Effect of short term, prepartum feeding level and type of protein on subsequent lactation
by Brent Lyle Roeder

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Animal Science
Montana State University

Abstract:
Fifty-eight mature, twin bearing Targhee and Columbia ewes were stratified by breed to study the effects of short term protein supplementation on prepartum body composition change and early lactation performance. Ewes were fed 1.3 kilograms of an alfalfa-grass hay (8 % CP) at the PM feeding. In the AM, ewes were fed either a .42 kg (11 % CP) of a restricted diet (RES), .42 kg (24 % CP, 34 % UDP) of a soybean meal diet (SBM), or .37 kg (26 % CP, 61 % UDP) of a blood meal-feather meal mix diet (BM-FM). Treatment rations were fed 21 d prepartum and ewes were bled weekly to parturition. Following parturition ewes were group fed 2.3 kg^-1 hd^-1 d of alfalfa-grass hay and .45 kg^-1 hd^-1 d barley. The BM-FM group had higher total blood protein than RES (P<.01) and SBM (P<.05). Blood albumin levels were higher (P<.05) in both BM-FM and SBM than RES. The BM-FM group had higher (P<.01) BUN than RES, but lower (P<.05) than SBM. BM-FM had higher (P<.05) colostral protein concentrations than either RES or SBM. At 21 d, BM-FM and SBM milk contained higher (P< .1) concentrations of protein than RES. These results suggest restricting protein intake during late pregnancy decreased protein content of milk during peak lactation. These data indicate that late pregnancy feeding of ruminally undegradable protein was not advantageous to more conventional supplements. Key Words: Sheep, Protein, Lactation.

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ABSTRACT

Fifty-eight mature, twin bearing Targhee and Columbia ewes were stratified by breed to study the effects of short term protein supplementation on prepartum body composition change and early lactation performance. Ewes were fed 1.3 kilograms of an alfalfa-grass hay (8 % CP) at the PM feeding. In the AM, ewes were fed either a .42 kg (11 % CP) of a restricted diet (RES), .42 kg (24 % CP, 34 % UDP) of a soybean meal diet (SBM), or .37 kg (26 % CP, 61 % UDP) of a blood meal-feather meal mix diet (BM-FM). Treatment rations were fed 21 d prepartum and ewes were bled weekly to parturition. Following parturition ewes were group fed 2.3 $kg^{-1}hd^{-1}d$ of alfalfa-grass hay and .45 $kg^{-1}hd^{-1}d$ barley. The BM-FM group had higher total blood protein than RES ($P<.01$) and SBM ($P<.05$). Blood albumin levels were higher ($P<.05$) in both BM-FM and SBM than RES. The BM-FM group had higher ($P<.01$) BUN than RES, but lower ($P<.05$) than SBM. BM-FM had higher ($P<.05$) colostral protein concentrations than either RES or SBM. At 21 d, BM-FM and SBM milk contained higher ($P<.1$) concentrations of protein than RES. These results suggest restricting protein intake during late pregnancy decreased protein content of milk during peak lactation. These data indicate that late pregnancy feeding of ruminally undegradable protein was not advantageous to more conventional supplements. Key Words: Sheep, Protein, Lactation.

INTRODUCTION

Montana sheep producers have in past years aggressively pursued increased efficiency by maximizing the kilograms of clean wool and lamb weaned per ewe, while maintaining sheep genetically suited to the environment. This was accomplished partially by increasing number of lambs born per ewe. However, as lambing rate increases, lamb mortality also increases (Jordan et. al., 1988). To achieve the maximum increase in efficiency, research is needed to identify new technologies that can be implemented into traditional management strategies. One of the few remaining areas where Montana producers could increase efficiency is to increase lamb survivability in early life (Kott and Thomas, 1987). Although positive results have been reported (Burfening and Kott, 1987; Thomas and Kott, 1995) from past reseach on winter supplementation programs to decrease lamb mortality, few researchers have explained the physiological changes that occurred. Current research needs to address the physiologic and endocrinologic changes associated with these winter supplementation programs. Hypothetically the increase in lamb survivability may be due to increased birth weights minimizing body-heat loss, additional brown adipose tissue maximizing thermoregulation of cold-stressed newborns, or improved immune response by optimizing the passive transfer system. The objectives of this project were to examine several physiological and endocrinological parameters that may be influenced by different winter supplementation programs. Specifically we were interested in how physiological changes in the ewe affect the passive transfer system.

LITERATURE REVIEW

Pregnancy

Pregnancy in sheep causes progressive changes in the partitioning of nutrients to meet the needs of the developing conceptus. Bazer et. al. (1989) suggested the conceptus influences its development from the earliest stages of gestation by secretion of hormones and growth factors into the lumen of the uterus. After placental attachment, manipulation of the maternal environment occurs by secretion of hormones directly into the maternal circulation (Bassett, 1992). There is disagreement over the effect pregnancy has on feed intake. Rattray (1992) stated pregnancy appears to cause a reduction in intake of some forages. Forbes (1986) and Weston (1988) concluded the changes observed could neither be completely explained by restriction of space in the abdominal cavity or the endocrine changes associated with late pregnancy. Lindsay (1971, 1973) attributed the two-fold increase in glucose production during pregnancy to increased food intake (higher precursor availability) coupled with increased liver size. Excretory nitrogen, in the form of urea and ammonia, crosses the placenta by diffusion (Faulkner, 1983). However, there is insufficient evidence to determine what role it may play in nitrogen recycling in the ewe. As acidic acids are not excreted, it has been assumed transamination occurs in the fetus and the requirements for different amino acids modifies due to different growth rates of various fetal organs (Faulkner, 1983).

Fetal Glucose

The most readily recognized modification is glucose conservation for preferential placental uptake. Weekes (1991) stated tissue glucose uptake occurs by two mechanisms, insulin-mediated glucose uptake (IMGU) and non insulin-mediated glucose uptake (NIMGU). Muscle and adipose are the two primary glucose dependent tissues in the ruminant. As the placenta is a NIMGU organ (Hay et. al., 1988), insulin is not necessary to facilitate glucose uptake. Therefore, when glucose and insulin concentrations are low, the placenta has preferential use of available plasma glucose.

