77	8.64	0.07	0.31
Turnout BW, kg	17.1	17.2	0.83	0.96
Weaning BW, kg	42.1	41.4	1.27	0.73

[1] HIGH = 12.5% UIP, 880 IU/kg supplemental vitamin E, 176 mg/kg chelated Zn, and 352 mg/kg chlortetracycline.
[2] LOW = 7.56% UIP, no supplemental vitamin E, no chelated Zn, and no chlortetracycline.
[3] Birth BW were taken within 12 hours of birth. Turnout BW were taken on 32 and 27 d after average lambing date in 2007 and 2008, respectively. Weaning BW were taken on 117 and 127 d after average lambing in 2007 and 2008, respectively.
[4]n=4

Table 3.13. Least square means of percent lamb survival born to ewes fed 227 g·ewe^{-1}·d^{-1} of either HIGH or LOW supplemental treatments the last 30 d gestation in experiment 3 (2 pens per treatment)[1,2,3]

n = 4	Treatments			
	HIGH	LOW	SEM[4]	*P*-value
Singles				
Birth, %	100	100	-	-
Turnout, %	92.4	92.7	0.01	0.85
Weaning, %	86.1	87.6	0.02	0.75
Twins				
Birth, %	200	200	-	-
Turnout, %	172	170	0.05	0.90
Weaning, %	156	155	0.07	0.91

[1] HIGH = 12.5% UIP, 880 IU/kg supplemental vitamin E, 176 mg/kg chelated Zn, and 352 mg/kg chlortetracycline.

[2] LOW = 7.56% UIP, no supplemental vitamin E, no chelated Zn, and no chlortetracycline.

[3] Birth BW were taken within 12 hours of birth. Turnout BW were taken on 32 and 27 d after average lambing date in 2007 and 2008, respectively. Weaning BW were taken on 117 and 127 d after average lambing in 2007 and 2008, respectively.

[4] n=4

CHAPTER 4

DISCUSSION

The overall goal of this project was to develop a late gestational supplement that improved lamb production, particularly in thin and old ewes Supplementation of UIP protein has been shown to improve ewe BW (Roeder et al., 2000), indices of immunity (Annett et al., 2005), and lamb production (Annett et al., 2005). Zinc supplementation has increased indices of immune function (Spears et al., 1991) and lamb production (Hatfield et al., 1995). Vitamin E supplementation has been reported to improve humoral immune transfer from ewe to lamb (Reffett et al., 1988; Rittacco et al., 1986; Gentry et al., 1992) and lamb production (Gentry et al., 1992; Kott et al., 1998). Chlortetracycline supplementation is commonly recommended as a late gestation supplementation to reduce pathogen proliferation (SID, 2002) and has been shown to improve piglet survival and growth (Maxwell et al., 1994). Furthermore, ewe age and body condition impact lamb survival and growth (Al-Sabbagh et al., 1995).

However, supplementation research that has investigated the effects of these additives has been inconsistent. Late gestation supplementation of UIP (Ramsey et al., 2000; Roeder et al., 2000), Zn (Spears et al., 1998), and vitamin E (Dafoe et al., 2008; Daniels et al., 2000) have all been reported to have no effect on animal production. However, it is also important to note that no research to our knowledge has reported negative biological responses as a result of incorporating these additives into a late gestational supplement.

Experiment 1

Ewe DMI was not affected by supplement. The HIGH supplement was targeted to increase protein that is absorbed for systemic use, rather than enhance rumen fermentation. Three yr old ewes digested more of the grass hay and subsequently had greater DMI than 6 yr old ewes. Nonetheless, greater DMI by 3 yr old ewe did not resulted in greater ewe BW or BCS changes during individual supplementation and lamb production was not different from 6 yr old ewes.

Lamb PI_3 titers were greater in 3 yr old HIGH than 3 yr old LOW supplemented ewes. Six yr old LOW ewes had greater lamb PI_3 titers than 3 yr old LOW supplemented ewes and 6 yr old HIGH supplemented ewes were not different among all other treatments for lamb PI_3 titers. This data does not support our objective to improve immune transfer in the "high risk" 6 yr old ewes. On the contrary, 3 yr old ewe immune transfer to lambs appeared to be improved with the HIGH supplement. Due to the fact that ewe PI_3 titers and colostral IgG concentrations were similar among treatments and lamb production was not altered, this data lack evidence that either supplementation or age had a major impact on immunological transfer from ewe to lamb.

Neither, age nor supplement treatments appeared to enhance d 3 or 10 milk production or milk composition in a consistent pattern that would translate into improved lamb production. However, d 3 somatic cell counts were numerically lowest in 3 yr old HIGH and GOOD HIGH supplemented ewes and their lambs had high anti-PI_3 titers. Elevated milk somatic cell counts mainly reflect the number of leukocytes that migrate from blood to the mammary gland in response to an infection in the mammary gland

(Rupp et al., 2008) and are indicators of chronic mastitis. This may indicate that the HIGH supplemented 3 yr old or GOOD conditioned ewes were more capable of passing humoral immunity to their lambs and humoral protection from mastitis.

