DIGESTIVE AND METABOLIC CHANGES IN FALL-CALVING BEEF COWS DUE TO STAGE OF PRODUCTION AND EARLY POSTPARTUM PROTEIN SUPPLEMENTATION

By

JUAN MANUEL GONZALEZ

Bachelor of Science in Agriculture

Oklahoma State University

Stillwater, Oklahoma

1984

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 1987

DIGESTIVE AND METABOLIC CHANGES IN FALL-CALVING BEEF COWS DUE TO STAGE OF PRODUCTION AND EARLY POSTPARTUM PROTEIN SUPPLEMENTATION

Thesis Approved:

Charles A. Hibbard
Thesis Adviser

David S Buchanan

Rodney D. Geisert

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGEMENTS

Sincere appreciation to my advisor, Dr. Charles Hibberd for his assistance and guidance during my studies at Oklahoma State University. Also thanks to members of my committee, Dr. David Buchanan and Dr. Rodney Geisert. The friendship of other fellow students has made my stay at OSU most pleasant. Special thanks to laboratory assistance of Stephanie and Tana as well as assistance of Ron and Bruce.

A very special thanks to my parents for their economic and moral support and to my fiancee Isabel for her patience and understanding.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The gestating cow undergoes a series of metabolic and digestive changes that prepare her for the increased nutrient demand from both the growing fetus during the last trimester of gestation and the mammary gland at the onset of lactation. In late gestation, 69% of fetal energy consumption is through oxidative metabolism, which is dissipated as heat, reducing the efficiency with which metabolizable energy is used (Bauman and Currie, 1980).

Reduced intake as high as 12 percent due to decreased ruminal capacity has been reported during the last two weeks of gestation (Jordan et al., 1968). Consequently, the cow experiences an even greater energy deficit which forces mobilization of body fat.

At the onset of lactation, nutrient demands from the mammary gland receive priority over peripheral body tissue. Nutrient deficiencies are met by partitioning nutrients from body reserves either directly to the mammary gland or to the liver for recycling and transport to the mammary gland. Increased feed intake following parturition (Hartnell and Satter, 1979) aids in reducing the nutrient deficiency.

Quality of native tallgrass species in Oklahoma decreases dramatically from late July to early April. Waller et al, (1972) observed increased dry matter content of the forage (56.5 to 96.0%), increased crude fiber (33.1 to 43.1%) and decreased crude protein to as low as 1.95% in March. Fall-calving beef cows typically calve in September and October so that nutrient requirements are highest in the fall. Dry matter content ranged from 66.5 to 94.4% from October to December. Crude fiber content in the fall months ranges from 35.5 to 38.6% while crude protein content falls as low as 2.63%.

A 550 kg mature beef cow in the last third of gestation requires 5.9% crude protein and 52% TDN (NRC., 1984). Poor forage quality coupled with decreased forage intake during late gestation leaves the cow nutrient deficient. At parturition, fall-calving beef cows experience a marked increase in nutrient requirements for milk production. Crude protein requirements for a 550 kg lactating beef cow rise to 9.2% and TDN requirements to a minimum of 55% (NRC., 1984). Although forage intake may increase during the first few months postpartum, the lactating beef cow may be unable to meet her requirements because of the increased nutrient demand for milk production and the continuous decline in forage quality through the fall and winter.

Protein supplementation of fall-calving beef cows is frequently initiated in November or December in Oklahoma to

help reduce the protein deficit in the lactating cow. Supplementation of low-quality roughages with small quantities (.5 to 1.0 kg) of concentrated protein sources increases both forage digestibility and intake as a result of increased microbial activity and faster particulate rate of passage (Lyons et al., 1970; Kartchner, 1980). Early postpartum supplementation of lactating beef cows with small quantities of protein should increase forage digestibility and intake resulting in higher total energy and protein intake. Consequently, reduced body weight loss and increased milk production should result in heavier calf weights at weaning. Improved nutritional status should increase conception rates as well.

The extent to which digestive and metabolic parameters of the fall-calving beef cow change through late gestation and early lactation is unclear. In addition, the magnitude of the response of early-lactation beef cows to protein supplementation is unknown. The purpose of this study was to characterize digestive, ruminal and blood parameters associated with metabolic and digestive changes occuring in late gestation and early lactation of fall-calving beef cows. Also, the digestive and metabolic responses to early postpartum protein supplementation were evaluated.

CHAPTER II

LITERATURE REVIEW

Metabolic Changes from Late Gestation through Early Lactation

Nutrient demands from the developing fetus, uterus and mammary gland require metabolic changes in the cow during the last one-third of gestation. Bauman and Currie (1980) estimate a difference in nutrient requirement of up to 75% between gestating Holstein cows at the end of pregnancy and unbred Holstein cows. They also reported that nutrient demands during the last two months of pregnancy are equivalent to that of a cow producing 3 to 6 kg of milk per day.

Fetal demands include growth and oxidative metabolism. Battaglia and Meschia (1978) reviewed available research results and indicated that fetal tissue consumes seven to nine ml oxygen/kg fetal weight. For cattle in late pregnancy, 2.3 Mcal/d of energy were consumed in oxidative metabolism compared to only 1 Mcal/d accumulated in the fetus; thus, roughly 69% is dissipated as heat (Bauman and Currie, 1980). The great maintenance cost of the conceptus explains the low efficiency (25%) with which metabolizable

energy is used by the gestating cow (Moe and Tyrrel, 1972; Blaxter, 1962). The metabolic cost is even higher since the substrates used for oxidative metabolism in fetal tissues are glucose (50 to 70%) and lactate (20 to 25%) with amino acids providing the remaining metabolic fuel (Bauman and Currie, 1980). Glucose concentrations increase even when intakes are kept constant suggesting gluconeogenesis (Bennink et al., 1972). The substrates used in the liver for gluconeogenesis are propionate, amino acids, lactate and glycerol. High fetal uptake of amino acids (1.5 g N/kg/d) is roughly twice the quantity (.65 g N/kg/d) accumulated in the fetus indicating high amino acid catabolism via gluconeogenic pathways in the fetus or placenta (Bauman and Currie 1980). Even though fructose is found in significant quantities in the fetus, it serves as a source of energy storage for the conceptus.

In late gestation, mammary development overlaps with rapid conceptus growth which further increases the nutrient demand from the dam. Consequently, mobilization of body fat may be necessary to meet gestational energy requirements resulting in both a decrease in lipogenesis (Mcnamara and Bauman, 1978; Vernon et al, 1981), and an increase in lipolysis (Sidhu and Emery, 1973; Metz and van den Bergh, 1977). Because most of the substrates used in oxidative metabolism and mammary development are also used for fetal anabolism, regulation of nutrient partitioning

during pregnancy involves homeorrhetic controls arising from the conceptus (Bauman and Currie, 1980).

During late gestation, the cow must prepare for the onset of lactation. Consequently, hormonal changes are observed during late gestation setting the stage for regulation of nutrient flow during lactation. The increase in placental lactogen coincides with the period of rapid growth of the fetus (Currie et al., 1977; Chan et al., 1976). Kaplan and Grumbach (1974) proposed that placental lactogen in ewes coordinated maternal liver and adipose tissue metabolism in a way to supply nutrients to the developing fetus. This homeorrhetic control has not been established definitively, but rather the hypothesis based on positive relationships between placental lactogen concentrations in maternal serum and blood concentrations of free fatty acids, number of fetuses, or birth weight of the fetus. Estrogens and progesterone could also participate in controlling nutrient partitioning since changing the ratio of estrogen to progesterone alters the blood supply to the uterus, therefore affecting nutrient availability to the fetus (Caton et al., 1973). Two to three weeks before parturition, progesterone levels decrease and progesterone receptors in the mammary gland decrease resulting in increased synthetic activity of mammary tissue (Shymala and McBlain, 1979). Simultaneously, estrogen levels rise followed by a prolactin surge and an increased number of prolactin

receptors in the mammary tissue (Meites and Clemens, 1972). All of the above changes play a positive role in growth and development of the mammary gland.

Parturition and Lactogenesis

At parturition, the mammary gland receives priority over other body tissues for the synthesis and secretion of milk. Nutrients required during lactation are water, glucose, amino acids, fatty acids, calcium and potassium. Because of the great demand for these nutrients, negative balances occur early in lactation and could be as much as 7 kg/d of lipid, 3 kg/d of glucose, 330 g/d of amino acids and 7 g/d of calcium, depending on the productivity of the cow (Convey, 1974; Bauman and Currie, 1980; Mepham, 1982; Bauman and Elliot, 1983). Nutrient deficiencies are met by partitioning nutrients from body reserves either to the liver for recycling and transport to the mammary gland, or sent directly to the mammary gland. The major changes involved in setting metabolic priority of the mammary gland include a shift in blood flow to the mammary tissue, a decrease in use of these nutrients by peripheral tissues and an increase in metabolic activity of mammary tissue. The endocrine control of these events is accomplished through changes in hormone concentration in the blood and sensitivity to hormones such as growth hormone, prolactin and thyroxine caused by alteration in hormone receptor population.

As mentioned earlier, nutrients required for lactation include glucose, amino acids, fatty acids and calcium. Glucose is utilized for lactose and glycerol synthesis. Because little glucose can be stored, the increased requirement is met partially by an increase in intake but primarily through gluconeogenesis from propionate, amino acids, lactate and glycerol in the liver. Bennink et al. (1972) reported that glucose continued to increase even when intake remained constant indicating that gluconeogenesis from body reserve protein was taking place. Amino acids are also needed for milk protein synthesis; the increased demand results in increased partitioning of amino acids from body reserves (Mepham, 1982). The majority of the energy for milk synthesis and mammary gland oxidative needs, however, is provided by long-chain fatty acids and two-carbon acetate. This energy demand requires massive mobilization of fatty acids from body stores. Dairy cows can lose 20 to 50 kg of fat in the first six weeks of lactation (Belyea et al., 1978; Bines and Hart, 1982). Consequently, lipolysis is increased while lipogenesis is retarded resulting in increased free fatty acids in the blood at parturition as mammary fat synthesis increases (Collier et al., 1982). The major change in the composition of the blood plasma lipids was in the nonesterified fatty acids which accounted for as much as 34% of total plasma fatty acids at parturition (Noble et al., 1971). Increased nonesterified fatty acids are

probably a reflection of the changing energy status of the cow. This state is maintained through early lactation when low intake coupled with high nutrient requirements keep the animal in a negative nutrient balance. This trend is reversed as intake increases and the cow reaches a positive nutrient balance.

Calcium is also required in large quantities. A two-to-threefold increase in requirement from late gestation to early lactation is seen (van't Klooster, 1976; Care et al., 1980). Increased absorption of dietary calcium coupled with bone mobilization should meet the cow's calcium requirement (DeLuca, 1978; Care et al., 1980).

Because all milk precursors reach the mammary gland via the blood, rate of milk synthesis is dependent on both rate of mammary blood flow and rate of nutrient uptake by the mammary gland. Linzell (1974) observed that mammary blood flow as a percent of cardiac output increased at the initiation of lactation. Therefore, this increase in blood flow has the effect of diverting nutrients away from peripheral tissue towards milk synthesis. Blood flow can be affected directly or indirectly by substrate concentration (Lomax and Baird, 1983) and by hormones such as growth hormone that increase milk synthesis indirectly (Davis et al., 1983).