The pregnant uterus may account for up to 70 % of total glucose turnover in the pregnant ewe (Silver, 1976). Forty to fifty percent of absorbed glucose is utilized by the fetus and the remainder by the uterus (Faulkner, 1983). Thirty to fifty percent of the glucose absorbed by the placenta is converted to lactate (Girard et. al., 1979). There is no active gluconeogenesis in the fetus until immediately after birth (Faulkner, 1983).

The fetus and placenta, which are washed by fetal blood (Basset et. al., 1985; Bassett, 1986; Hodgson et. al., 1991), are highly dependent on maternal plasma glucose concentration. The rate of glucose transfer is related to the gradient between the maternal and fetal portions of the placenta. Therefore, utilization of glucose by fetal tissues has a large impact on glucose transfer. Consequently, the concentration of insulin in the fetus plays a principle role in the regulation of glucose transfer from maternal circulation (Bassett, 1992).

Warnes et. al. (1977) reported high concentrations of glucagon in fetal pancreas and plasma, but glucagon was unresponsive to changes in plasma glucose concentrations.

Fetal growth hormone levels rose during hypoglycemia and fell during hyperglycemia, but cortisol was unresponsive (Faulkner, 1983). Shelly et. al. (1975) found infusion of adrenaline caused a rise in glucose concentrations.

Fetal Lipid

Faulkner (1983) stated most fetal lipids are synthesized from acetate and glucose in fetal liver and adipose tissue. Fetal lipids accumulate early in gestation and reach maximum levels several weeks before birth. Vernon (1980) found the rate of lipid synthesis from glucose in the fetus is twice that in the adult.

Most peripheral and abdominal lipid tissue consists of brown adipose tissue. Subcutaneous fat, mainly white adipose tissue, regresses in late pregnancy. Fetal utilization of white adipose tissue is hastened by maternal starvation in late pregnancy. As a result, concentrations of essential fatty acids are low in the fetus.

Glycogen stores in the fetal liver and skeletal muscle tend to increase throughout pregnancy. Fructose may act as a carbohydrate store since glucose is converted to fructose, with no conversion back. However, the enzymes required for fructose metabolism develop at birth, and most are excreted through the kidneys (Ballard and Oliver, 1965). Girard et. al. (1979) stated ewe starvation results in a shift from glucose to amino acid metabolism, with mobilization of glycogen and lipid reserves.

Placenta

Similar to the transfer of glucose from mother to fetus, glucose uptake by the

placenta from fetal circulation is regulated by concentration and number of transporter sites, and is not dependent on insulin (Di Giacomo and Hay, 1989; Hay, 1991). Placental size directly influences growth rate and subsequent perinatal lamb survival (Mellor, 1983; Bassett, 1986, Hay, 1991). Winter supplementation of ewes in mid-pregnancy may increase lamb survivability over non-supplemented ewes (Thomas and Kott, 1995). In extreme cases, reduced cotyledonary weights due to mid-gestation undernutrition, may not be corrected by excess feeding in late pregnancy. This may lead to reduced birth weight and lamb viability, especially when in young or poor conditioned ewes (Owens, 1985; Vincent et. al., 1985; Geentry and Rattray, 1987). Placental size may also influence milk production (Rattray and Trigg, 1979; Davis et. al., 1980). Differences observed between mammary gland sizes in single verses twin lambing ewes may be due to placental lactogens. Just prior to lambing, the drain of glucose by the developing fetus and associated tissues is compounded by the increasing uptake of glucose by the developing mammary gland.

Maternal Energy Reserves

There are several progressive changes that occur in the ewe from conception to parturition that ensure an adequate glucose supply for late pregnancy when fetal demands are high. In early and mid-pregnancy there is a general increase in energy stores in the ewe in the form of fat, increased adipoctye volume, and glycogen accretion (Faulkner, 1983). This process is facilitated by a decreased response of adipocytes to the catecholamines, an increase in the number of insulin receptors, and the lower fetal energy

drain. During late pregnancy, these stores are important. Several changes occur during this period of the production cycle to enhance the availability of these stores. In the last 8, 4, and 2 weeks of gestation, the fetus gains the equivalent to 85, 50, and 25 % of its final birth weight respectively (Robinson, 1983). During the last third of pregnancy there is a steady reduction in the capacity for lipid synthesis and a decreased sensitivity of adipocytes to insulin. Increased sensitivity of these cells to the lipolytic activity by the beta-adregnic agonists (Vernon et. al., 1981; Guesnet et. al., 1991) and a decrease in plasma insulin levels (Faulkner, 1983) result in increased circulating free fatty acids, B-hydroxybuterate, and ketones (Guada et. al., 1982). Bassett (1992) stated that an increase in plasma growth hormone often follows lipid mobilization in late pregnancy. Increased free fatty acid concentrations well prior to hypoglycemia, indicate a shift in the balance of substrates used by maternal tissues (Mellor et. al., 1987). This process is associated with decreased plasma insulin and increased plasma growth hormone (Bassett, 1974). Bassett (1992) reported the increase in growth hormone only occurred near partition and there was no significant relationship during the last six weeks of pregnancy and the total weight of lamb born per ewe. Lamb birth weights were negatively correlated with mean plasma glucose and plasma insulin and positively correlated with mean plasma free fatty acids (Bassett, 1992). Plasma pancreatic glucagon concentrations were not correlated with weight of lamb born. He also reported, increased autonomic nervous activity and the release of catecholamines are the most important mechanism for maintaining normoglycemia. Part of this effect is mediated through glucagon (Cryer, 1981; Gerich, 1988). Adrenaline infusions in late pregnant, fasted ewes resulted in rapid increases in

plasma glucose concentrations, with elevated levels maintained for many hours (Bassett, 1971; Leenanurksa and McDowell, 1985). Noradrenaline infusion under these same conditions increased plasma free fatty acids similar to adrenaline, but only caused a slow, continuous increase in plasma glucose and insulin concentrations with the addition of cortisol. Girard et. al. (1979) found the contribution of glucose to oxidative metabolism falls to 30 % in the starved pregnant ewe with increasing oxidation of amino acids.