Ewe BW at the start of the experiment was greater in the 6 yr old ewe than 3 yr old ewes. However, ewe BW and BCS did not change during the supplementation period. Trends in BW and BCS change for age or supplemental treatment did not indicate that any treatment improved or inhibited ewe weight and condition stasis. Moreover, differences in lamb birth, turnout, and weaning BW were not detected for age or supplement treatments. Although, lamb survival was not analyzed in experiment 1, lamb loss was factored into lamb BW. Therefore, if lamb loss difference were present among treatments, it would have been detected in lamb BW data.

Experiment 2

Ewe DMD and DMI were not affected by supplemental treatment. Ewe and lamb PI_3 and colostral IgG concentrations were also similar between supplemental treatments. Unlike the age x supplement interactions detected for lamb PI_3 titers in experiment 1, ewe BCS x supplement interactions were not detected for lamb PI_3 titers in experiment 2.

On d 3, ewe BCS and supplement impacted some milk components, however, there were no consistent treatment responses, and more importantly no differences in milk composition could be traced to differences in indices of lamb production. On d 10, GOOD conditioned ewes did produce more milk in two hours than POOR conditioned ewes. Furthermore, GOOD ewes on the HIGH supplement had improved milk protein

and solids not-fat concentrations. However, milk production and milk composition increases did not lead to any differences in lamb production at turnout, indicating that relative difference were a mute point in relation to lamb production. As was seen in experiment 1, ewe treatment with the highest ewe PI_3 titers (GOOD HIGH) had the lowest somatic cell counts. Reiterating the fact that titer responses due to treatment may relate to other indices of immune function. Furthermore, experiment 2 refutes our original objective to improve immune function in "high risk" POOR conditioned ewes.

Supplementation had no effect on ewe BW and BCS change. From the start of supplementation to weaning, GOOD conditioned ewes lost more body condition than did POOR conditioned ewes. However, ewes experiencing condition loss did not relate to a decrease in lamb production. Similar to experiment 1, lamb loss was factored into lamb BW at turnout and weaning.

Experiment 3

Supplementation of approximately 600 ewes in two groups and replicated over two years did not indicate that the HIGH treatment improved ewe BW, ewe BCS, lamb growth, or lamb survival at turnout or weaning. The results of experiment 3 are consistent with the two previous experiments.

CHAPTER 5

IMPLICATIONS

Our findings indicate that under the conditions of our study the HIGH supplement (containing additional UIP, vitamin E, chelated Zn, and chlortetracycline) did not improve ewe or lamb production or impact indices of immune function. Although supplemental treatment did alter specific humoral immune transfer from ewe to lamb depending on age, the response was not consistent across age or type of supplement. More importantly, there were no meaningful interactions between age or BCS and the type of supplement. We had anticipated that the HIGH supplement would benefit the "at risk ewes" (old or poor body condition). This was not the case. The cost associated with the HIGH supplement, even for at risk ewes, was not warranted under the conditions of our study.

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CHAPTER 6

LITERATURE REVIEW

Western range sheep producers typically sell lambs immediately after weaning. Many of those lambs go directly into feedlots. Light lambs that enter the feedlot can become too fat, reducing consumer appeal (Southam and Field, 1969). However, marketing lamb at heavier weights is advantageous for the sheep industry by reducing small primal cuts and increasing processing efficiency (Botkin et al., 1988). Model simulation of lamb production has reported that grazing lambs on high quality pasture after weaning (backgrounding) and prior to feedlot entry would increase consumer appeal via lower fat content and increase producer profitability given that the pasture costs are less than or equal to feedlot costs (Blackburn et al., 1991).

Backgrounding

For the purpose of this literature review, backgrounding will refer to management of livestock after weaning on some type of forage based diet prior to feedlot entry. Backgrounding or stocker cattle feeding is common in the beef cattle industry, in which calves are weaned and maintained on a forage based diet for various amounts of time prior to feedlot entry. Stocker cattle are backgrounded to add weight to the calves and spread out the number of calves entering the feedlot at one time (Klopfenstein, 1999). In addition, same premise backgrounding can reduce stress associated with shipment (Arthington et al., 2008) and improve cattle ranch profitability (Mathis et al., 2008).

However, little peer reviewed research has reported the effects of lamb backgrounding on feedlot health, performance, and carcass characteristics.

Marketing

Most Western range sheep producers wean and market their lambs in late summer (SID, 2002). Market studies show that feeder lambs in the US are sold for the lowest price during the summer and the price of feeder lambs steadily increases from September through April (Ward, 1995). Therefore, backgrounding of Western range lambs from August/September to October/November would delay the sale of lambs during a period in which normal yearly trends report increased lamb prices. However, this need to be balanced with the fact that heavier lambs sale for less dollars per lb. Economic analysis of simulated lamb production reported greater returns from alfalfa backgrounded lambs prior to finishing than lambs finished directly after weaning (Blackburn et al., 1991). In addition, beef cattle models predicted that backgrounding calves can improve livestock producer returns in an increasing calf price market but can decrease producer returns in a decreasing calf price market (Reisenauer Leesburg et al., 2007).