As mentioned previously, direct regulation of metabolism through the endocrine system involves changes in blood hormone concentrations and changes in receptor

population and affinity. The changes in receptor numbers and sensitivity occur with glucose metabolism, lipid metabolism and milk synthesis. Mammary glucocorticoid receptor numbers increase at lactogenesis (Gorewit and Tucker, 1976). This can be a result of increased glucocorticoids at parturition or decreased progesterone since progesterone competes with glucocorticoids for receptor sites (Collier and Tucker, 1978). Insulin receptors increase in mammary tissue and decrease in adipose tissue at parturition (O'Keefe and Catrecasas, 1974; Flint et al., 1979). Affinity of mammary tissue for insulin is high during estrus and early gestation and lower during late gestation and lactation (Inagaki and Kohmoto, 1982). Whether these binding components are different subunits or simply a conversion of the same receptors from high to low affinity is not yet known. Adrenergic receptor population increases in adipose tissue at the onset of lactation resulting in increased epinephrine-stimulated fatty acid release. The decrease in insulin receptors as well as the increase in adrenergic receptors in adipose tissue explains the increase in lipolysis and the decrease in lipogenesis. Mammary gland prolactin binding is also increased at parturition in animals producing placental lactogen (Holcomb et al., 1976). This increase in binding is probably due to decreased placental lactogen at parturition thus removing it as a competitor for the prolactin receptor. In addition to these changes in

receptor numbers and affinity, changes in growth hormone and prolactin direct milk synthesis and the partitioning of body stores of the substrates required for milk production.

Two major adaptations occur in hormone concentrations during lactation. First, changes in basal concentrations, and second, changes in secretion in response to suckling stimulus. Prolactin has been proposed to not only affect milk production but also play an important role in coordinating lipid metabolism. Blocking prolactin during lactogenesis not only decreased milk production but increased lipid synthesis (Agius et al., 1979; McNamara and Bauman, 1978; Zinder et al., 1974) and reduced rate of lipid mobilization from adipose tissue. However, it is possible that these changes in adipose tissue metabolism result as a consequence of the change in nutrient utilization by the mammary tissue caused by prolactin and not by a direct effect of prolactin on the adipose tissue itself. Insulin concentration is negatively related to milk yield (Koprowski and Tucker, 1973) but the low insulin concentration observed at lactogenesis is a function of the energy status of the cow rather than stage of lactation.

One very important hormone in the metabolism of adipose tissue is growth hormone. Growth hormone increases at parturition and concentrations are related to stage of lactation (Koprowski and Tucker, 1973). Experiments utilizing growth hormone injections in dairy cattle have resulted in higher milk yields and apparent improvement in

feed efficiency (Bines et al., 1980; Peel et al., 1981). This improvement in feed efficiency is probably due to preferential nutrient partitioning to the mammary gland at the expense of other peripheral body tissues rather than increased utilization of metabolizable energy for milk production. Davis et al. (1983) support this theory in that mammary blood flow as a percent of cardiac output increased in dairy cattle treated with growth hormone. Peel et al. (1981) reported that cattle dosed with growth hormone experienced an increase in milk production with no change in feed intake suggesting again that growth hormone increases lipolysis. Thyroxine concentrations are negatively correlated with milk production (Shaw et al., 1975) and decreased thyroid secretion rates are observed during lactation. This response could reduce peripheral tissue metabolism allowing preferential utilization of the substrates by the mammary tissue.

Digestive Changes from Late Gestation through Early Lactation

Digestive parameters such as feed intake, gastrointestinal tract fill, digestibility, liquid rate of passage and particulate rate of passage are known to change from gestation to early lactation (Kris et al., 1985). These changes appear to be highly correlated with feed intake. Hartnell and Satter (1979) observed a decrease in

intake of 25 to 43% during the dry period. A 12 percent decrease in feed intake during the last two weeks of gestation was reported by Jordan et al., (1968). Hashizume et al. (1964) also observed a significant reduction in feed intake as pregnancy advanced. In contrast, Broster et al. (1964) found no decline and Campling (1966) and Johnson et al. (1966) suggested that if pregnancy had an effect on intake, it was insignificant. Most data, however, suggest a reduction in dry matter intake as pregnancy advances. Changes in rumen capacity during late gestation support this evidence. Makela (1956) concluded that the uterus may occupy a considerable amount of the abdominal cavity normally occupied by the alimentary canal. Forbes (1968) used serial sectioning of frozen, slaughtered animals to show a reduction in the combined volume of the digesta of the rumen and intestine in the last five weeks of pregnancy.

If ruminal volume is decreased, particulate passage should also be affected. Particulate passage rate appears to increase as gestation advances (Thompson et al., 1978; Gonzalez et al.; 1985). This would be expected since the pressure of the uterus on the distended rumen would reduce its capacity and so increase the rate of excretion of food particles. If feed particles move faster through the rumen and small intestine, digestibility of the feed should be reduced due to decreased residence time of ingesta in the alimentary canal. Gonzalez et al. (1985) confirmed this

hypothesis when ewes in late gestation had decreased organic matter intake and organic matter digestibility. Faichney and White (1980) claim that increased digesta passage rate due to pregnancy occurs in particulate as well as fluid turnover. The result of increased passage rate is a reduction in the energy supply for maintenance, fetal growth and mammary development thus increasing the demand for nutrients from body stores.

During late gestation, increased non-ammonia nitrogen reaches the small intestine due to increased particulate passage rates. Faichney (1983) showed increased non-ammonia protein reaching the abomasum of gestating ewes and Gonzalez et al. (1985) confirmed this response with gestating and lactating ewes.

Changes in digestive parameters following parturition are an attempt by the cow to increase nutrient intake to satisfy the nutrient requirements of lactation. Intake increases following parturition. Hartnell and Satter (1979) observed a 10 kg increase in total ruminal ingesta from 6 to 18 weeks postpartum. Hypertrophy of the gastrointestinal tract and increased absorptive capacity are attributed to prolactin in rats (Mainaoy, 1978). Whether or not prolactin has the same effect in ruminants has not been established. They also reported that apparent dry matter digestibility was higher in the lactating groups when compared to the gestating group. Kris et al. (1985) showed increased mean retention time of liquid phase,

gastrointestinal tract fill and intake after calving while passage rates decreased. Digestive and physiological changes undergone at parturition are well documented. However, hormonal or metabolic control of these changes are neither well understood nor documented.

Forage Intake and Digestibility

Voluntary forage intake is the major dietary factor determining level and efficiency of production in grazing cattle. Rate of ingesta passage, reticulo-ruminal fill, body condition and the already discussed physiological stage of the cow are primary factors affecting voluntary intake for cattle grazing dormant range. Kind and amount of supplementation is a management-controlled factor that also affects intake by range ruminants.

The coarse and fibrous nature of most forages along with their low digestible energy content places emphasis on gut fill as an intake regulator. Removal of swallowed hay from the reticulo-rumen encouraged feed intake and conversely addition of hay into the reticulo-rumen decreased hay intake (Campling and Balch, 1961). When nutrient requirements cannot be met via intake, cows tend to eat to a constant rumen fill. Campling and Balch (1961) observed that intake ceased at similar amounts of ruminal dry matter. However, intraruminal additions of water had no effect on intake suggesting that forage moisture content

has no effect on voluntary dry matter intake in that same experiment. Van Soest (1982), however, believes that water retention by the sponge effect of the coarse components of ingested forage may have an inhibitory effect on intake.

Rate of disappearance of digesta from the reticulo-rumen depends on the chemical and physical properties of the forage consumed (Hungate, 1966). The rapidly fermentable fractions of the forage occupy space in the reticulo-rumen for a short time while the structural components of the roughage cell wall have slower passage rates. Therefore, digestibility of the forage affects passage rate and voluntary intake. Blaxter and Wilson (1962) showed that passage rate increased with digestibility of the forage when intake was kept constant. Hutton (1963) reported a decrease in forage intake in dairy cows when forage digestibility exceeded 70%. Conrad (1966) suggested passage rate controls intake on forages with up to 66% digestibility; above this, other factors are involved. Consequently, increased voluntary intake coincides with increased forage digestibility up to a certain point (66 to 70% digestibility). At higher digestibilities, intake tends to decline.

Another factor affecting passage rate is particle size. Ground roughages that readily flow out of the reticulo-rumen increase rate of passage resulting in greater voluntary intake (Minson, 1963; Poppi et al., 1981a). Therefore, particle size reduction to less than

1.2 mm through mastication and microbial fermentation play an important role in passage rate. Since the fermentable fraction of the forage disappears rapidly in the reticulo-rumen, the fraction that would be of concern is the indigestible fraction. Large amounts of indigestible fiber result in slower passage rates and decreased voluntary intake. Rumination, therefore, is highly correlated with cell wall content to allow particle size reduction of the indigestible portions of the cell wall. Although fluid rate of passage usually parallels feed intake (Evans, 1981), increased indigestible dry matter results in increased fluid passage rate due to greater salivary output (Cole et al., 1976). Fluid turnover rate has been reported to decrease linearly 2.7 hours for each 25% increase in dry matter intake per unit of body weight (Adams and Kartchner, 1982). Thus, liquid turnover rate is dependent on digestibility and quantity of forage intake.

Voluntary intake is related to body condition. Because body condition is a reflection of metabolic adequacy of grazing animals, it is a better indicator of nutritional status than body weight. This relationship is especially useful during gestation when fetal growth is most rapid and in early lactation when increased intake makes changes in liveweight a poor indicator of actual body weight loss. Arnold et al. (1964) noted that as thin sheep became fat, intake decreased. Compensatory gains in thin animals are related to increased feed intake. Thin sheep

may consume up to 20% more than fat sheep grazing together (Langlands, 1968; Allden, 1968). Differences in voluntary intake due to body condition may be limited by the digestibility of the forage.

Kind and amount of supplementation is a management-controlled variable that affects voluntary forage intake. Energy supplementation decreases forage intake by the substitution effect when forage is not limiting (Elliot, 1967; Cook and Harris, 1968; Rittenhouse et al., 1970; Lusby et al., 1967; Lake et al., 1974). Conversely, protein supplementation of low-quality roughages increases both digestibility and intake (Elliot, 1967; Cook and Harris, 1968; Lyons et al., 1970; Kartchner, 1980). Increased digestibility and intake are associated with increased microbial activity which results in faster rate of passage. Cottonseed meal supplements for cattle grazing dormant range increased ruminal ammonia concentrations (Wagner et al., 1983). McCollum and Galyean (1985) reported that supplementation (800 g cottonseed meal/d) increased intake by 4.6 g/kg of body weight and particulate passage rate from 2.9 to 4.5% per hour. Forero et al. (1980) observed that cattle grazing dormant range consumed more forage when fed similar quantities of 40% versus 15% crude protein supplements. Intake responses to protein supplementation have been documented with forages that contain less than 8% crude protein (Blaxter and Wilson, 1963; Elliot and Topps, 1963; Milford and Minson, 1965).

Apparently, crude protein concentrations below 7% do not meet the nitrogen demands of the ruminal microorganism (Van Soest, 1982).

Ruminal protein degradation is of importance to animal performance because nitrogen requirements of the microbial population in the rumen must be met. If the forage is deficient in meeting microbial nitrogen requirements, protein supplementation may efficiently increase fiber fermentation. Nitrogen-deficient microbes also grow slower and thus decrease the quantity of microbial protein reaching the duodenum. Under these circumstances, feeding a supplement that will not only meet ruminal requirements but also increase the amount of non-ammonia nitrogen reaching the duodenum because of low ruminal degradability may be beneficial. Zinn et al. (1981) showed that cottonseed meal was less degradable in the rumen than soybean meal and that the protein bypass value of cottonseed meal was 41%. Supplementation with the proper quantities and proportions of ruminal degradable and bypass protein should optimize forage utilization and animal performance. Because protein supplementation increases both forage digestibility and intake, the total amount of nutrients supplied also increases resulting in reduced body weight and condition loss in cattle grazing dormant native grass range (Clanton and Zimmerman, 1970; Rush and Totusek, 1976).