Maternal Protein

There is also a simultaneous deposition of protein in the liver and muscle. Faulkner (1983) reported an 8.5 % increase in lean tissue during early and mid-pregnancy. He also stated in late pregnancy there is a mobilization of liver and muscle protein reserves irrespective of maternal crude protein intake, indicating possible hormonal control. Hay (1991) reviewed the accumulation of amino acids in the fetal blood due to active transport by the placenta. Everts (1985) reported lamb birth weights have responded to rumen undegradable protein (UDP). Bassett (1992) stated gluconeogenic amino acids play a role in modulating glucose metabolism in the utero placenta. Fetal urea synthesis in late pregnancy indicates that amino acids comprise 30 to 60 % of fetal oxygen consumption (Lemans and Schreiner, 1984; Faichney and White, 1987). Ewes appear to become more efficient in utilizing digested nitrogen (Faulkner, 1983). Graham (1968) reported when food intake was reduced by 75 %, urea excretion by the non-pregnant ewes declined. However, excretion by the pregnant ewes increased or declined to a lesser extent than the non-pregnant ewes.

Physiology

In ruminants, glucose supply and responsiveness to insulin are normally limited. The further antagonism of insulin action may offer little additional advantages during late gestation as insulin resistance in late pregnancy diminishes sensitivity to insulin of several parameters of whole-body glucose utilization (Petterson et. al., 1994). However, conflicting data state that late pregnancy has no major adverse effects on the handling of large intravenous glucose loads by well nourished ewes (Bassett, 1989). It appears that quantity of UDP had little influence on serum insulin concentrations. Ewes fed supplements with the highest biological value had the lowest blood insulin levels while those fed supplements with the lowest biological value had the highest insulin values (Peterson et. al., 1992). Harmon (1992) reported dietary protein is a stronger stimulator of insulin release than glucose and propionate and Gambill et. al. (1994) stated without reservation that the addition of UDP in supplements increased the quantity of crude protein available for intestinal absorption. Thomas et. al. (1994) reported a linear increase in body weight gain and serum total protein concentrations in wethers as feather meal replaced soybean meal.

Digesta Kinetics

The degradation of true dietary protein in the rumen declined by about 50 % and protein digestion distal to the stomach increased by 20 % from conception to late pregnancy (Faichney and White, 1988). There was a highly significant ($P<.01$) increase in the flow of non-ammonia nitrogen to the small intestines as pregnancy progressed. These

researchers also reported a small but highly significant ($P<.01$) increase in digestibility distal to the stomach. The amount of microbial nitrogen in the rumen declined during gestation when expressed in grams and as a proportion of the non-ammonia nitrogen pool. Microbial nitrogen flow from the stomach decreased during gestation, and the contribution of microbial nitrogen to non-ammonia nitrogen leaving the stomach declined by approximately 40 %. Water intake increased during late gestation (Faichney and White, 1988) and fluid transit times decreased (Faichey and White, 1988; Coffey et. al., 1989; Gunter et. al., 1989). Faichney and White (1988) suggested the low concentrations of cations indicated by the low osmolarity may have been responsible for reduced microbial growth and efficiency. Although net microbial protein synthesis decreased and degradation of dietary protein in the rumen was reduced, the net result was an increase in the digestion of protein in the intestines. This occurs at a time when amino acid supply is important for fetal growth. Gunter et. al. (1989) reported a reduction in both gastrointestinal and ruminal mean retention time of 5.8 and 6.3 hours respectively.

Environmental Temperature

Winter shearing of pregnant, cold exposed ewes has been shown to increase lamb weight per ewe (Rutter et. al., 1972; Austin and Young, 1977) and lamb survival rate (Rutter et. al., 1972). Cartsens (1994) stated that shearing of pregnant ewes increased feed intake, but subsequent increased lamb birth weight was a consequence of cold exposure and not the level of intake (Rutter et. al., 1972; Thompson et. al., 1982; Symonds et. al., 1986). Thompson et. al. (1982) stated that increased birth weight could

be a result of increased plasma glucose concentration in the cold stressed ewe, this is supported by Stevens et. al. (1990) who reported infusion of glucose into the fetus resulted in increased birth weight. Cold stressed ewes also exhibited changes in glucose metabolism, fat mobilization, fatty acid oxidation, respiration rate, and ewe rectal temperatures (Fennessy and Owens, 1985; Symonds et. al., 1986, 1988; Black and Chestnutt, 1990). The changes seen in the shorn animal are consistent with those observed due to increased sympathetic activity (Bassett, 1992). Weekes et. al. (1983) stated the elevated sympathoadrenomedullary activity during cold exposure inhibits insulin secretion. Samson et. al. (1983) found prolonged gestation and increased cortisol levels in cold stressed ewes. Glucagon, together with catecholamines and corticosteriods, is the major hormone regulating glucostasis during stress, but may depend on the substrates employed (Weekes, 1991). McBride and Christopherson (1984) found lactation was adversely affected when cold stressed ewes were required to nurse more than one lamb. Heat stress reduces lamb birth weights and survivability (Shelton and Huston, 1968; Alexander and Williams, 1971), due to a reduction in maternal glucose concentrations (Shelton and Huston, 1968).

Lactation

Rattray (1992) postulated feeding during lactation has a greater effect on total lamb production than feeding during gestation. However, Mellor and Murray (1985a) and Mellor et. al. (1987) reported undernutrition in late pregnancy retards udder development. Also, Davis et. al. (1980) determined productivity per unit of udder tissue was similar in ewes suckling singles or twins. Milk production from ewes suckling twins may be 20 to 50% higher than that of ewes suckling singles and production from triplets may be 15 to 20 % higher than twins (Treacher, 1983; Hough et. al., 1986; Rattray, 1986). Other factors that affect milk production are the number suckling, level of udder evacuation, and the suckling stimulus effects on prolactin and oxytocin (Treacher, 1983; Loerch et. al, 1985; Rattray, 1986).