Recent market studies (King, 2006) documented that Superior Livestock Auction (131 East Exchange Avenue, Suite 121, Fort Worth, Texas 76106) cattle buyers pay more for calves backgrounded for 45 d under the value added calf program (VAC-45) than calves sold directly after weaning. This VAC-45 program consists of backgrounding calves on the premise of rearing after weaning for at least 45 days and requires one of several vaccination protocols. This program was initiated by the Texas Cooperative

Extension Service based on cattle production data collected from a ten year Ranch to Rail program (Cleere, 2005).

Health

Lamb weaning, transportation and adaptation to a feedlot environment are stressful situations that reduce the lambs' ability to resist common infectious agents (Brown, 1976). Backgrounding lambs in a familiar environment post weaning can separate the stress of weaning from transportation and feedlot stressors. According to a survey done by USDA National Health Monitoring System (2004), one of the most important pre-arrival lamb procedures requested by feedlot operators was weaning lambs two weeks prior to shipping. In addition, the USDA National Health Monitoring System (2004) reported that only 17 percent of the feedlot lambs per year had been weaned two weeks prior to shipping to the feedlot.

Feedlot operators reported that respiratory disease accounted for 30 percent of lambs lost (USDA, 2004). Pneumonia is a common disease of sheep in all major sheep-producing countries, where it causes mortality and depresses growth (Goodwin et al., 2004). Pneumonia in sheep is a disease complex involving host, multiple agents, and environment. Defense mechanisms of the lung are compromised and proliferation of pathogens occurs when a certain threshold dose of invading microorganisms relative to host susceptibility and non-specific defense mechanisms are reached (as reviewed by Goodwin et al., 2004). In New Zealand, Black (1997) estimated that across the country lamb pneumonia was present in 4 to 13 percent of grass fed slaughter lambs.

At South Dakota State University, Daniel et al. (2006) evaluated the incidence of lung lesions in feedlot lambs. While only 7 % of feedlot lambs were treated for visual signs of respiratory disease, moderate and severe lung lesions were present in 26 and 38 % of the harvested lambs, respectively. Lung lesions were greater at d 50 and 71 of the feedlot period than at weaning (Daniel et al., 2006). Authors concluded that the stress of weaning predisposed the lambs to respiratory infections and the infections grew more severe over time.

Although the major economic impacts of increased lung lesions are the decreased acceptability for certain kosher/halal lamb markets, there were also some production difference. Lambs with severe lung lesions had lower total feedlot ADG than lambs with normal or moderate lung lesions (Daniel et al., 2006; Daniel and Held, 2006). However, there was a positive correlation between lambs with severe lung lesions and ADG during the initial 28 d feedlot period. Daniels and Held (2006) concluded that aggressive eating behaviors during the adaptation to the feedlot ration lead to a greater incidence of lung lesions.

To our knowledge, no lamb research has looked at lamb health during the backgrounding period or the subsequent feedlot period, however, work in cattle suggests that backgrounding has a positive impact on health. Mathis et al. (2008) reported that calves backgrounded for 45 days immediately after weaning on native range with protein supplementation had lower death loss than drylot backgrounded calves during the feedlot finishing period. Moreover, calves weaned and maintained on pasture (prior to transport had lower serum acute phase proteins (indicator of stress) after transport and feedlot entry

than calves weaned on the day of transport (Arthington et al., 2005). The magnitude of this acute phase protein response is negatively correlated to calf ADG after transport (Arthington et al., 2005; Qui et al., 2007) and positively associated with the incidence of morbidity and subsequent requirement for antimicrobial treatment (Carter et al., 2002). Therefore, further research is warranted to investigate lamb feedlot death rate and percent feedlot lambs showing signs of illness from different backgrounding treatments.

Growth

Lamb growth from birth to weaning under ideal nutritional conditions has been described as linear with age (Dickerson et al. 1972). However, typical range operations do not provide adequate nutrition at all times from birth to weaning. Bush and Lewis (1977) reported that Western range lamb growth over time was best fitted by a third order polynomial; with a gradual decrease in ADG over time.

Along with overall body weight change, body composition changes due to lamb maturity and nutritional environment. Lamb growth models by Wang and Dickerson (1991) predict that as lambs grow older protein accretion decreases and fat deposition increases. Therefore age and environment effect the body composition of lambs entering the feedlot. Both of which would be altered through most backgrounding programs.

Lambs backgrounded on native forage would most often be nutritionally restricted. Nutritionally restricted sheep mobilize body tissue for normal bodily function and lose overall body weight. Muscle and fat are the main sources of energy storage. Restricted lambs have less protein and fat per unit of body weight than unrestricted lambs (Black, 1974; Davies and Lloyd, 1982). However, when the restricted sheep were

realigned to an adequate diet they may (Turgeon, 1986) or may not (Drouillard et al., 1991) deposit tissue faster than non-restricted sheep. An advanced rate of gain post restriction is commonly referred to as compensatory growth (Allden, 1970).

Searle and Graham (1975) concluded that restriction of growth (4 to 6 mo) after weaning does not cause any permanent change in their chemical composition and free access to a good diet (2 mo) results in rapid recovery of the original composition. However, lambs that experience a period of nutritional restriction followed by realignment on concentrate diets have different concentrations of body protein and fat as compared to lambs finished after weaning on a concentrate based diet (Turgeon et al., 1986; Drouillard et al., 1991).