Metabolism of Carbohydrates

Plants are composed primarily of carbohydrates such as the polysaccharides cellulose, hemicellulose, pectins, fructans and starches. Of these, cellulose is the most abundant in forages (Van Soest, 1983). Ruminal microbial fermentation of carbohydrates yields carbon dioxide, volatile fatty acids, lactic acid, methane, ethanol, hydrogen and hydrogen sulfide. The specific carbohydrate being fermented has an effect on the endproduct. Of these endproducts, volatile fatty acids are the most important to the ruminant. The three most abundant volatile fatty acids produced by microbial fermentation of carbohydrates are acetate, propionate and butyrate (Church, 1976). Acetate is produced in larger concentrations when fibrous carbohydrates are fermented (Church, 1976). Acetate to propionate ratios will decrease when starch is fed reflecting altered microbial populations or fermentation patterns (Church, 1976). Ruminal fermentation of fibrous feeds is affected by microbial ruminal population, supply of microbial requirements, feed particle size and lignin content.

Protein Metabolism and Absorption

Studies evaluating the chemical composition of ruminal contents suggest that microbes contain 47 to 81% of the ruminal nitrogen (Weller et al., 1958; Hobson, 1973). The amount of nitrogen found in the microbes is dependent on

the amount of nitrogen in the diet, solubility and/or degradability of the protein and time after feeding. A large proportion of the protein entering the rumen is converted to ammonia. Consequently, concentrations of free amino acids are very low in the rumen (Gutowski et al., 1960; Hoshima and Hirose, 1964; Prokudin, 1967). Ammonia concentrations are quite variable and are also a reflection of nitrogen content of the feed, solubility and degradability of the protein, fermentability of the diet, time after feeding, ruminal volume and location of sampling. Satter and Roffler (1975) showed a positive correlation between ruminal ammonia and the amount of protein in the diet. However, when dietary nitrogen is inadequate, urea recycling becomes more efficient and ammonia concentrations may not be indicative of dietary protein concentrations (Somers, 1961).

Protein degradation in the rumen is dependent on solubility and level of intake. Highly soluble proteins such as casein and soybean meal supply greater ruminal ammonia concentrations. Ruminal ammonia concentrations are not necessarily correlated with microbial protein synthesis, since experiments with urea increased ammonia concentrations but resulted in the lowest level of total ruminal protein (Davis and Stallcup, 1967). Any excessive degradation would tend to be wasteful because excess ammonia would be absorbed through the ruminal wall, converted to urea in the liver and excreted in the urine.

Ammonia concentrations vary depending on time after feeding. Elliot and Topps (1963) observed that peak ruminal ammonia concentrations occured 1 to 4 hours after feeding and this peak extended as the protein content of the diet increased when feeding high roughage diets. Ruminal volume also affects ruminal ammonia concentrations. Diets high in low-quality roughage increase rumination and subsequent salivary output. Consequently, total ruminal ammonia concentrations may be decreased due to dilution.

Microbial protein, produced via fermentation of fibrous feeds, supplies a large proportion of the protein requirement of the ruminant. Crude protein content of ruminal bacteria and protozoa is difficult to determine because of contamination with ingesta and differences in chemical technique. Values range from 26 to 55% for protozoa and 36 to 44% for bacteria (Johnson et al., 1944; Smith and Baker, 1944; McNaught et al., 1954). More important than total crude protein content is amino acid composition of the microorganisms. Ibrahim and Ingalls (1972) reported that protozoa are higher in lysine and glutamic acid but bacteria were higher in histidine, threonine, serine, cystine and methionine. Microbial protein can provide most of the necessary protein requirements of cattle in maintenance as long as microbial nutrient supply is adequate.

Milk Production and Calf Growth

Profitable cow-calf production requires adequate nutrient supply during lactation so the cow can produce milk for calf growth and also maintain the body condition necessary to rebreed. Milk production is affected by numerous factors such as sex of the calf, age of dam, feed intake and environment. Melton et al. (1967) observed an advantage of cows nursing females but Pope et al.(1968) reported that cows nursing males produced significantly greater amounts of milk. Christian et al. (1965) found no significant difference in milk production attributable to calf's sex. Age of dam has a quadratic effect on milk yield with a peak at 8.4 years (Rutledge et al., 1971). Calf birth weight has a positive effect on milk production. Drewry et al. (1959) showed correlations of .43 and .29 between calf's birth weight and milk production in the first and second month while Gleddie and Berg (1968) reported correlations of .62, .75 and .56 for the first three months. Christian et al. (1965), however, did not observe any correlation between calf's birth weight and milk production.

Calf growth due to milk consumption appears to be important in early stages of lactation. Bartle et al. (1984) concluded that milk production is of major importance for calf growth until nine weeks of age. Gifford (1949) also reported a correlation between milk

production and calf growth during the first and second month that dropped in the third and fourth month. The time when milk production will not support maximum calf growth is not well defined. An increase of .02 kg per day per additional kilogram of grass consumed during the third, fourth and fifth month suggests that forage consumption does impact calf growth (Boggs et al., 1980). Up to sixty percent of the variation in 205-day adjusted weight could be attributed to direct influence of dam's milk production (Rutledge et al., 1971). Experiments by Boggs et al. (1980), showed that each additional kg of milk produced per day resulted in an additional 7.24 kg of adjusted 205-day weight. Milk composition was shown to have a nonsignificant correlation with 205-day weight (Rutledge et al., 1971), suggesting that milk quantity and not quality is of primary importance in weaning weight.

CHAPTER III

DIGESTIVE AND METABOLIC CHANGES IN FALL-CALVING BEEF COWS DUE TO STAGE OF PRODUCTION AND EARLY POSTPARTUM PROTEIN SUPPLEMENTATION

Abstract

Two experiments were conducted with fall-calving Hereford x Angus cows maintained on low-quality native grass to characterize digestive and metabolic changes during late gestation and early lactation and to evaluate the response to early postpartum protein supplementation. In the production study, 38 Hereford x Angus fall-calving cows were paired as they calved and randomly assigned to a control (unsupplemented) or supplemented group (.82 kg cottonseed meal/d). Supplemented cows lost less body weight (25.4 kg) and condition (.29 units) than control cows. Calves suckling supplemented cows gained 7.8 kg more weight than calves suckling control cows. By the end of the trial, supplemented cows produced 2.2 kg/d more milk than control cows. Production responses are due to increased hay organic matter intake (72.4 to 100.3 g/kg.75) and digestible organic matter intake (32.2 to 56.9 g/kg.75) for the supplemented cows. An intensive study was

performed with 14 mature, gestating Hereford x Angus cows (549 kg) housed individually and fed native grass hay (4.75% crude protein, 34.8% acid detergent fiber). Supplemented cows received 1.14 kg cottonseed meal/d starting at parturition. Similar to the production study, supplemented cows lost less body weight (71.3 kg), and condition (.75 units), produced more milk (3.04 kg) and supported increased calf gain (9.7 kg) compared to the control cows. Hay organic matter intake and digestible organic matter intake decreased prior to parturition but increased during the first 5 weeks postpartum for the control cows. Supplementation increased ($P<.001$) postpartum intake resulting in 104% more digestible organic matter intake by week 5. Ruminal ammonia concentrations increased in supplemented cows resulting in increased ($P<.01$) organic matter and acid detergent fiber digestibilities. Supplemental protein increased particulate ($P<.0002$) and liquid ($P<.0002$) passage rates. Plasma nonesterified fatty acid concentrations remained high (1510 to 2135 µmol/l) throughout the study for the control cows but decreased ($P<.0001$) with postpartum supplementation. Protein supplementation effects on plasma urea-nitrogen and albumin were not significant. Lactating beef cows maintained on low-quality forage may lose substantial quantities of body weight and condition resulting in impaired milk production and calf growth. Small quantities of supplemental protein (.82 to 1.14 kg

cottonseed meal/d) can improve cow performance through increased (77 to 104%) energy (digestible organic matter) intake.

(Key Words: Beef cattle, Supplement, Intake and Digestibility)

Introduction

Fetal nutrient demands for growth along with nutrient wastage due to fetal catabolism increase the nutrient demands of the gestating cow during late gestation (Bauman and Currie, 1980). At the onset of lactation, energy and protein demands are increased to the extent that the cow may be unable to consume sufficient nutrients to meet her requirements.

Fall-calving beef cows maintained on dormant native range confront a continuous decrease in forage nutrient content through the fall and winter (Waller et al., 1972) that make nutrient deficits even greater, especially at the onset of lactation. Protein supplementation of dormant native range increases both digestibility and intake of the forage (Kartchner, 1980). When forage supplies are adequate, protein supplementation should reduce body weight and condition losses in the cow as well as increase milk production, resulting in increased calf growth.

Digestive and metabolic changes attributed to physiological status of the fall-calving beef cow have not been characterized. Decreased digestibility, increased

rate of passage and decreased intake during late gestation may place the beef cow in a nutrient deficient status during late gestation (Gonzalez et al., 1985). Although intake and digestibility should increase following parturition (Kris et al., 1985), metabolic changes at the onset of lactation favoring nutrient partitioning and blood flow to the mammary gland result in a tremendous energy and protein deficit in the lactating beef cow (Bauman and Elliot, 1983). Severe nutrient deficiencies could result in decreased milk production and calf growth in addition to decreased reproductive performance. This experiment was designed to characterize changes in digestive and metabolic parameters due to physiological status and to evaluate their response to early postpartum protein supplementation.

Materials and Methods

Production study:

Thirty-eight mature Hereford x Angus cows (average weight 500 kg) maintained on native grass pastures at the Southwest Livestock and Forage Research Laboratory, El Reno, OK were paired based on date of parturition and randomly assigned to a supplemented (.82 kg cottonseed meal/d) or control group (unsupplemented). Cows were separated by treatment and group-fed in two adjacent native tallgrass pastures dominated by Andropogon scoporius. Cottonseed meal was fed 5 d/week on Monday, Tuesday, Wednesday, Friday and Saturday. Both groups had free

access to a mineral mix containing 50% dicalcium phosphate and 50% trace mineralized salt.

Postpartum cow weight and body condition (1=emaciated, 9=obese) were taken 2 to 5 d following parturition and calves weighed and bull calves castrated within 24 h after birth. Cows were weighed and scored for condition on an average of 16, 30 and 44 d postpartum following an 18-h shrink. Body condition was evaluated by two independent observers. Calves were weighed on the same days with a 3-h shrink. Milk production was measured by the weigh-suckle-weigh method on an average of 30 and 44 d postpartum. Calves were removed from the cows for 8 h and suckled twice at 6-h intervals. The sum of milk produced in the two sucklings was doubled to estimate 24-h milk production.

Pastures were rotated following each weigh period. Four esophageally fistulated heifers were utilized to collect forage samples. Forage samples were stored at -18 C, dried for 72 h (40 C) in a forced-air oven and ground through a Wiley Mill equipped with a 1-mm screen. Sample analyses included a continuous acid detergent fiber (ADF), permanganate lignin (PL) procedure (Goering and Van Soest, 1970); and dry matter (DM), ash and crude protein (N x 6.25) by Kjeldahl (AOAC., 1975). Cellulose content was estimated by difference (ADF minus PL minus ADF-ash).

Twelve cows (six from each group) were continuously dosed for 6 d with ytterbium-labeled hay (.17 g Yb/hd). Fecal samples were taken 6 times over a 48-h period

(samples represented every 4 h of a 24-h day) and composited for each individual cow. Extraction of ytterbium was accomplished using the EDTA extraction procedure (Hart and Polan, 1984) and concentrations determined using atomic-absorption spectrophotometry. Fecal output was calculated by dividing Yb dose by fecal Yb concentration. Hay OM (organic matter) intake was estimated by the formula (FO-ISOM)/HIND were FO is total fecal output, ISOM is indigestible supplement OM and HIND is indigestibility of the hay obtained from a companion study. All data were subjected to least squares analysis with a model that included treatment. The model for intake data added body weight (covariate) and body weight by treatment interaction. The model for production parameters included birthdate (covariate), birthweight (covariate) and calf sex.