Nutrition

When Treacher (1970) held ewes at the same weight for the last trimester, these ewes produced milk with higher concentrations of fat and protein and decreased lactose on days one and three than ewes gaining normally. He explained this as a slower onset of lactation with persistence of milk with colostrum-like characteristics. Live weight changes in lactation were in the inverse order to gains in late pregnancy. Ewes that gained no weight during pregnancy gained weight during the first 6 weeks of lactation (Treacher, 1970). Milk yield increased as the digestibility of crude protein fed decreased. Live weight gain during the last 8 weeks of gestation was affected by protein level. Net body weight

change was affected by level and type of protein fed (Forbes and Robinson, 1967). Ewes on lower levels of protein intake during pregnancy tended to lose less weight during lactation than those on the higher levels. Ewe live weight loss during early lactation, lamb growth rates from birth to 3 weeks, and ewe milk yield tended to decrease with decreased protein intake during pregnancy (Robinson and Forbes, 1967). Cows fed a diet high in UDP prepartum produced milk containing a higher mean percentage of protein (Van Saun et. al., 1993). However, the diets were not isonitrogenous for total crude protein intake, and it is therefore risky to conclude the variation observed was due to differences in rumen degradability. Also, prepartum body weight gain and milk production increased quadratically in response to an increased prepartum crude protein intake. Sahlu et. al. (1995) reported milk fat, protein, and SNF were affected quadratically by increased prepartum crude protein intake.

Physiology

There are several fundamental differences between maintenance of glucose homeostasis in pregnancy and lactation, primarily due to a continual decrease in insulin concentrations despite normoglycemia. During lactation in sheep, insulin at physiological levels failed to stimulate net glucose utilization (Vernon and Taylor, 1988) or acetate utilization for fatty acid synthesis in adipose tissue (Vernon and Finley, 1988). The ability of insulin to increase lipogenesis (Vernon and Finley, 1988) and activate the lipogenic enzyme acetyl-CoA carboxylase was blocked by somatotropin in adipose tissue (Vernon et. al., 1988). This causes a repartitioning of nutrients away from the peripheral tissues

(NIMGU). The response to catecholamines is enhanced during lactation in sheep (Vernon and Finley, 1985). The ability of high producing cows to maintain elevated glucose output with reduced cortisol levels, suggests cortisol has only a small role in the glucose homeostasis of lactating cows (Weekes, 1991). The rate of lipolysis is regulated by the availability of the blood carrier albumin. The saturation of the carrier binding sites leads to an accumulation of fatty acids in the adipocyte and a decrease in the rate of lipolysis (Vernon and Peaker, 1983b). Intake of the lactating ewe will increase and peak at week 5 or 6 (Bocquier et. al., 1987). Peak milk production usually occurs during week 2 or 3 (Rattray et. al., 1982; Treacher, 1983; Rattray, 1986). Rattray (1992) concluded that lipolysis is stimulated by noradrenaline levels and the rate is dependent on adipocyte cell volume.

Immunology

Brambell (1969) determined syndesmochorial placentation in the ruminant animal prevents transplacental transfer of antibodies during gestation. Because of this type of placentation, the ruminant fetal immune system is immature at birth in comparison to other species. Offspring of ruminants are born agammaglobulinemic. It is not until six months of age that calves will have immune responses similar to the adult ruminant. Newborns are, therefore, dependent on the colostrum of dams to provide passive immunity. Halliday (1978) stated there are three main antibody classes in sheep: 1) immunoglobulin M (IgM) is a macroglobulin produced early in the immune response; 2) immunoglobulin A (IgA) is preferentially secreted by various glands and secretory IgA plays a major role in the defense of the digestive and respiratory tracts; 3) the principal immunoglobulin of serum and the major component of colostral immunoglobulins is immunoglobulin G (IgG).

Mortality

The technology currently exists to substantially increase the proportion of ewes giving birth to multiple lambs. However, as lambing rate increases, mortality rate also increases (Jordan et. al., 1988). Safford and Hoversland (1960) reported the total death loss of lambs from birth to weaning in 1952 through 1954 was 23.5 % of the lambs born. Autopsies were performed on 14.7 % of these lambs to determine the cause of death. Lamb deaths attributed to predation were not included in the autopsy results. Seventy-

two percent of the deaths could be classified into 5 major categories. These were pneumonia (16 %), unknown (15.8 %), stillborn (14.3 %), starvation (13.8 %), and dysentery (11.8 %). The remaining 28 % were due to delayed birth, enterotoxemia, prepartum death, liver rupture, and anomalies. Of the lambs that were examined, 56 % died in the first 3 days of life and 73 % in the first 5 days. In a more recent study, Kott and Thomas (1987) reported the percentage of lambs weaned in Montana increased by 17 % between 1967 and 1984. During this period, there was a small decease in lamb mortality. They stated the major causes of death for lambs in 1982 through 1984 were predation (35.5 %), weather (30.6 %), disease (9.1 %), and lambing complications (8.9 %). They concluded most of the deaths could be corrected by implementing improved management strategies.

Mammary gland

Campbell et. al. (1977) stated during the latter part of gestation the concentration of serum Ig's decrease due to their transfer to the mammary gland. This accumulation begins 12 days prepartum and reaches high levels 3 d before lambing. Colostrum yields from each teat are very similar, and therefore the amount of colostrum lambs obtain from suckling one teat are strongly correlated with the amount obtained by milking the other teat (Halliday, 1978). However, there are usually enormous variations in total yield of colostrum and subsequent Ig concentrations within any group of ewes.

Approximately 80% of colostral immunoglobulin is subclass IgG, specifically IgG_1, although all subclasses of immunoglobulin are present in colostrum. Initially, the

immunoglobulin in mammary secretion was believed to be of two origins. It was thought to be serum derived or produced locally by lymphoid cells found near the glandular epithelium. Applied research resolved that the majority of immunoglobulin in colostrum is serum derived. Smith et al. (1946) determined colostral immunoglobulin was similar to serum-globulin with respect to size, electrophoretic mobility, and precipitation characteristics. Larson and Kendall (1957) reported a decrease in serum-globulin levels as cows near calving. Dixon (1961) also reported a decrease in serum-globulin corresponding with a proportional accumulation in colostrum near calving.