Turgeon et al. (1986) fed lambs corn stalkage and added grain to achieve lamb gains of 10 kg in 60, 100 or 200 d. They reported that in the growth restricted lambs (100 and 200 d) greater proportions of tissues deposited were protein rather than fat. Upon subsequent realignment on a concentrate based diet, compensatory growth of restricted lambs occurred in two stages: the first stage of compensatory growth showed increased rates of protein deposition, while the second stage of compensatory growth showed increased rates of fat deposition as compared to 60 d lambs (Turgeon et al., 1986). Drew and Reid (1975) reported that sheep experiencing compensatory growth following 70 d of weight loss not only grow faster but synthesize less fat and retain more nitrogen than sheep continuously fed. In contrast, lambs restricted to only maintain weight for 35 days did not deposit tissue differently during the realignment phase than did unrestricted lambs of similar age (Drouillard et al., 1991).

Carcass Composition

In cattle, Choat et al. (2003) reported that steers backgrounded on wheat pasture had heavier carcass wt, higher dressing percentage, larger longissimus muscle area (LMA), similar 12th rib fat, and similar body weight adjusted LMA than range backgrounded steers. In contrast, Mathis et al. (2008) found no difference in carcass traits of steers that had been backgrounded in a drylot compared to native range Backgrounding durations of 120 and 45 days were implemented for Choat et al. (2003) and Mathis et al. (2008), respectively.

In lambs, McClure et al. (1995) reported that lambs backgrounded on ryegrass (22% CP) for 62 d prior to finish had less fat and more lean tissue than lambs finished after weaning. To the contrary, unpublished research found that Western range lambs backgrounded for 90 d on native range prior to concentrate finish had lower dressing percentage, less external fat, and smaller LMA than lambs finished directly after weaning (Kott, personal communication).

Carcass Quality

Klopfenstein (2000) concluded in a review of the literature that backgrounding had little or no effect on marbling or carcass quality grades when steers were fed to a common rib fat end point. According to the Agriculture Marketing Service (AMS, 2009) from 1989 to 2008, 87 to 94% of all commercially graded lambs were USDA choice. Similarly, Nichols et al. (1992) reported that greater than 90% of wethers graded USDA choice after a 105 d wheat pasture backgrounding and 56 d confinement finishing. Hatfield et al. (2000) backgrounded lambs for 0, 90 or 120 d prior to feedlot finishing and

reported similar flavor intensities among treatments. Therefore, lamb backgrounding of less than 120 days should not negatively affect lamb carcass quality post confinement finishing.

Feedlot Performance

Feedlot performance of calves backgrounded on winter stubble and summer grass for 365 days prior to feedlot entry had less days on feed (DOF), had higher DMI (dry matter intake) and ADG (average daily gain), but lower G:F (gain to feed ratio) than calves that entered the feedlot immediately after weaning (Sindt et al., 1991). Carstens et al. (1991) reported that steers restricted to one third the ADG for 189 days of continuously gaining steers prior to feedlot entry had higher feedlot ADG, tended to have lower feedlot DMI, and higher feedlot G:F ratios than continuously gaining steers.

Mathis et al. (2008) reported that range backgrounded steers had higher initial ADG compared to drylot backgrounded steers. Similarly, range backgrounded steers had higher DMI, higher ADG, better G:F, and less DOF than wheat backgrounded steers (Choat et al., 2003).

Early research of compensatory growth showed that sheep experiencing compensatory growth consumed 3 to 4 times as much food and apparent digestibility increased from 60 to 90% during the first few days after realignment (Thorton et al., 1979). Nitrogen utilization (Graham and Searle, 1975) and feed efficiency (Drew and Reid, 1975) of restricted lambs were also higher during the first few days after realignment.

Turgeon et al. (1986) reported that lambs held on low rates of gain (200 d) prior to finishing had higher ADG, higher DMI, higher G:F, and less DOF than lambs on rapid rates of gain (64 d) prior to finishing. Similarly, lambs backgrounded on ryegrass for 62 d prior to finish had higher finishing DMI (McClure et al., 1995) than lambs finished directly after weaning. In contrast to Turgeon et al. (1986), McClure et al. (1995) reported that ryegrass backgrounded lambs had lower ADG, lower G:F, and more DOF than lambs finished after weaning. Differences in the studies could be attributed to type and duration of restriction. Turgeon et al (1986) restricted diet intake with low quality forage and lambs gained very little weight over time (100 and 200 d). However, McClure et al (1995) restricted lamb growth to less than 5 kg over 62 d on ryegrass pasture. Drouillard et al. (1991) restricted lambs with either energy or protein deficient diets for 35 d and reported that protein restricted lambs had higher G:F ratios than energy restricted lambs during the first two weeks of realignment but did not differ over the entire feedlot period. Furthermore, lamb backgrounding research conducted in cooperation with our laboratory (MSU, unpublished data) found that lambs backgrounded for 90 days on native range with protein supplementation prior to feedlot entry had higher ADG, higher DMI, similar G:F, and less DOF than lambs sent directly to the feedlot. Therefore, type of nutrient restriction and duration of restriction will impact feedlot performance of backgrounded lambs.