Intensive study:

Fourteen mature, gestating Hereford x Angus cows (average weight 549 kg) were randomly assigned to individual concrete-slatted pens (4.7 x 2.3 m) with free access to water. Hay harvested in mid-July from a native grass pasture (major species include Andropogon gerardi, Andropogon scoparius, Panicum virgatum and Sorghastrum nutans) was coarsely chopped (5-cm screen) and fed based on the previous day's consumption plus 2.3 kg. Cows were treated similarly prepartum but paired based on date of

parturition and randomly assigned to either a control or a supplemented group (1.14 kg cottonseed meal/d). Pens were rotated randomly every two weeks.

The trial lasted a total of nine weeks. On day 3 of each week, all cows were weighed, scored for body condition by three independent evaluators and dosed (0800) with Co.EDTA (1.07 g Co) blended with ytterbium-labeled native grass hay (.84 g Yb/dose). Fecal grab samples (450 g as-is) were collected twice daily (0800 and 2000) on d 4 to 7, stored at 2 C and composited by animal at the end of each period. Timed fecal samples (300 g as-is) were collected simultaneously with composite fecal samples to represent 0, 24, 36, 48, 60, 72, 84, and 96 h postdosing. Both composite and timed fecal samples were dried at 50 C for 72 h in a forced-air oven. Hay and supplement samples were collected on d 1 and 3. Orts were collected and weighed on d 3, 5 and 7, composited and subsampled. Hay intake was recorded for all cows (d -1 to 6) and calculated as hay DM offered minus hay DM refused for the entire period.

Calves were weighed within 24 h of birth and bull calves elastrated. Calves were also weighed on d 3 of each week following birth. Milk production was estimated using the weigh-suckle-weigh method described in the production study.

Hay, ort, supplement and fecal composite samples were ground through a 1-mm screen (Wiley Mill). Samples were sorted according to weeks pre- and postpartum for each

individual cow with 0 being the week of calving (-3, -2, -1, 0, 1, 2, 3, 4 and 5) and stored at -18 C. Laboratory analyses were identical to the production study with the addition of acid insoluble ash (AIA, Van Keulen and Young, 1977). Nutrient digestibilities were calculated by the marker ratio technique using AIA as the reference marker (Schneider and Flatt, 1975). Cottonseed meal OM digestibility was assumed to be 76% (NRC., 1984). Hay OM digestibility was calculated by subtracting indigestible supplement OM from total fecal OM.

Timed fecal samples were ground through a Wiley Mill equipped with a 1-mm screen and stored at -18 C. Dry matter was determined at 100 C for 24 h. Simultaneous extraction of Yb and Co was accomplished using the EDTA extraction procedure (Hart and Polan, 1984). Concentrations of Yb and Co were determined by atomic-absorption spectrophotometry. Particulate and liquid passage rates were estimated from the slope of the regression of the natural logarithm of Yb and Co concentrations over time. The 24-h and 36-h Yb concentrations were omitted since they appeared to be on the upslope of the Yb excretion curve.

Ruminal samples were collected by stomach tube on d 7 and pH measured immediately after sampling using a combination electrode. Ruminal fluid (250 ml) was strained through 4 layers of cheesecloth and acidified (1 ml 20% H2SO4 /50 ml ruminal fluid) and stored at -18 C. Ruminal

ammonia concentrations were determined by the phenol-hypochlorite assay (Broderick and Kang, 1980).

Blood samples (20 ml) were obtained via jugular venapuncture using 10-ml vacutainers, transferred to test tubes containing an anticoagulant (.2 ml of 6.25% oxalate solution) and centrifuged at 2000 rpm for 20 min. Plasma was decanted and stored at -18 C. Plasma nonesterified fatty acids (NEFA) were determined using the salting technique (Smith, 1975). Plasma albumin concentrations (Doumas et al., 1971) and urea nitrogen (Searcy et al., 1961) were obtained using colorimetric procedures.

Changes in the physiological status of the control group were evaluated using least squares analysis with a model that included period and cow. Polynomial equations were fitted to establish the shape of the response curve. To evaluate response to postpartum cottonseed meal supplementation, data were analyzed as a split-plot design with treatment as the main unit, cows as replications and periods as the subunits. The model included treatment, period, cow(treatment) and the treatment by period interaction. Body weight (covariate) and the body weight by treatment interaction were added to the model for intake and digestibility data. The model for calf performance data included treatment, calfsex and birthweight (covariate). Treatment responses within each period were evaluated by t-test.

Results and Discussion

Production Study:

The tallgrass native range pastures utilized in this study were dominated by little blue-stem and averaged 5.71% CP (table 1). High lignin (9.86%) and ADF (46.8%) concentrations verify the marginal quality of these pastures in October. Quality of Oklahoma forages decreases through the fall and winter averaging 3.79% CP in October (Waller et al., 1972).

Control (unsupplemented) cows lost 50 kg of body weight and .32 units of body condition by the end of the 44-d study (table 2). Supplementation (.82 kg cottonseed meal/d) decreased body weight losses by 25.3 kg ($P<.0001$) and body condition loss by .29 units ($P<.07$). Thus, only 1.43 kg of cottonseed meal were required for each kg of reduced weight loss in this study. Similar conversions of high-protein supplements to weight gain have been observed with stocker cattle grazing native grass pastures in late summer (Lusby et al., 1982).

Calves suckling supplemented cows gained 7.8 kg (.18 kg/d) more weight ($P<.003$) during the 44-d trial (table 2). Supplemented cows produced 2.2 kg/d more ($P<.0001$) milk than control cows by d 44 postpartum. Increased calf gain observed in this study is due to increased milk production. Correlations reported by Bartle et al. (1984) between milk production and calf weaning weights were significant for

TABLE I

CHEMICAL COMPOSITION OF FORAGE AND SUPPLEMENT

	Production Study		Intensive Study		
	Forage	CSM[a]	Hay	CSM[a]	SEM[b]
Acid detergent fiber, %	46.80	14.49	34.80	19.51	2.469
Lignin, %	9.86	3.05	5.20	2.79	2.919
Cellulose, %	29.46	11.13	34.82	16.26	3.846
Ash, %	11.87	11.39	6.81	6.97	3.959
Crude Protein, %	5.71	44.20	4.70	44.03	.831

[a]Cottonseed meal.
[b]Standard error of the mean.

TABLE II

EFFECT OF EARLY POSTPARTUM (44 DAYS) PROTEIN SUPPLEMENTATION ON THE PERFORMANCE OF FALL-CALVING COWS AND THEIR CALVES[a]

	Treatment		
	Control	Cottonseed Meal	SEM[b]
Cow weight, kg			
Initial	517.6	519.4	7.63
Final	467.6	494.9	8.17
Change, 44 d	50.0[c]	24.5[d]	3.90
Cow body condition, units			
Initial	5.93	5.75	.187
Final	5.61	5.72	.190
Change, 44 d	-.32[e]	-.03[f]	.105
Calf weight, kg			
Initial	31.4	30.1	1.07
Final	68.1	74.6	1.39
Change, 44 d	36.7[c]	44.5[d]	1.39
Milk production, kg/d			
30 d postpartum	8.1	10.1	.37
44 d postpartum	8.0[c]	10.2[d]	.35

[a]Least square means.
[b]Standard error of the mean.
[c,d]Means within rows with different superscripts differ ($P<.005$).
[e,f]Means within rows with different superscripts differ ($P<.07$).

the first nine weeks suggesting increased milk production during early lactation should have the greatest impact on weaning weights. Therefore, early postpartum protein supplementation effects on milk production observed in this trial should result in heavier calves at weaning. Fecal output was significantly higher ($P<.004$) for the supplemented group (table 3). Therefore, intake estimates for hay OM intake and digestible OM intake were also higher ($P<.0001$) for supplemented cows. Positive intake responses to protein supplementation of low-quality forages have been reported (Kartchner et al., 1980). Supplemental protein also increases protein intake and microbial protein synthesis and therefore, protein supply reaching the duodenum (Orskov, 1982). Increased energy intake and protein supply observed in this study should improve the energy and protein status of the lactating beef cow.

Intensive Study:

Native grass hay of marginal nutritional quality (4.7% CP, 34.8% ADF and 5.2% lignin) was used in this study (table 1). Fall-calving beef cows grazing native tall grass pastures would experience a forage base providing as little as 3.79% CP and 35.8% crude fiber in October (Waller et al.,1972).

Body weight (1.59 kg/d) and condition (.27 units/wk) of control cows decreased linearly ($P<.0001$) from week one through week five postpartum (figure 1). Increased

TABLE III

INTAKE RESPONSE TO EARLY POSTPARTUM PROTEIN SUPPLEMENTATION

	Treatment		
	Control	CSM[a]	SEM[b]
Fecal output, g/d	4927[c]	6089[d]	210.4
Hay OM Intake, $g/kg^{.75}$	72.4[c]	100.3[d]	3.03
Digestible OM Intake, $g/kg^{.75}$	32.2[c]	56.9[d]	1.48

[a]Cottonseed meal.
[b]Standard error of the mean.
[c,d]Means within rows with different superscripts differ ($P<.01$).

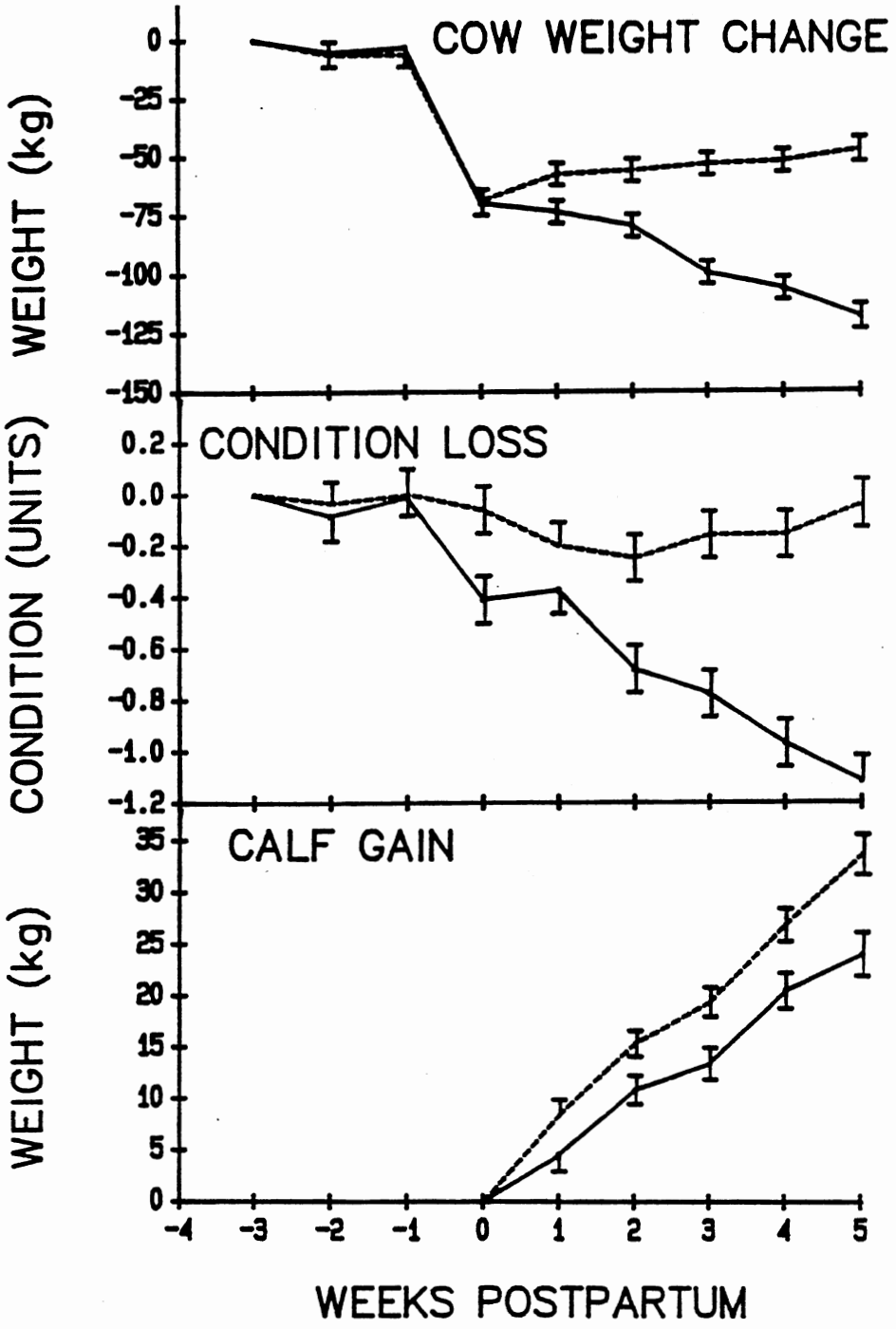

Figure 1. Weight and Condition Changes of Fall-calving Cows and Calves as Affected by Stage of Production and Cottonseed meal Supplementation (——control, ----supplemented).

nutrient requirements due to milk synthesis coupled with low forage quality create a large nutritional void. Consequently, mobilization of body stores is required to meet the demands imposed by the mammary gland (Bauman and Currie, 1980) resulting in body weight and condition loss.