The transfer of immunoglobulin, specifically IgG_1, from dam serum into the mammary gland is selective (Brandon and Lascelles, 1973). However, IgG_1, is the only immunoglobulin selectively transferred from serum to colostrum. The transfer of IgG_1 is active, selective, and receptor-mediated. The IgG_1 diffuses from the blood across the vascular epithelium and is bound by specific IgG_1-Fc receptors on the basal membrane of the mammary secretory epithelium. The IgG_1 is then taken up by micro pinocytotic vesicles that transverse the epithelial cells which secrete the IgG_1 into colostrum. The number of IgG_1-Fc receptors increases dramatically during colostrum formation, accounting for the selective transfer of IgG_1 (Sasaki et al., 1977).

Colostral immunoglobulin concentrations are 5 to 10 times greater than serum concentrations. The IgG concentrations in colostrum, however, are extremely variable. The average concentration is 100 mg/ml of colostrum (Halliday, 1978). Long gestations are correlated with increased immunoglobulin concentrations in the mammary gland prior to birth, while decreased colostral IgG concentrations are associated with premature

births. Gilbert et. al. (1988) found a linear increase in colostral IgG_1 with increased litter size and higher concentrations of IgG_1 in yearling colostrum. They concluded this was a function of a similar mass of Ig in a smaller volume.

Lamb immunology

Consumption of dam colostrum by newborn ruminants confers near adult levels of immunoglobulin immunity (Newby and Bourne, 1977). Colostrum protects young from septicemia, and enteric and respiratory infections. However, to be effective, colostral consumption must occur within the first 24 to 48 hours of life prior to closure (Besser, 1994). Closure is a natural process which marks the end of non-specific macromolecular transport of immunoglobulin across the epithelium of the small intestine in the calf. To confer protective immunity, enough colostrum must be consumed by the calf to allow for calf serum concentrations to reach $\geq$ 10 mg/ml.

Halliday (1978) reported when lambs were fed at 1 and 7 hr, those lambs which obtained high concentrations from the first feeding absorbed relatively little from the second feeding. Absorption of Ig from colostrum is a non-selective process and is affected by many factors. Concentrations tend to be positively correlated to gestation length and negatively correlated to with dam's serum and litter size. Holliday (1978) reported colostrum production does not increase sufficiently with the number of lambs born to compensate for the greater needs of multiple litters. However when large amounts of colostrum are produced, the concentration of Ig is relatively low, but more Ig is available. Also, lamb vigor plays an important role in increasing absorption. Transfer of

Ig is lower from ewes with their first litters due to incomplete mammary development and inexperience in lambing. Furthermore as the date of lambing in the spring advances, the concentrations obtained by lambs declines. Gilbert et. al. (1988) reported similar results and indicated most of the variation associated with day born could be explained by changes in maximum temperature. Halliday (1978) stated that no connection between lamb serum or colostrum concentrations of Ig or subclasses of Ig and survivability could be made as the antibodies need to be relevant to the local disease situation.

Gilbert et. al. (1988) reported low correlations between serum IgG1 concentrations at 36 hr and performance of surviving lambs through increased disease susceptibility. Conversely, McGuire et al. (1976, 1983) reported increased susceptibility to disease and death loss has been associated with low serum immunoglobulin concentrations in newborn lambs and calves. Incidence of disease is related to failure of passive transfer of immunity at birth. Failure of passive transfer is often due to management factors (ie. newborn does not suckle) and(or) age of dam at parturition. Age of dam is a limiting factor in that mammary development is not as great in younger dams (two year olds) as in mature dams.

Nutrition

Strategic short-term supplementation using protein meals is an effective way to increase the nutritional status of pregnant ewes, and consequently lamb birth weights and associated lamb survival should increase (Stephenson and Bird, 1992). Burfening and Kott (1993) found supplementation during the last 21 d of gestation and the first 23 d of

lactation significantly improved lamb survival and growth rate of lambs born to ewes in relatively poor body condition. However even with these findings, few researchers speculated in detail how nutrition influences lamb survivability.

Blecha (1981) reported calves from first-calf beef heifers fed a restricted prepartum protein diet had a reduced ability to absorb IgG from pooled colostrum. Holland et. al. (1987) fed a restricted prepartum protein diet to first calf beef heifers with either an identical twin or full-sib embryo. They reported the restricted intake heifers produced a smaller volume of colostrum with higher concentrations of Ig. When the total grams of IgG were compared, the amount was similar between the two groups. Also, calves fed restricted dam's colostrum had higher serum concentrations of IgG and IgM. Undernutrition in late pregnancy reduces colostrum yield and subsequent secretion rates (Mellor and Murray, 1985a, 1985b; Mellor et. al., 1987; Robinson, 1990a). Mellor and Murray (1985) found that underfeeding ewes reduced colostral yield by 79 % at the one hour postpartum milking with a reduced yield out to 18 hr postpartum.

Rumen undegradable protein

Dunn (1986) reported that in any feedstuff there is a portion of the crude protein unavailable for microbial degradation. This portion, called by-pass or rumen undegradable protein (UDP), passes through the rumen and is degraded in the lower gastrointestinal tract. Due to different feed processing methods, the amount of UDP in feeds differs (NRC, 1985). The amount of UDP is also dependent on the source of the feed. Animal by-products tend to have a higher proportion of UDP than plant derived feeds. NRC (1985) divided protein into three categories based on UDP percentage: low by-pass (less than 40 %); medium by-pass (40-60 %); and high by-pass (greater than 60 %).

Murphy et. al. (1992) concluded feather meal is a suitable range supplement as long as rumen degradable crude protein requirements were met first. Thomas and Beeson (1977) reported steers fed feather meal (FM) had decreased rumen ammonia concentrations and crude protein digestibility than those fed soybean meal (SBM), with no differences in nitrogen retention. Cozzi et. al. (1995) reported that a lamb finishing diet containing a mix of SBM, BM, and FM resulted in a more balanced fermentation pattern leading to an increase in feed efficiency when compared to a diet were SBM was the only protein source. Gambill et. al. (1994) stated without reservation that the addition of UDP in supplements increased the quantity of crude protein available for intestinal absorption. Harmon (1992) stated dietary protein was a potent stimulator of insulin release in comparison to glucose and propionate. Peterson et. al. (1992) concluded the quality of UDP had little influence on serum insulin concentrations and feeding supplements with the

lowest biological value had the greatest influence on insulin concentration. McFaddin et. al. (1996) reported a decrease in kg of lamb weaned when ewes were supplemented on New Mexico range with a UDP supplement compared to a RDP supplement. Appeddu et. al. (1996) reported cows fed a UDP supplement repartitioned nutrients away from milk production in early lactation as calves from these cows had lower weights throughout the study. This reduced cow body weight loss and increased the number of cows rebreeding during the first 21-d breeding period. However, no advantage was realized over the entire breeding period. When cows were fed 4.5 kg of hay on winter range and supplemented with either a SBM-based supplement or a SBM-based supplement that was 13 % FM, the addition of FM reduced body weight loss (Murphy et. al., 1992). However there was no difference when winter range was the sole source of forage.