Summary

No lamb study to our knowledge has combined different systems of backgrounding (dormant range vs improved pasture vs drylot) into one study to measure backgrounding's effect on tissue deposition over time, feedlot performance, lamb health, and carcass characteristics. Backgrounding lambs on forage based diets has the potential to increase producer profitability and improve lamb feedlot health and performance without diminishing carcass quality.

CHAPTER 7

MATERIALS AND METHODS

Animals, Treatments, and Research Sites

Seventy-two (Black-face X Western white-face) lambs were randomly selected at weaning (average BW, 31 ± 0.67 kg) from the Red Bluff Research Ranch ewe flock. Lambs were assigned to treatments in such a manner that average lamb BW and the number of wethers and ewe lambs was similar in all backgrounding treatments (18 lambs per treatment). All background treatments lasted 29 d, starting when lambs were 140 ± 5.9 d of age and lasting until the beginning of the feedlot period. Treatments were: 1) lambs not separated from their dams at Red Bluff Research Ranch (**LATE WEAN**); 2) lambs removed from the ewes for 4 d then returned to graze with the ewe flock at Red Bluff Research Ranch (**RANGE**); 3) lambs weaned and moved to grass paddocks at Fort Ellis Research Farm (**GRASS**); 4) lambs weaned and allowed ad libitum access to an 80% alfalfa: 20% barley pellet (Table 7.1) in a drylot at Fort Ellis Research Farm (**PELLET**).

Red Bluff Research Ranch elevation ranges from 1,402 to 1,889 m, and annual precipitation ranges from 35.5 to 43.1 cm. Vegetation is a typical foothill bunchgrass type. Bluebunch wheatgrass (*Agropyron spicatum*) and Idaho fescue (*Festuca idahoensis*) are the major grasses. Rubber rabbit brush (*Chrysothamnus nauseosus*), fringed sagewort (*Artemisia frigida*), lupine (*Lupinus spp.*), milkvetch (*Astragalus spp.*)

and western yarrow (*Achillea millefolium*) are commonly occurring shrubs and forbs (Harris et al., 1989).

Fort Ellis Research Farm near Bozeman, MT has an approximate elevation of 1,500 m and received 61 cm of precipitation in 2007 (NCDC, 2009). Sheep pastures were predominantly smooth brome (*Bromus inermis*), crested wheat (*agropyrom cristatum*), and Kentucky blue (*poa pratensis*) grasses. Prior to the experiment, paddocks A and B (0.53 and 1.42 ha, respectively) were grazed by sheep in the spring and summer. Fall regrowth produced most forage available for the GRASS backgrounded lambs.

Backgrounding

On September 6, 2007 all lambs except LATE WEAN were moved from Red Bluff to Fort Ellis (56 km). At Fort Ellis, PELLET, RANGE, and GRASS treatment lambs were placed on paddock B for 4 d. Then on September 10, RANGE lambs were returned to the ewe herd at the Red Bluff Research Ranch, PELLET lambs were moved to a drylot pen with self-feeders containing 80% alfalfa: 20% barley pellets (Table 7.1), and GRASS lambs were moved to paddock A. Lambs remained on their respective treatments for 29 d.

Feedlot

On October 9, 2007 all lambs were removed from their respective backgrounding treatment, orally drenched with an anthelmintic (Valbazen; Pfizer Animal Health, Exton, PA), vaccinated against Clostridial perfringens C and D (Bar-Vac CDT**;** Boehringer

Ingelheim Vetmedica, Inc., St. Joseph, MO), and allowed to graze paddock B for 48 h. On October 11 (d 0) lambs were held off feed and water for 12 h and shrunk BW were obtained. Lambs within backgrounding treatments were randomly assigned to pen (6 lambs per pen and 3 pens per treatment) so that each treatment pen had similar average lamb BW and similar number of ewes and wethers. Feedlot rations consisted of 80% alfalfa: 20% barley pellets, whole corn, and a supplemental pellet designed to be fed at 0.227 $kg \cdot lamb^{-1} \cdot d^{-1}$ (Table 7.1). Each ingredient was sampled throughout the feedlot period. Proximate analysis and mineral concentrations were determined by Midwest Laboratories, Inc (Omaha, Nebraska; Table 7.1). Rations were hand mixed and placed in self-feeders, which allowed ad libitum access. Rations started at 30% concentrate and moved up 10 percentage points in concentrate for every 26.7 kg of pen intake (~4.45 kg/lamb). Finishing lamb rations were held constant at 70% concentrate.

After all pens had reached the 70% concentrate ration (October 30th, 2007; d 19 post start of feedlot period), it was considered the end of the step-up period. Some pens reached the 70% concentrate diet prior to this date. On d 19 all lamb unshrunk weights were recorded and lambs were vaccinated against Clostridial perfringens C and D (Bar-Vac CDT**;** Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO). On December 18 (d 68), ultrasonography (Aloka Co., LTD, Wallingford, Connecticut 06492) determined that more than half of the lambs had achieved the target 0.5 cm 12th-rib fat thickness and the feedlot period was concluded. Lambs were removed from the feedlot pens and weighed. Lambs were then held off feed and water over night and shrunk weights were measured.