Cows receiving 1.14 kg cottonseed meal/d lost less body weight (71.3 kg) and condition (.75 units) than control (unsupplemented) cows by week 5 postpartum (figure 1). In fact, supplemented cows gained weight postpartum although some of this response may be due to added gut fill. Cows with greater body weight losses experienced increased body condition score loss ($r=.34$, $P<.0006$). Winter protein supplementation minimizes body weight and condition score losses (Clanton and Zimmerman, 1970; Rush and Totusek, 1976). Compared to control cows, supplemented cows in the production study lost less body weight than supplemented cows in the intensive trial (24 kg vs 46 kg) although condition losses were similar (.03 vs .04 units). Treatment differences for body weight in the production study were probably more accurate since cows were shrunk for 18 h.

Supplemented cows produced 3.04 kg more milk and calves gained 9.7 kg ($P<.09$) more weight than control cows by week 5 postpartum (figure 1). The supplementation response in milk production (3.04 vs 2.22 kg) and calf gain (9.7 vs 7.8 kg) were similar in intensive and production studies.

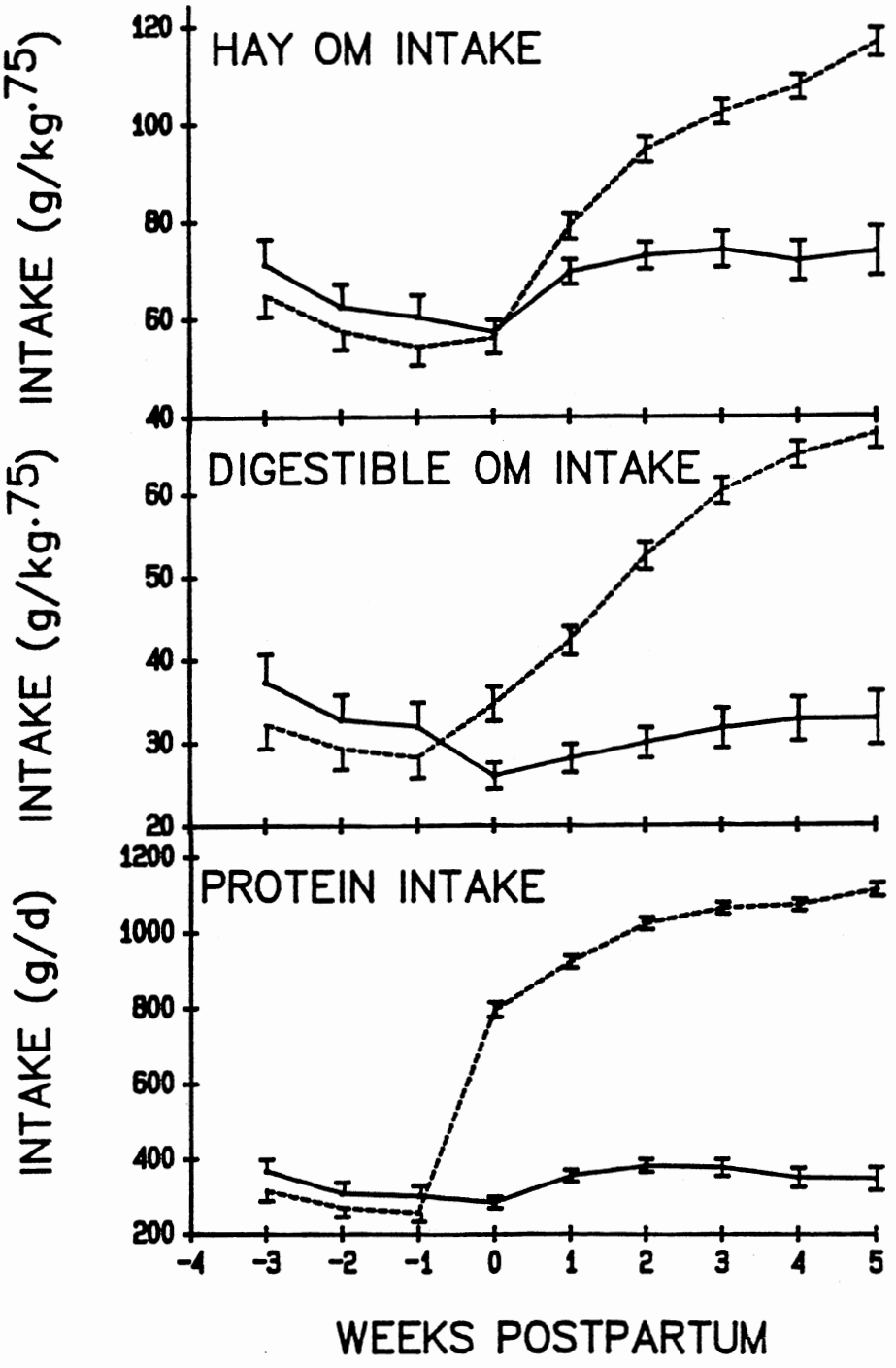

Figure 2. Changes in Hay, Digestible Organic Matter and Protein Intake of Fall- calving Cows Due to Stage of Production and Protein Supplementation (——control, ----supplemented).

Hay intake for control cows (cubic response, P<.002) decreased 8% from week -3 through parturition (figure 2). Postpartum hay intake increased rapidly and levelled by week 2. Digestible OM intake showed similar trends. Prepartum feed intake depressions of 12% have been reported (Jordan et al., 1968). Forbes (1968) showed a reduction in the combined volume of digesta in the rumen and intestine in the last five weeks of pregnancy suggesting that the physical size of the conceptus may decrease digestive capacity in late gestation. In the early postpartum period, Hartnell and Satter (1979) observed a 10 kg increase in total ruminal ingesta of dairy cows by 18 weeks postpartum. Increased hay and digestible OM intake in the postpartum cow may be attributed to increased physiological demands from lactation in addition to increased abdominal space.

Supplementation (1.14 kg cottonseed meal/d) increased hay and total OM intakes rapidly following parturition and had not stabilized by week 5 postpartum (figure 2). By the end of the study (week 5 postpartum), supplemented cows consumed more hay OM (53 g.kg-.75.d-1), digestible OM (104%) and protein (769 g/d) than control cows (figure 2). Protein supplementation has been reported to increase digestibility and intake of low-quality forages (Kartchner, 1980). Increased energy and protein intake in the supplemented cows explains the reduction in body weight and condition losses compared to the controls. In addition,

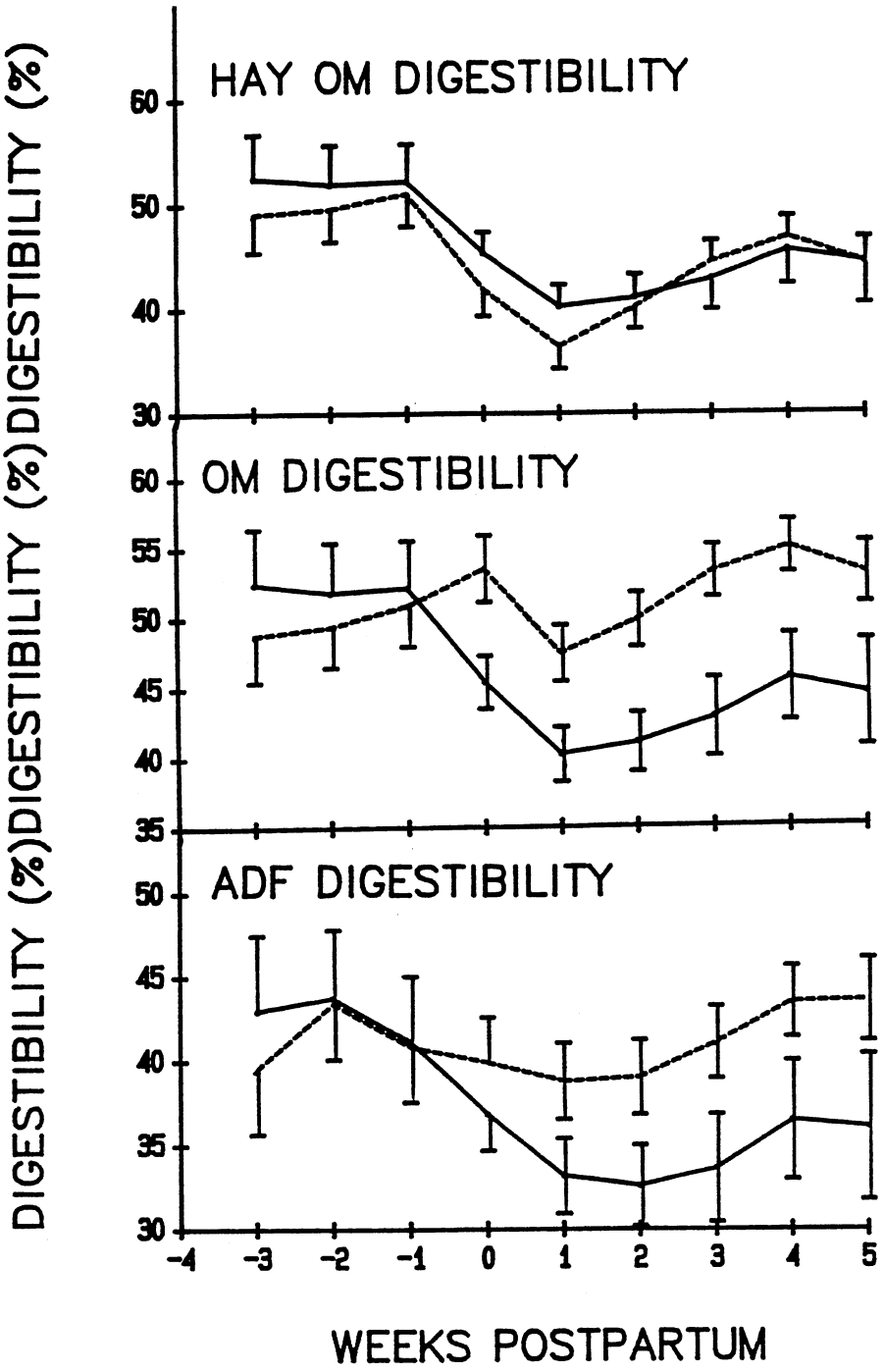

Figure 3. Hay OM, Apparent OM and ADF Digestibility Changes in Fall-calving Cows Due to Stage of Production and Protein Supplementation (——control,----supplemented).

cows fed higher energy diets produce more milk and calf gain (Bartle et al., 1984).