MSU Research

Miner and Peterson (1989) suggested that BM increased fermentation rate by supplying a slow release of amino acids or carbon chains that stimulated microbial activity. Wiley et. al. (1991) concluded that cows fed a UDP supplement had increased postpartum weight gain and reduced postpartum interval. Hoagland et. al. (1992) increased blood albumin, protein, glucose, and blood urea nitrogen concentrations, wool growth and ewe body weight change by feeding BM compared to urea and SBM. Padula et. al. (1992) concluded ewes consuming a low quality roughage should be fed a high starch supplement. Also, protein utilization was improved by feeding a high by-pass supplement when the primary source of carbohydrate available was cellulose. Schloesser et. al. (1993)

reported substituting SBM with BM failed to show any enhancement of the nutritional status of pregnant ewes. Soder et. al. (1993) reported protein supplementation had no effect on fecal output or forage dry matter intake when ewes were grazing winter range. Thomas et. al. (1994) determined a linear increase in body weight gain and serum total protein concentration as FM replaced SBM in a diet fed to wethers. Roeder et. al. (1996) reported ewes fed a diet high in UDP showed few additional advantages over ewes fed a more conventional diet containing SBM. Thomas and Kott (1995) summed several years of winter supplementation research by concluding protein supplementation was of little value unless ewes could not afford to lose weight, needed to gain weight, or winter weather reduced forage intake. Substitution of SBM of alfalfa based supplements with UDP supplements, such as BM or FM, was recommended only when an advantage in cost per unit protein was realized.

EXPERIMENTAL PROCEDURE

Beginning in March, 1995 a trial was conducted at the Montana State University, Ft. Ellis Research Ranch near Bozeman, Montana. At shearing, fifty-eight mature (3 to 5 y of age) Targhee and Columbia ewes carrying twins were stratified by breed and randomly allotted to one of three treatment rations. Fetal numbers were estimated using real-time ultrasound diagnosis. Feeding of rations began approximately three weeks prepartum in March of 1995. All ewes were individually fed both hay and concentrate portions of the diet.

Rations

In the morning (0630 h), ewes were fed either .42 kg of a restricted (RES), .42 kg of a soybean meal (SBM), or .37 kg of a blood meal-feather meal mix (BM-FM) concentrate (Table 1). After all ewes had consumed their supplement (at approximately 0715 h), they were released into a large dry-lot with access to water and a trace mineralized salt. In the evening (1800 h), ewes were sorted, penned, and individually fed an 8 % crude protein, long stem, alfalfa-grass hay at a rate of 1.8 % of body weight (Table 2). Pens were cleaned and refused hay was collected and weighed. Refused hay was composited daily by feed group and reweighed after one week of collection as a quality control measure. For every 1000 g of refused hay, 100 g was taken as a sub-sample for nutrient analysis. Following parturition, ewes were group fed 2.3 $kg^{-1}hd^{-1}d$ of the alfalfa-grass hay and .45 $kg^{-1}hd^{-1}d$ barley. Ewes were fed in groups of twenty based on

parturition date alone.

Concentrates were formulated so that ewes total diet met either 75 % for RES or 100 % for SBM and BM-FM of NRC (1985) CP requirements for ewes during the last four wk of gestation (180 to 225 % lamb rate expected). All diets provided 100 % of the NRC requirement for DE and a minimum of 100 g/d RDP, while UDP intake varied. The RES and BM-FM diets were formulated to be isonitrogenous for total crude protein intake. After formulation, hay and concentrate samples were ground through a 1mm screen in a Wiley mill and analyzed for DM, ash, CP, (AOAC, 1984) and ADF (Van Soest and Wize, 1967) and ADIN (Goering and Van Soest, 1970). Crude protein of the concentrates were 11, 24, and 26 %, while UDP percentages were 32, 34, and 61 for RES, SBM, and BM-FM respectively. The amount of BM-FM concentrate fed was adjusted to .37 kg to achieve correct protein intakes.

Ewes

Ewes were weighed and body condition scored on two consecutive days at the beginning of the trial. Body condition was based on a scale of 1 to 5 with a score of one designating an emaciated ewe and 5 designating an obese ewe (Russel et. al., 1969). Weights and condition scores were taken weekly to 3 wk postpartum and at turnout to summer range (approximately one month postpartum).

Ewes were bleed weekly through parturition. Blood samples were collected via jugular puncture (Lindsay, 1978) using nonhepranized vacutainers. Serum samples were analyzed for total protein (TP), creatinine (CRE), urea nitrogen (BUN), albumin (ALB),

and glucose (GLC). A serial bleed was conducted approximately one week prior to the start of lambing. Six ewes were randomly selected from each group and bled one hour preconcentrate feeding via jugular puncture. Ewes were bled hourly for a ten hr period and samples were analyzed for insulin and growth hormone.

At parturition, lambs were immediately separated from their dams. Colostrum let down was artificially stimulated by intra jugular injection of 2 ml of oxytocin (Hatfield et. al., 1993) and ewes were hand milked. Only data from ewes that had not been suckled prior to sampling were included in this portion of the trial. Colostrum volume was measured and 60 ml samples were taken for fat, protein, lactose, and SNF analysis. At 21 d of age, lambs were removed and milk let down was again artificially stimulated with oxytocin. Ewes were hand milked and samples were collected for fat, protein, lactose, and SNF analysis.