Percent shrink was averaged on each lamb and a pencil shrink was applied to d 19 lamb BW.

At the conclusion of the step-up (d 19) and finishing (d 68) periods, feed orts were removed from the self-feeders and weighed. Pen intakes during the step-up, finishing and total feedlot periods were determined by subtracting orts from feed supplied to self-feeders.

Lamb health was monitored during the feedlot period. Lambs showing signs of acidosis were drenched with sodium bicarbonate saturated in water. One RANGE lamb died during the step-up period and its data was removed from the study.

Table 7.1. Chemical composition (DM basis) of feedlot ration ingredients.[1]

	Feedlot Ration		
	Whole Corn	Alfalfa:Barley Pellet	Supplemental Pellet
DM, %	85	90	86
CP, %	9.96	17.8	22.8
CF, %	3.97	1.40	2.30
ADF, %	3.48	30.5	19.1
Ash, %	1.32	8.35	10.4
TDN, %	91.9	71.2	73.2
Sulfur, %	0.12	0.32	0.44
Phosphorus, %	0.29	0.30	0.66
Potassium, %	0.36	2.20	1.39
Magnesium, %	0.13	0.36	0.36
Calcium, %	0.01	1.96	1.38
Sodium, %	<0.01	0.06	1.29
Iron, ppm	24	133	276
Manganese, ppm	8	40	108
Copper, ppm	4	6	15
Zinc, ppm	21	20	86
Bovatec, mg/kg	0	0	264

[1]Chemical analysis conducted by Midwest Laboratories Inc. (Omaha, NE).

Carcass and Ultrasound Evaluation

At the conclusion of the feedlot period, 20 lambs (5 lambs/treatment) of similar weight (average 53 $\pm$ 4 kg) were selected for slaughter. On December 20 slaughter lambs were taken to a local abattoir (96 km) and harvested the next morning. After an approximate 24 h chill, carcass weight, kidney fat, 12^{th} rib fat thickness, and LM area were recorded.

Ultrasound measurements of LM area and 12^{th}-rib fat thickness were taken at $12^{th}/13^{th}$ rib transverse using an Aloka SSD-500V real-time ultrasound device with a 3.5 MHz, 12.5-cm linear array transducer and standoff guide. On d -29, 0, 19, and 68 lamb LM area was measured using ultrasonography. On d 19 and 68 lamb fat thickness was measured using ultrasonography. All ultrasound measurements were collected and interpreted by the same technician. Technician bias was -0.018 and 0.12 cm for REA and FD, respectively. Standard error of prediction was 0.63 and 0.17 cm for REA and BF, respectively. Standard error of repeatability was 0.55 and 0.07 cm for REA and BF, respectively.

Statistical Analysis

Data were analyzed as a completely random design using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). Means were separated by the LSD procedure and differences were considered different at $P < 0.10$. Pen was the experimental unit for feedlot performance data, with 3 pens per treatment. Lamb was the experimental unit for ultrasound and carcass data. The model included backgrounding treatment. All animal

procedures were approved by the Montana State University Institutional Animal Care and Use Committee (Protocol #AA-030).

CHAPTER 8

RESULTS

Feedlot Performance

No differences ($P > 0.35$) among backgrounding treatments (Table 8.1) were detected for DMI, ADG, or G:F during the step-up (d 0 to 19) or finishing (d 19 to 68) periods. Differences were detected for the total feedlot period (d 0 to 68). Lambs backgrounded on PELLET treatments had the greatest DMI ($P < 0.10$) among treatments. Average daily gain was greater ($P < 0.10$) for PELLET than RANGE and LATE WEAN treated lambs. Feed efficiency was greater ($P < 0.08$) for GRASS than RANGE lambs.

Table 8.1. Effects of backgrounding treatment on lamb DMI, ADG, and G:F during feedlot periods (3 pens per treatment)[1]

	Treatment[2]				
	GRASS	LATE WEAN	PELLET	RANGE	SE
Step-up					
DMI, kg	1.31	1.24	1.34	1.15	0.08
ADG, kg	0.16	0.10	0.08	0.06	0.05
G:F	0.120	0.079	0.049	0.048	0.024
Finishing					
DMI, kg	1.66	1.68	1.79	1.65	0.06
ADG, kg	0.24	0.25	0.28	0.25	0.02
G:F	0.144	0.148	0.156	0.152	0.009
Total					
DMI, kg	1.56[a]	1.56[a]	1.67[b]	1.51[a]	0.04
ADG, kg	0.22[ab]	0.20[a]	0.23[b]	0.20[a]	0.01
G:F	0.139[a]	0.132[ab]	0.135[ab]	0.131[b]	0.003

[ab] Row means with different superscripts differ ($P < 0.10$).

[1] Step-up was 19 d period during which lambs were adjusted from 30 to 70% concentrate rations.
Finishing was 47 d period that lambs remained on the 70% concentrate ration.
Total was 68 d feedlot period.

[2] Treatments were applied to lambs for 29 d after weaning.
GRASS lambs were maintained on grass paddocks at the Fort Ellis Research Center.
LATE WEAN lambs were not weaned from dams.
PELLET lambs were self-fed alfalfa:barley pellets.
RANGE lambs were weaned from dams for 4 d and returned to range.