Hay OM and total OM digestibilities were relatively constant during late gestation (figure 3). In contrast, Gonzalez et al. (1985) observed decreased digestibility in ewes during the last few weeks prepartum. For control cows, prepartum hay OM (51.8 to 52.5%) and ADF (41.0 to 43.8%) digestibilities were higher than postpartum hay OM (40.0 to 45.6%) and ADF (33.0 to 36.5%) digestibilities (figure 3). Increased hay intake following parturition (figure 2) probably decreased ruminal residence time which should decrease digestibility (Kris et al., 1985).

Hay OM digestibility was not affected ($P<.9970$) by supplementation (figure 3) probably due to the dramatic increase in intake observed in the supplemented cows. A negative correlation ($r=-.28$, $P<.008$) was observed between hay OM intake and hay OM digestibility. In contrast, supplementation increased ($P<.01$) OM (53% vs 44%) and ADF (44% vs 36%) digestibility. Ruminal ammonia concentrations increased rapidly after calving and the initiation of supplementation (figure 4). Additional ruminal ammonia should stimulate microbial growth, increase fermentation of fiber and increase digestibility (Guthrie et al., 1984).

Particulate passage rate of the control group (figure 4) changed quadratically ($P<.009$); increasing as gestation advanced (2.95 to 3.96%/h) and declining following parturition (3.69 to 2.76%/h). Faichney and White (1980)

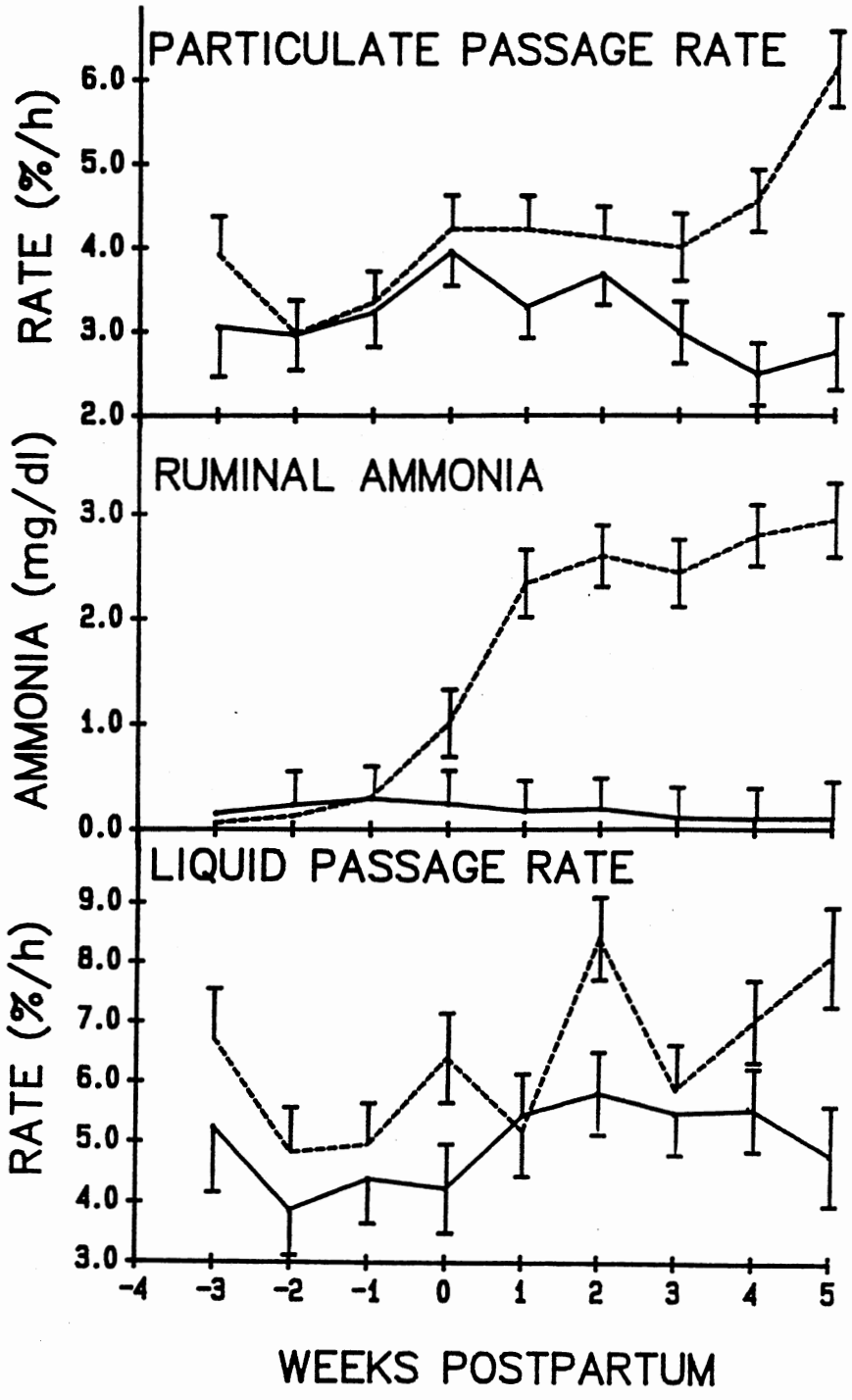

Figure 4. Changes in Ruminal Ammonia Concentrations and Passage Rates Due to Stage of Production and Protein Supplementation (——control, ----supplemented).

suggested that both particulate and liquid passage rates should increase as pregnancy advances. Following parturition, increased hay intake due to increased abdominal space and lactational demands may combine to speed particulate passage rate. Particulate rate of passage was significantly higher ($P<.0002$) for the supplemented group (6.14%/h) than for the control group (2.76%/h) by period 5 (figure 4). McCollum and Galyean (1985) showed an increase in ruminal passage rate of 4.5 vs 2.9%/h for supplemented steers grazing blue grama pastures. Protein supplementation appears to increase ruminal fermentation rate which should increase particulate passage rate (Guthrie et al., 1984). Increased passage rate is a major factor associated with increased intake (figure 2) in the supplemented cattle ($r=.26$, $P<.02$). In addition, Van Soest (1982) suggests that once ruminal volume is maximized, larger particles may be allowed to pass through the reticulo-omasal orifice. Although supplementation may increase ruminal fermentation rate, increased passage rate coupled with increased intake may explain the lack of response in extent of hay OM digestion (figure 3).

Liquid passage rate (Co.EDTA) was also higher ($P<.0002$) for the supplemented cows 8.1 vs 4.8%/h by week 5 (figure 4). Because hay OM intake increased in the supplemented group with little effect on hay OM digestibility, indigestible hay OM intake also increased ($P<.0001$). Cole et al. (1976) suggested that liquid

passage rate should increase with increased indigestible organic matter intake.

High plasma concentrations of nonesterified fatty acids (NEFA) for the control group throughout the study indicated adipose tissue mobilization and negative energy balance (figure 5). The energy demand experienced by the lactating cow requires mobilization of fatty acids from body fat stores to the mammary gland (Collier et al., 1982). Consequently, blood free fatty acid concentrations increase during late gestation and early lactation (Bauman and Currie, 1980). Decreased NEFA concentrations in the control group after period two may be due to increased blood flow to the mammary gland and consequently faster removal of NEFA from the blood stream.

Supplemented cows had significantly ($P<.0001$) lower plasma NEFA concentrations than control cows (983 vs 1510 μmol/l) by the end of the trial (figure 5). Increased energy intake (figure 2) observed in the supplemented group reduced the energy deficit experienced by the lactating cow and thus, decreased lypolysis. Open, non-lactating cows fed submaintenance energy levels had higher blood NEFA than normal (Russell and Wright, 1983). Thus, NEFA concentrations can be used to evaluate the energy status of the lactating beef cow. Higher concentrations of NEFA in the control group suggest a high negative energy status for lactating cows maintained on dormant native grass. Submaintenance energy status for the control cows is

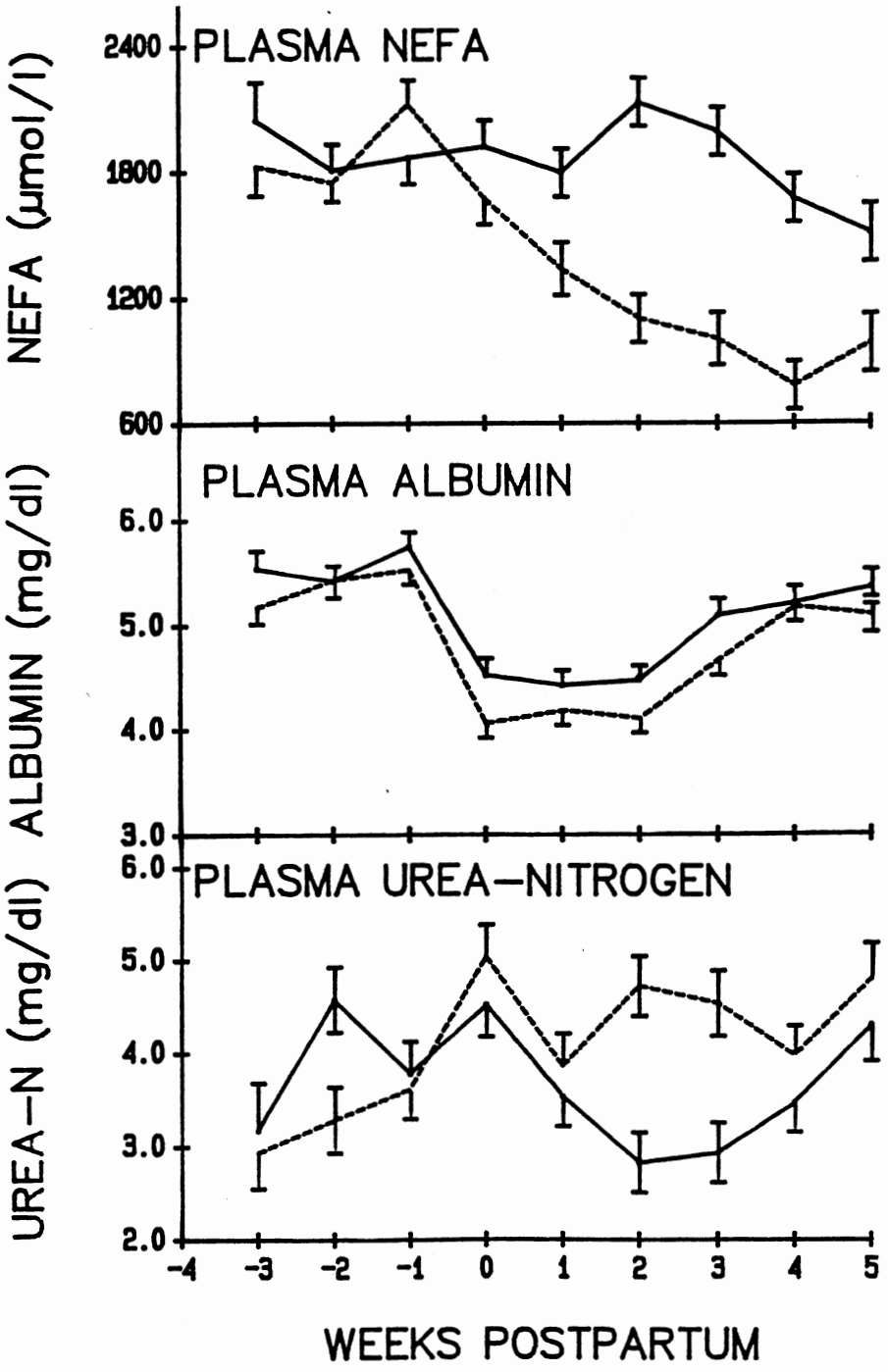

Figure 5. Plasma Metabolite Changes Due to Stage of Production and Early Postpartum Protein Supplementation (——— control, ----supplemented).

verified by extreme body weight and condition losses during the first 5 weeks postpartum (figure 1).