Lambs

Lambs were separated from their dams until colostrum samples were taken. A maximum of sixty ml of colostrum was fed to each lamb using an esophageal tube. Date of birth, time of birth, sex, birth weight, and amount of colostrum fed was recorded for each lamb. Lambs were given .5 ml of Bo-Se and navels were clipped to 7.5 cm and dipped in a 7 % iodine solution. A 2 hr lamb watch was maintained during the lambing period. Ewes and lambs were reunited after lambs were tubed. Lambs were ear tagged and Columbia rams were castrated. All dead lambs were autopsied and cause of death determined.

Statistics

Analyses were conducted using the GLM procedure of SAS (1988). The model used for analysis of all traits included the fixed effects of ration and breed of ewe. Date of parturition was included as a covariate in the analysis. Prepartum blood metabolites were analyzed using the split-plot-in-time. Because no treatment by time interaction was detected, a mean value for each ewe was calculated and analyzed using GLM. All two-way interactions were evaluated and if nonsignificant were removed from the model. Least significant differences were used to determine individual mean differences when F-values were significant ($P<.1$).

RESULTS AND DISCUSSION

Total feed intakes did not differ (P>.10) between treatments (Table 3). Total DM intakes were 1728.2, 1737.4, and 1657.4 g/d for RES, SBM, and BM-FM respectively. The respective total CP intakes for RES, SBM, and BM-FM were 164.9, 223.7, and 218.6 g/d. Expressed as a percentage of NRC requirements, they were 77.1, 104.5, and 102.1 % for RES, SBM, and BM-FM respectively. Diets were formulated to be approximately 75 % forage and 25 % concentrate (Table 4). Crude proteins expressed as percentages of the diets were 8.9, 12.0, and 12.3 % and ADF's were 29.7, 31.4, and 33.0 % for RES, SBM, and BM-FM respectively. RES and SBM had 5.2 Mcals of DE, while the BM-FM diet had 4.8 Mcals. All rations provided a minimum of 100 g/d of RDP (Table 5). The SBM and BM-FM were formulated to be isonitrogenous for total CP intake and yet differ by a minimum of 20 g/d RUP. While RES and BM-FM were balanced to provide equal amounts of RDP and differ in total CP intake.

Body condition scores (BCS) for RES, SBM, and BM-FM ewes were 3.0, 3.0, and 3.1 respectively when taken 3 wk prior to lambing. The BM-FM ewes had higher (P<.1) BCS at birth than either RES or SBM (Table 6). As there was no clear trend in the data, these results were noted with caution. Ration treatment had no effect (P>.10) on BCS in the three weeks from birth to peak lactation. A significant treatment by breed interaction occurred when ewes were body conditioned at turnout to summer range. Columbia ewes fed BM-FM diet prepartum had higher (P<.01) BCS at turnout (Table 7); however as there was no definite trend in the data, this finding was considered to be more

a function of chance than a treatment effect. By weaning, most ewes had attained a BCS similar to the 3 wk prepartum scores. Treatment had no effect on BCS change (Table 8). The RES, SBM, and BM-FM ewes lost 0.66, 0.64, and 0.53 BCS points from 3 wk prior to lambing to birth. Approximately one third of this loss or 0.2 points was lost due to dehydration in the lambing process, as all groups gained back BCS points the week following lambing. All treatment groups had a net loss of BCS to peak lactation with RES, SBM, and BM-FM losing 0.18, 0.23, and 0.44 points respectively. All treatment groups either remained constant or gained a slight amount of body condition from peak lactation to turnout. The net respective gains in BCS points from birth to weaning for RES, SBM, and BM-FM were 0.46, 0.47, and 0.41. However, a treatment by breed interaction was detected from day +21 to turnout for BCS change (Table 9). This appears to be a carryover effect detected in Table 7 and was considered a function of chance.

Ewe body weights at 3 wk prior to lambing for RES, SBM, and BM-FM were 71.9, 71.4, and 71.6 respectively (Table 10). Treatment had no effect on ewe body weight. Ewes lost an average of 13.5 kilograms at birth. This agrees well with Forbes and Robinson (1967) who reported an average weight loss at birth of 13.9 kilograms. Ewes fed the BM-FM diet lost less weight than SBM ewes in the week prior to birth and less weight in the last three weeks of pregnancy than ewes fed the restricted diet (Table 11). Forbes and Robinson (1967) reported an average ewe weight loss during the first three weeks of lactation of 4.9 kilograms compared to 6.2 kilograms for this study.

This work supports the data reported by Thomas and Kott (1995). They suggested feeding a high UDP supplement in mid-pregnancy will decrease ewe weight loss

when ewes are in poor condition or winter weather severe. They, however, reported no advantages in feeding ewes in good condition a high UDP protein supplement over a SBM supplement. The increase in weight associated with the time period just postpartum was due to the fact that the ewes were considerably dehydrated during birth. Ewe weights at parturition were recorded only after they had been milked dry and fetal membranes expelled. The loss of ewes from the data set for weight and condition score calculations was primarily due to the ewes losing one or both of the suckling lambs.

Both level and type of protein fed affected prepartum blood metabolites (Table 12). Thomas et. al. (1988) reported blood metabolite concentrations for the last four weeks of gestation. Total protein, albumin, and globulin concentrations were 6.6, 3.7, and 2.8 g/dl respectively. Blood urea nitrogen and glucose were 28.5 and 69.7 mg/dl. Most concentrations reported in this study agree with these findings. Lower blood urea nitrogen levels (28.5 vs. 9.9) can be explained by the increased nitrogen utilization of ewes carrying twins as described by Graham (1968). Sahlu et. al. (1995) determined plasma urea concentrations in goats fed increasing levels of protein increased quadratically, a response not observed in this study.

Albumin was higher ($P<.05$) in SBM and BM-FM than RES. However no speculation was made as numerous physiological factors impact this metabolite.