Lamb Growth

Lambs backgrounded on the PELLET treatment had the greatest ($P < 0.10$) BW among treatments (Table 8.2) at the start of the feedlot period (d 0). After lambs were stepped up onto the 70% concentrate diet (d 19), PELLET and GRASS treated lambs had greater BWs ($P < 0.05$) than RANGE and LATE WEAN treated lambs. At d 68, PELLET treated lambs had greater lamb BWs ($P < 0.05$) than all other backgrounding treatments.

Table 8.2. Effects of backgrounding treatment on feedlot lamb BW (3 pens per treatment)

	Treatment[2]				
Period[1]	GRASS	LATE WEAN	PELLET	RANGE	SE
Weaning BW, kg	32	31	31	31	
Feedlot BW, kg					
d 0	33[a]	33[a]	35[b]	33[a]	0.59
d 19	36[b]	35[a]	36[b]	34[a]	0.60
d 68	48[a]	47[a]	51[b]	46[a]	0.87

[ab] Row means with different superscripts differ ($P < 0.10$).

[1] *Weaning* (d -29) represents removal of lambs from ewes when lambs were 140 ± 5.9 d.
d 0 lambs were removed from backgrounding treatments and began step-up rations.
d 19 lambs finished the transition period and began the finishing ration.
d 68 was the conclusion feedlot period.

[2] Treatments were applied to lambs for 29 d after weaning (n = 12).
GRASS lambs were maintained on grass paddocks at the Fort Ellis Research Center.
LATE WEAN lambs were not weaned from dams.
PELLET lambs were self-fed alfalfa:barley pellets.
RANGE lambs were weaned from dams for 4 d and returned to range.

Ultrasonography Data

After backgrounding (d 0), PELLET and GRASS lambs had greater ($P < 0.05$) LM areas than RANGE and LATE WEAN treated lambs (Table 8.3). After the step-up period (d 19), PELLET lambs had a greater ($P = 0.07$) LM area than RANGE backgrounded lambs but did not differ from GRASS and LATE WEAN treated lambs. At

the conclusion of the feedlot period (d 68), PELLET and GRASS treated lambs had greater ($P < 0.05$) LM areas than RANGE and LATE WEAN treated lambs.

PELLET lambs had the greatest ($P < 0.05$) 12th-rib fat thickness among treatments at the end of the step-up phase (d 19). At the conclusion of the feedlot, there were no differences ($P > 0.50$) in 12th-rib fat thickness among treatments.

Table 8.3. Ultrasound measurements of LM area and 12th-rib fat thickness of backgrounded lambs (18 lambs per treatment)[1]

	Treatment[2]				
	GRASS	LATE WEAN	PELLET	RANGE	SE
LM area, cm^2					
Weaning	8.18	7.61	7.93	7.83	0.27
d 0	9.49[a]	8.47[b]	9.96[a]	8.43[b]	0.30
d 19	11.04[ab]	10.43[ab]	11.13[a]	10.39[b]	0.30
d 68	16.53[a]	15.46[b]	16.46[a]	15.27[b]	0.37
12th-rib fat thickness, cm					
d 19	0.28[a]	0.27[a]	0.36[b]	0.26[a]	0.01
d 68	0.53	0.51	0.51	0.50	0.02

[ab] Row means with different superscripts differ ($P < 0.10$).

[1] *Weaning* (d -29) represents removal of lambs from ewes when lambs were 140 ± 5.9 d.
d 0 lambs were removed from backgrounding treatments and began step-up rations.
d 19 lambs finished the transition period and began the finishing ration.
d 68 was the conclusion feedlot period.

[2] Treatments were applied to lambs (n = 72) for 29 d after weaning.
GRASS lambs were maintained on grass paddocks at the Fort Ellis Research Center.
LATE WEAN lambs were not weaned from dams.
PELLET lambs were self-fed alfalfa:barley pellets.
RANGE lambs were weaned from dams for 4 d and returned to range.

Carcass data

No differences ($P > 0.10$) were detected among treatments for chilled carcass weight, LM area, or kidney fat (Table 8.4). Lambs backgrounded on GRASS, RANGE, and LATE WEAN treatment had greater 12th-rib fat thickness ($P < 0.10$) than PELLET treated lambs.

Table 8.4. Effects of backgrounding treatment on lamb carcass characteristics taken after a 68 d feedlot period (5 lambs per treatment)

	Treatment[1]				
	GRASS	LATE WEAN	PELLET	RANGE	SE
Chilled carcass wt, kg	26.5	26.3	26.6	25.8	0.46
LM area, cm^2	17.2	16.1	16.0	15.9	0.77
12^{th}-rib fat thickness, cm	0.46[a]	0.48[a]	0.33[b]	0.46[a]	0.05
Kidney fat, kg	1.16	0.97	1.16	1.00	0.05

[ab] Row means with different superscripts differ ($P < 0.10$).

[1] Treatments were applied to lambs for 29 d after weaning.
GRASS lambs were maintained on grass paddocks at the Fort Ellis Research Center.
LATE WEAN lambs were not weaned from dams.
PELLET lambs were self-fed alfalfa:barley pellets.
RANGE lambs were weaned from dams for 4 d and returned to range.