Plasma albumin concentrations of the control cows showed a quartic response ($P<.0005$); decreasing at parturition and increasing by the end of the trial (figure 5). Plasma urea nitrogen (PUN) concentrations (figure 5) changed cubicly ($P<.0004$); increasing prepartum, decreasing rapidly by 2 weeks postpartum, and increasing from weeks 3 through 5 postpartum. Low postpartum albumin and PUN concentrations may be a consequence of the tremendous demand for protein set by the mammary system at the initiation of lactation and increased mammary blood flow (Linzell, 1974). Increased plasma urea concentrations by week 5 postpartum suggest increased proteolysis by the cows to try and meet mammary gland protein demands (Mepham, 1982).

Treatment responses in plasma albumin concentrations were not significant ($P<.2779$) suggesting the liver may closely regulate plasma albumin (figure 5). Albumin concentrations were similar to those reported by Bull et al. (1984) for protein-deficient heifers (4.32 to 4.49 mg/dl). Plasma urea nitrogen concentrations increased with supplementation in all periods but was significant in periods 2 and 3, only (figure 5). Plasma urea nitrogen concentrations below 10 mg/dl for both groups suggests that all cows were protein deficient (Preston et al., 1965).

Conclusion:

This study illustrates that lactating beef cows maintained on low-quality native grass pastures can lose large quantities of body weight (45 to 50 kg) in a short period of time (44 d). Rapid weight loss during the early postpartum period decreases milk production, calf growth and reproductive function (Rakestraw et al., 1983). Small quantities of supplemental protein efficiently increase forage utilization and weight gain in grazing calves (Guthrie et al., 1984; Lusby et al., 1982). In our study, small quantities of cottonseed meal (.82 to 1.14 kg/d) efficiently decreased body weight (71.3 kg) and condition (.75 units) loss, and increased milk production (3.04 kg/d) and calf weight gain (9.7 kg). In fact, most of the cost (70 to 80%) of the cottonseed meal supplement is recovered in increased calf weight gain.

The performance response observed in this study is attributable to increased digestible OM intake (77 and 104% in the production and intensive studies, respectively). The magnitude of this response illustrates that lactating cows maintained on low-quality forage are primarily deficient in protein and are very responsive to low quantities of supplemental protein. Lactating beef cows may show a large adaptive response to the rigors of milk synthesis once their nutrient requirements have been satisfied.

Nutritional status of lactating beef cows may be difficult to monitor using schemes such as body condition scoring because changes in body condition in early lactation are small. Blood metabolites such as nonesterified fatty acids have been proposed as reliable indicators of the energy status of cattle in negative energy balance (Russell and Wright, 1983). Large treatment differences (up to 800 µmol/l) observed in our study verifies the potential use of nonesterified fatty acids as an indicator of nutritional status. In contrast, plasma albumin concentrations did not respond to dietary treatment. Protein supplementation increased plasma urea-nitrogen concentrations in early lactation validating its use as an indicator of protein status.

CHAPTER IV

SUMMARY

Nutrient composition of native tallgrass starts to decrease in quality in late summer and declines rapidly through the fall and winter. Consequently, fall-calving cows encounter marginal nutrient supply at a time when nutrient demands (energy and protein) are increasing due to demands set by the mammary system. Although most fall-calving beef cattle calve in adequate body condition (5.5 to 7.0), nutrient mobilization from body stores may result in a dramatic body weight and body condition loss by spring. Even though nutrient partitioning favors the mammary system at the onset of lactation, marginal nutrition may result in decreased milk production and consequently, lower calf weights at weaning. Management practices that would improve the nutrient status of the fall-calving beef cow without increasing net cost of production are needed.

Energy supplementation with concentrates, as well as low protein cubes are known to have a substitution effect and decrease digestibility of low-quality native grass. If forage is abundant, this practice would also increase the cost of production. Results obtained in this experiment with early postpartum protein supplementation suggest the

possibility that this practice be implemented for fall-calving beef cattle on dormant native tall grass range. Increased protein and energy status of the cow was reflected by decreased body weight and condition loss as well as increased milk production and calf gains. Heavier calves at weaning, better conception rates and shorter postpartum intervals are possible with early postpartum protein supplementation.

Characterization of digestive and metabolic parameters associated with physiological stage of production of the cow need to be extended and hormonal regulation of those parameters fully understood to determine management practices necessary to ensure adequate nutrient supply for both fetal development and milk production.

Although results presented in this study indicate a positive response to early postpartum protein supplementation, research must continue to determine minimum amounts of protein required and differences in response to sources of protein. Bypass protein utilization and non-protein nitrogen sources could be used as alternative protein sources to determine whether increments of quality protein reaching the duodenum or meeting microbial nitrogen requirements for increased forage fermentation rate is more critical. This study needs to be taken through weaning to determine whether the advantage in calf gains observed 44 days postpartum are further increased and maintained. Days to first estrus as well as conception rates need to be

measured along with protein sources to determine type and amount of protein with better response.

Finally, the use of blood metabolites such as nonesterified fatty acids, blood urea nitrogen, albumin, glucose, and creatinine to determine nutritional status of the cow needs to be perfected to allow producers to utilize them along with visual appraisals resulting in more precise evaluation of the herd's nutritional status.

BIBILIOGRAPHY

Adams, D.C. and R.J. Kartchner. 1984. Effect of level of forage intake on rumen ammonia, pH, liquid volume and liquid dilution rate in beef cattle. J. Anim. Sci. 58:708.

Agius, L., A.M. Robinson, J.R. Girand, and D.L. Williamson. 1979. Alterations in the rate of lipogenesis in vivo in maternal liver and adipose tissue on premature weaning or lactating rats: A possible regulatory role of prolactin. Biochem. J. 180:689.

Allden, W.G. 1968. Undernutrition of the Merino sheep and its sequelae. IV. Herbage consumption and utilization of feed for wool production following growth restrictions imposed at two stages of early post-natal life in a Mediterranean environment. Aust. J. Agr. Res. 19:977.

AOAC. 1975. Official Methods of Analysis (12th Ed.) Association of Official Analytical Chemists, Washington, D.C.

Arnold, G.W., W.R. McManus, and I.G. Bush. 1964. Studies in the wool production of grazing sheep. I. Seasonal variation in feed intake, liveweight and wool production. Aust. J. Exp. Agr. Anim. Husb. 4:392.

Bartle, S.J., J.R. Males, and R.L. Preston. 1984. Effect of energy intake on the postpartum interval in beef cows and the adequacy of the cow's milk production for calf growth. J. Anim. Sci. 58:1068.

Battaglia, F.C. and G. Meschia. 1978. Principal substrates of fetal metabolism. Physiol. Rev. 58:499.

Bauman, D.E. and J.M. Elliot. 1983. Biochemistry of Lactation. North-Holland Biomedical Press. Amsterdam, Netherlands. p 437.

Bauman, D.E. and W.B. Currie. 1980. Partitioning of nutrients during pregnancy and lactation: A review of mechanisms involving homeostatsis and homeorrhesis. J. Dairy Sci. 63:1514.

Belyea, R.L., G.R. Frost, F.A. Martz, J.L. Clark, and L.G. Forkner. 1978. Body composition of dairy cattle by potassium-40 liquid scintillation detection. J. Dairy Sci. 61:206.

Bennink, M.R., R.W. Mellenberger, R.A. Frobish, and D.E. Bauman. 1972. Glucose oxidation and entry rate as affected by the initiation of lactation. J. Dairy Sci. 55:712 (Abstr.).

Bines, J.A. and I.C. Hart. 1982. Metabolic limits to higher milk production with special reference to the roles of growth hormone and insulin. J. Dairy Sci. 65:1375.

Bines, J.A., I.C. Hart, and S.V. Morant. 1980. Endocrine control of energy metabolism in the cow. The effect on milk yield and levels of some blood constituents of injecting growth hormone and growth hormone fragments. Brit. J. Nutr. 43:179.

Blaxter, K.L. and R.S. Wilson. 1963. The assessment of a crop husbandry technique in terms of animal production. Anim. Prod. 6:27.

Blaxter, K.L. 1962. The energy metabolism of ruminants. Hutchinson and Co. Ltd. London.

Blaxter, K.L. and R.S. Wilson. 1962. The voluntary intake of roughages by steers. Anim. Prod. 4:351.

Boggs, D.L., E.F. Smith, R.R. Schalles, B.E. Brent, L.R. Corah, and R.J. Pruitt. 1980. Effects of milk and forage intake on calf performance. J. Anim. Sci. 51:550.

Broderick, G.A. and J.H. Kang. 1980. Automated simultaneous determination of ammonia and total amino acids in ruminal fluid and in vitro media. J. Dairy Sci. 63:64.

Broster, W., H. Tuck, J. Valerie, and C.C. Balch. 1964. Experiments on the nutrition of the dairy heifer. 5. Nutrition in late pregnancy. J. Agr. Sci. (Camb.) 63:51.

Bull, R.C., D.O. Everson, D.P. Olson, L. F. Woodward, and L.C. Anderson. 1984. Blood metabolite levels in pregnant beef heifers restricted prepartum in protein and/or energy. Proc. West. Sec. Amer. Soc. Anim. Sci. 35:234.

Campling, R.C. 1966. A preliminary study of the effect of pregnancy and of lactation on the voluntary intake of food by cows. Brit. J. Nutr. 20:25.

Campling, R.C. and C.C. Balch. 1961. Factors affecting the voluntary intake of food by cows. I. Preliminary observations of the effect, on the voluntary intake of hay, of the changes in the amount of the reticula ruminal contents. Brit. J. Nutr. 16:523.

Care, A. D., J.P Bartlett and H.M. Abdel-Hafeez. 1980. Calcium and phosphate homeostasis in ruminants and its relationship to the aetiology and prevention of parturient paresis. In: Y. Ruckebusch and P. Thivend. (ED.) Digestive Physiology and Metabolism in Ruminants. Proc. of the 15th Int. Symp. on Ruminant Physiol. MIP Press Limited, Lancaster, England. pp. 429-446.

Caton, D.R., R.M. Abrams, L.K. Lackore, G.B. James, and D.H. Barron. 1973. Effects of progesterone administration on the rate of uterine blood flow of early pregnant sheep. Foetal and Neonatal Physiology. R.S. Comline, K.W. Cross, G.S. Dawes, and P.W. Nathanielsz, (ed.) Cambridge University Press, Cambridge. p.286.

Chan, J.S.D., H.A. Robertson, and H.G. Friesen. 1976. The purification and characterization of ovine placental lactogen. Endocrinol. 98:65.

Christian, L.L., E.R. Hauser, and A.B. Chapman. 1965. Association of preweaning and postweaning traits with weaning weight in cattle. J. Anim. Sci. 24:652.

Clanton, D.C. and D.R. Zimmerman. 1970. Symposium on pasture methods for maximum production in beef cattle: Protein and energy requirements for female beef cattle. J. Anim. Sci. 30:122.

Cole, N.A., R.R. Johnson, F.N. Owens and J.R. Males. 1976. Influence of roughage level and corn processing method on microbial protein synthesis by beef steers. J. Anim. Sci. 43:497.

Collier, R.J. and H.A. Tucker. 1978. Regulation of cortisol uptake in mammary tissue of cows. J. Dairy Sci. 61:1709.

Collier, R.J., S.G. Doelger, H.H. Head, W.W. Thatcher, and C.J. Wilcox. 1982. Effects of heat stress during pregnancy on maternal hormone concentration, calf birth weight and postpartum milk yield of Holstein cows. J. Anim. Sci. 54:309.

Conrad, H.R. 1966. Symposium on factors influencing voluntary intake of herbage by ruminants: Physiological and physical factors limiting feed intake. J. Anim. Sci. 25:227.

Convey, E.M. 1974. Serum hormone concentrations in ruminants during mammary growth, lactogenesis, and lactation: A review. J. Dairy Sci. 57:905.

Cook, C.W. and L.E. Harris. 1968. Effect of supplementation on intake and digestibility of range forage. Utah Agr. Exp. Sta. Bull. 475.