Sahlu et. al. (1995) also reported no time by treatment interaction of increased protein intake on total blood protein. Even though there was no interaction, serum total protein was higher ($P<.05$) in SBM and BM-FM than in RES ewes. However, the increase in total blood protein is probably a function of augmented circulating amino acids

absorbed from feedstuffs in the BM-FM ewes. Elevated levels of total blood protein in the SBM ewes could be explained by increased microbial outflow from the rumen; because SBM ewes, who had the highest total RDP intake, had the highest ($P<.05$) BUN concentrations. Blood urea nitrogen was lowest ($P<.05$) for RES ewes and BM-FM ewes had a BUN concentration intermediate to the other two diets. As RES and BM-FM were isonitrogenous for RDP, the difference in BUN levels may be attributed to increased hepatic catabolism of absorbed amino acids in ewes fed the BM-FM diet. This would indicate that in these late-pregnant ewes energy was more limiting than protein.

In contrast with this study, Stephenson and Bird (1992) reported lower concentrations of glucose in ewes fed a high RUP diet. Also in disagreement, Sahlu et. al. (1995) concluded creatinine increased quadratically as protein intake increased.

Previous researchers (Robinson and Forbes, 1967; Treacher, 1970; Mellor and Murray, 1985) concluded that restricted nutrient intake prepartum negatively influenced lactation. In contrast, reduced colostrum volume in RES ewes was not observed (Table 13). Conflicting results could be due to a higher level of protein intake and shorter period of nutrient restriction in this study. Thomas et. al. (1988) reported an average of 883 ml of colostrum from the first milking, while Pattinson et. al. (1995) had an average of 762 g. Using a density of 1.14 for colostrum calculated from this study, 762 g would be equivalent to 870 ml. Low colostrum production in this study could be attributed to breed. Thomas et. al. (1988) used a Finn/Targhee cross and Pattinson et. al. (1995) research was conducted with Suffolk/Cambridge ewes. However, all three studies agree there is a large degree of variation in the volume of colostrum accumulated prepartum.

Thomas et. al. (1988) determined the protein percentage and total grams of protein in the first milking were 18.3 and 160 respectively (Tables 13 and 14). With a protein concentration of 21.8, the findings of this study agree well. However, the average total grams of protein secreted in the first milking in this study was only 32.3 g compared to 160 g. Most of this variation can be explained by the large difference in volume. Thomas et. al. (1988) also reported a fat concentration of 16.0 percent, which agrees with the 18 percent average recorded for this study (Table 13).

The increased ($P<.05$) concentration of protein and SNF in the colostrum of BM-FM is probably a function of similar amounts of metabolites in a smaller volume and is in agreement with Holland et. al. (1987) and Gilbert et. al. (1988). Although the BM-FM ewes secreted approximately half the total grams of protein (Table 14), there was no treatments effect.

Ewes fed the BM-FM diet tended to have a higher ($P<.17$) concentration of IgG in their colostrum (Table 14). As approximately half of the protein in colostrum is comprised of immunoglobulin protein, a higher colostral protein concentration might indicate elevated levels of immunoglobulin. The average colostral IgG concentration of 187 mg/ml reported in this study is higher than most levels reported in the current literature. However when converted to a total grams of IgG produced on a dry matter basis, the average of 26.4 g is lower than other studies. Thomas et. al. (1988) reported a concentration of 61.3 mg/ml and a total production of 49.3 g of IgG. Pattinson et. al. (1995) and Gilbert et. al. (1988) reported concentrations of 116 and 69 mg/ml respectively. As ewes on this study secreted only half the volume of colostrum in the first

hour when compared to other studies, the elevated levels of IgG may again be a function of a similar mass in a smaller volume. Although the total grams of IgG reported for this study is approximately half that found by Thomas et. al. (1988), they make no mention of converting to a dry matter basis. With colostrum being between forty and fifty percent dry matter, the numbers would be comparable.

Lambs born to ewes fed the BM-FM diet prepartum had higher ($P<.05$) concentrations of serum IgG at three d than RES (Table 15). This agrees with Holland et. al. (1987) who found that calves nursing cows with higher concentrations of IgG in their colostrum had significantly higher levels of serum IgG. Blecha et. al. (1981) reported that calves born to cows fed a prepartum diet deficient in protein had a reduced ability to absorb IgG from colostrum. One major difference between the Holland and Blecha study was that Blecha fed pooled colostrum. As more research is currently in progress on how other colostrum metabolites influence absorption, Blecha results may be misleading. It is quite possible that another colostral component may facilitate absorption of IgG. We already know that restricting nutrient intake in late pregnancy reduces the total colostral volume, but elevates the concentration of the metabolites. By feeding pooled colostrum, a researcher would inadvertently remove a natural process that allows the newborn to compensate for an inadequate volume of colostrum.

The average lamb serum IgG concentration of 61.3 mg/ml is in agreement with the current literature. Gilbert et. al. (1988) found an average serum IgG concentration of 31.3 mg/ml. Our study supports Gilbert et. al. (1988) who found no difference in serum IgG concentration between male and female lambs taken at three d of age. They indicated

there was a low correlation lamb serum IgG concentration at three days of age on dam's colostral concentration. They also reported a decline in lamb serum IgG as the lambing season progressed and a low but positive correlation between lamb serum IgG concentration and weaning weight. Due to the large number of observations used in the study, they were able to conclude the heritability of colostral IgG concentration was .19. These researchers did not find a difference in colostral concentration of IgG between Targhee and Columbia ewes. Contrary to their study, we observed a mean concentration of 167 and 207 mg/ml for Targhee and Columbia respectively.

A treatment by amount of colostrum fed interaction was detected with the lamb serum IgG concentrations at three days (Table 16). Suckled lambs were lambs which had already removed the wax plug from the teat before separation was possible. With the other two groups of lambs, the ewes were milked out completely at birth. If the ewe secreted enough colostrum for both sampling and tubing, the lambs were given a maximum of 60 ml of colostrum. Eleven ewes in this analysis did not secrete enough for both and the lambs were placed back with their dams without receiving any first hour colostrum. These lambs did have ad libitum access to the subsequent colostrum. An important factor to note is there was no difference in the serum concentrations of IgG at three d between lambs that naturally suckled and those that were tubed. Some concern was expressed prior to the study that a reduced ability to absorb IgG due to the fact that tubing might not activate the esophageal groove closure reflex. Even though the lambs were immediately placed back on the ewe, lambs not receiving any first hour colostrum had lower concentrations in the RES and BM-FM groups. Another interesting note is that