CHAPTER 9

DISCUSSION

After the 29 d backgrounding period, PELLET treated lambs had greater lamb BW than did all other treatments. Similarly, Mathis et al. (2008) reported that steers backgrounded on native range for 45 d after weaning prior to feedlot entry weighed less at the start of the feedlot period than did drylot backgrounded steers. After the feedlot step up period, both PELLET and GRASS treated lambs were heavier than RANGE and LATE WEAN treated lambs. Similarly, Mathis et al. (2008) reported that range backgrounded steers had lower interim steer BW than drylot backgrounded steers. At the conclusion of the present study, PELLET treated lambs had greater lamb BW than did GRASS, LATE WEAN, and RANGE treated lambs. In contrast, Mathis et al. (2008) reported similar final steer BW between background treatments. One reason for the difference could be that Mathis and others supplemented protein to the background treatment; whereas, our dormant range treatments were not supplemented. In addition, Kott (personal communication) reported that lambs backgrounded on native range for 90 d with protein supplementation had similar final BW to lambs finished directly after weaning.

In the present study, lamb backgrounding treatment did not affect step-up DMI or G:F. However, Drouillard et al. (1991) restricted lamb growth for 35 d with either deficiencies in protein or energy prior to feedlot entry. They reported that d 0 to 14 feedlot DMI was less in the unrestricted treatment than both energy and protein restricted

treatments and feedlot G:F was greater in protein than energy restricted lambs (Drouillard et al. 1991). Drouillard et al. (1991)'s restricted treatments lost BW during the 35 d period; whereas, the RANGE, LATE WEAN, and GRASS lamb maintained BW during the backgrounding period. Therefore, lamb BW change during background could very well affect feedlot performance during the first few weeks upon feedlot finishing.

During the 68 d feedlot period, RANGE, LATE WEAN, and GRASS treated lambs had less feedlot DMI. Drouillard et al. (1991) found that protein and energy restricted lambs had lower d 0 to 42 feedlot DMI than unrestricted lambs but total feedlot was not different among treatments (approximately 110 d).

Lambs on the RANGE and LATE WEAN treatments had lower feedlot ADG than PELLET treated lambs; whereas, GRASS treated lambs were similar among treatments. Mathis et al. (2008) found no difference in total feedlot ADG between range and drylot backgrounded steer treatments. Drouillard et al. (1991) reported greater feedlot ADG in the restricted lamb treatments vs. unrestricted lambs. Lambs backgrounded on native range for 90 d have been shown to have higher feedlot ADG than lambs finished directly after weaning (Kott, personal communication). It is not clear why this study's range background treatments did not have compensatory ADG. However, Turgeon et al. (1986) found that the greater the duration and degree of growth restriction prior to feedlot entry the greater the compensatory gain.

Ultrasound measurements of LM area show that LATE WEAN and RANGE treatments had less LM areas than GRASS and PELLET treated lambs at the start of the feedlot period. In addition, GRASS and PELLET treated lambs maintained larger LM

areas to the conclusion of the feedlot period. Similarly, Drouillard et al (1991) reported that restricted lambs (35 d) had less protein tissue than unrestricted lambs after the restriction period and that difference in protein tissue between treatments was not regained during the feedlot period. However, Turgeon et al. (1986) reported higher rates of protein deposition during the feedlot period in restricted (100 and 200 d) vs. unrestricted lambs. Differences in feedlot protein deposition among studies are most likely due to length of background or restriction prior to feedlot entry.

Fat thickness on d 19 was lower in RANGE, LATE WEAN, and GRASS treated lambs than PELLET treated lambs; however, upon feedlot completion all treatments reached a similar fat thickness. Similarly, Drouillard et al. (1991) and Turgeon et al. (1986) reported that restricted lambs had less fat than unrestricted lamb after the restriction period; however, upon realignment fat was deposited at greater rate in the restricted lambs.

Lambs of similar BW were selected for harvest and comparison of treatment among similar BW can be made. Although, PELLET treated lambs had less carcass fat thickness than all other treatments, ultrasound measurement of fat thickness across the entire treatment group was not different among treatment. Indicating that selection of similar BW among treatments artificially selected the leanest lambs from the PELLET treatment. Carcass weight, LM area, and kidney fat were all similar among treatments. Similarly, Mathis et al. (2008) reported similar carcass weight, LM area, and fat thickness between steer background treatments. In contrast, Kott (personal communication)

reported that 90 d of background reduced LM areas compared to lambs sent directly to the feedlot after weaning.

CHAPTER 10

IMPLICATIONS

In summary, PELLET background treatment allowed for greater feedlot lamb gains as compared to RANGE and LATE WEAN backgrounding treatments. The study also showed that GRASS treated lambs had similar feedlot lamb ADG to PELLET treated lambs; however, DMI was lower in the GRASS than PELLET treated lambs. In our study, differences in muscle tissue at the start of the feedlot period was maintained among treatment to the conclusion of the feedlot period; whereas, differences in adipose tissue at the start of the feedlot period was regained so that all treatments achieved similar fat depths at the conclusion of the feedlot period.

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