Currie, W.B., P.A. Kelly, H.G. Friesen, and G.D. Thorburn. 1977. Caprine placental lactogen: Levels of prolactin-like and growth hormone-like activities in the circulation of pregnant goats determined by radioreceptor assays. J. Endocrinol. 73:215.

Davis, R.F. and O.T. Stallcup. 1967. Effect of soybean meal, raw soybean, corn gluten feed and urea on the concentration of rumen fluid components at intervals after feeding. J. Dairy Sci. 50:1638.

Davis, S.R., R.J. Collier, J.P. McNamara, and H.H. Head. 1983. Effect of growth hormone and thyroxine treatment on dairy cows on milk production, cardiac output and mammary flow. Proc. New Zealand Soc. Endocrinol. 26:31.

DeLuca, H.F. 1978. Vitamin D and calcium transport. Ann. New York Acad. Sci. 307:356.

Douman, B.T., W.A. Watson, and H.G. Biggs. 1971. Albumin standards and the measurement of serum albumin wtih bromcresol green. Clin. Chim. Acta. 31:87.

Drewry, K.J., C.J. Brown, and R.S. Honea. 1959. Relationships among factors associated with mothering ability in beef cattle. J. Anim. Sci. 18:938.

Egan, A.R. 1965. The influence of sustained duodenal infusions of casein or urea upon voluntary intake of low-protein roughages by sheep. Aust. Jour. Agri. Res. 16:451.

Elliot, R.C. 1967. Voluntary intake of low protein diets by ruminants. I. Intake of food by cattle. J. Agr. Sci. (Camb.) 69:375.

Elliot, R.C. and J.H. Topps. 1963. Voluntary intake of low protein diets by sheep. Anim. Prod. 5:269.

Evans, E. 1981. An evaluation of the relationships between dietary parameters and rumen liquid turnover rate. Can. J. Anim. Sci. 61:91.

Faichney, G.J. 1983. Assessment of the protein value of ruminant feeds. In: G.E. Robards and R.G. Packham (Ed.). Commonwealth Agricultural Bureaux, Slough, pp 191-210.

Faichney, G.J. and G.A. White. 1980. Mean retention time of markers in the rumen of pregnant sheep. Proc. Aust. Soc. Anim. Prod. 13:455.

Flint, D.J., P.A. Sinnett-Smith, R.A. Clegg, and R.G. Vernon. 1979. Role of insulin receptors in the changing metabolism of adipose tissue during pregnancy and lactation in the rat. Biochem. J. 182:421.

Forbes, J.M. 1968. The physical relationships of the abdominal organs in the pregnant ewe. J. Agr. Sci. (Camb) 70:171.

Forero, O., F.N. Owens, and K.S. Lusby. 1980. Evaluation of slow-release urea for winter supplementation of lactating range cows. J. Anim. Sci. 50:532.

Gifford, W. 1949. Importance of high milk production in beef cows overestimated. J. Anim. Sci. 8:605.

Gleddie, V.M. and R.T. Berg. 1968. Milk production in range beef cows and its relationships to calf gains. Can. J. Anim. Sci. 48:323.

Goering, H.K. and P.J. Von Soest. 1970. Forage Fiber Analysis (apparatus, reagents, procedures and some application). Agricultural Handbook No. 379, USDA, ARS.

Gonzalez, J.S., J.J. Robinson, and C. Fraser. 1985. The effect of physiological state on digestion in the ewe and its influence on the quantity of protein reaching the abomasum. Livestock Prod. Sci. 12:59.

Gorewit, R.C. and H.A. Tucker. 1976. Glucocorticoid binding in mammary tissue slices of cattle in various reproductive states. J. Dairy Sci. 59:1890.

Guthrie, M.J., D.G. Wagner, and D.S. Buchanan. 1984. Effect of level of protein supplementation on intake and utilization of medium quality prairie hay by heifers. Okla. Agr. Exp. Sta. Misc. Pub. MP-116:156.

Gutowski, B., W. Barej, A. Temler, and I. Nowosieska. 1960. Liquid content of the rumen of heifers fed with greens. Nutr. Abstr. Rev. 30:1290.

Hart, S.E. and C.E. Polan. 1984. Simultaneous extration and determination of ytterbium and cobalt ethylen-diaminetetraacetate complex in feces. J. Anim. Sci. 67:888.

Hartnell, G.F. and L.D. Satter. 1979. Extent of particulate marker (samarium, lanthanum and cerium) movement from one digesta particle to another. J. Anim. Sci. 48:375.

Hashizume, T., H. Morimoto, T. Masubuchi, M. Abe, T. Hamada, S. Horii, Y. Zitsukawa, and C. Yokota. 1964. Studies on the feeding standard for dairy cattle. 6. Energy and protein requirements of a pregnant cow. Special Report of the National Institute of Animal Industry, Ministry of Agriculture and Forestry, Chiba, Japan.

Hobson, P.N., R. Summers, J.R. Postgate, and D.A. Ware. 1973. Nitrogen fixation in the rumen of a living sheep. J. Gen. Microbiol. 77:225.

Hodgson, J.C. and Thomas, P.C. 1975. A relationship between the molar proportion of propionic acid and the clearance rate of the liquid phase in the rumen of the sheep. Brit. J. Nutr. 33:447.

Holcomb, H.H., M.E. Costlow, R.A. Buschow, and R.L. McGuire. 1976. Prolactin binding in rat mammary gland during pregnancy and lactation. Biochem. Biophys. Acta. 428:104.

Hoshino, S. and Y. Hirose. 1964. Studies on protein digestion in ruminants. I. Casein degradation in rumen. Jap. J. Zootech. Sci. 34:139.

Hungate, R.E. 1966. The Rumen and Its Microbes. Academic Press, New York.

Hutton, J.B. 1963. Studies on the nutritive value of New Zealand dairy pastures. II. Herbage intake and digestibility studies with dry cattle. New Zealand J. Agr. Res. 5:409.

Ibrahim, F.A. and J.R. Ingalls. 1972. Effects of various roughages sources in complete feeds on milk production, composition, and rumen metabolism of dairy cows. J. Dairy Sci. 55:971.

Inagaki, Y. and K. Kohmoto. 1982. Changes in Scatchard plots for insulin binding to mammary epithelial cells from recycling pregnant and lactating mice. Endocrinology 110:176.

Johnson, B.C., T.S. Hamilton, W.B. Robinson, and J.C. Garey. 1944. Nonprotein-N utilization by ruminants. J. Anim. Sci. 3:287.

Johnson, W.L., G.W. Trimberger, M.J. Wright, L.D. Van Vleck, and C.R. Henderson. 1966. Voluntary intake of forage by Holstein cows as influenced by lactation, gestation, body weight and frequency of feeding. J. Dairy Sci. 49:856.

Jordan, W.A., E.E. Lister, and G.J. Rowlands. 1968. Effect of plane of nutrition on wintering pregnant beef cows. Can. J. Anim. Sci. 48:145.

Kaplan, S.L. and M.M. Grumbach. 1974. Effects of primate chorionic somatomammotropin on maternal and fetal metabolism. Lactogenic Hormones, Fetal Nutrition, and Lactation. J.B. Josimovich, M. Reynolds and E. Cobo, ed. John Wiley and Sons, New York, N.Y. p.183.

Kartchner, R.J. 1980. Effects of protein and energy supplementation of cows grazing native winter range forage on intake and digestibility. J. Anim. Sci. 51:432.

Kellog, D.W. 1969. Analysis of rumen fluid volatile fatty acids by chromatography with porapak QS. J. Dairy Sci. 52:1690.

Koprowski, J.A. and H.A. Tucker. 1973. Serum prolactin during various physiological states and its relationship to milk production in the bovine. Endocrinol. 92:1480.

Kris, E.S., K.R. Pond, R.W. Harvey, and L. Goode. 1985. Intake and digestibility of coastal bermudagrass pellets in beef heifers during mid and late gestation and early lactation. J. Anim. Sci. 61 (Suppl. 1):344.

Lake, R.P., D.C. Clanton, and J.F. Korn. 1976. Intake, digestibility and nitrogen utilization of steers consuming irrigated pasture as influenced by limited energy supplementation. J. Anim. Sci. 38:1291.

Langlands, J.P. 1968. The feed intake of grazing sheep differing in age, breed, previous nutrition, and liveweight. J. Agr. Sci. (Camb.) 71:167.

Linzell, J.L. 1974. Mammary blood flow and methods of identifying and measuring precursors of milk. In: B.L. Larson and V.H. Smith. (Ed.) Lactation. Academic Press, New York. Vol. 1 p.143.

Lomax, M.A. and G.D. Baird. 1983. Blood flow and nutrient exchange across the liver and gut of the dairy cow: Effects of lactation and fasting. J. Nutr. 49:481.

Lusby, K.S, D.F. Stephens, L. Knory, and R. Totusek. 1967. Forage intake of range cows as affected by breed and levels of winter supplement. Okla. Agr. Exp. Stat. Res. Rep. MP-96:27.

Lusby, K.S., D.R. Gill, and R.L. Ball. 1982. Energy vs protein supplementation of steers grazing native range in late summer and early fall. Okla. Agr. Exp. Sta. Misc. Pub. MP-112:36.

Lyons, T., P.J. Caffrey, and W.I. O'Connell. 1970. The effect of energy, protein and vitamin supplementation on the performance and voluntary intake of barley straw by cattle. Anim. Prod. 12:323.

Mainaoy, J.R. 1978. Possible influence of prolactin on intestinal hypertrophy in pregnant and lactating rats. Experientia. 34:1230.

Makela, A. 1956. Studies on the question of bulk in the nutrition of farm animals with special reference to cattle. Suomen Maata Loustieteelisen Seuran Julkaisuja 85.

McCollum, F.T. and M.L. Galyean. 1985. Influence of cottonseed meal supplementation on voluntary intake, rumen fermentation and rate of passage of prairie hay in beef steers. J. Anim. Sci. 60:570.

McNamara, J.P. and D.E. Bauman. 1978. Partitioning of nutrients between mammary and adipose tissue of the rat during lactogenesis. J. Dairy Sci. 61 (Supple. 1): 156.

McNaught, M.L., E.C. Owen, K.M. Henry, and S.K. Kon. 1954. Utilization of nonprotein N in the bovine rumen (VIII) nutritive value of the proteins from preparations of dried rumen bacteria, rumen protozoa, and brewer's yeast. Biochem. J. 56:151.

Meites, J. and J.A. Clemens. 1972. Hypothalamic control of prolactin secretion. Vit. Horm. 30:165.

Melton, A.A., J.K. Riggs, L.A. Nelson, and T.C. Cartwright. 1967. Milk production, composition and calf gains of Angus, Charolais and Hereford cows. J. Anim. Sci. 26:804.

Mepham, T.M. 1982. Amino acid utilization by lactating mammary gland. J. Dairy Sci. 65:287.

Metz, S.H.M. and S.G. van den Bergh. 1977. Regulation of fat mobilization in adipose tissue of dairy cows in the period around parturition. Netherlands J. Agric. Sci. 55:198.

Milford, R. and D.J. Minson. 1965. Intake of tropical pasture species. Proc. Int'l. Grass. Cong. 9:815.

Minson, D.J. 1963. The effect of pelleting and wafering on the feeding value of roughage. A review. J. Brit. Grassld. Soc. 18:39.

Moe, P.W. and H.F. Tyrrell. 1972. Metabolizable energy requirement of pregnant dairy cows. J. Dairy Sci. 55:480.

Noble, R.C., W. Steele, and J.H. Moore. 1971. The plasma lipids of the ewe during pregnancy and lactation. Res. Vet. Sci. 12:47.

O'Keefe, E. and P. Cuatrecasas. 1974. Insulin receptors in murine mammary cells: Comparison in pregnant and non-pregnant animals. Biochem. Biophys. Acta. 343:64.

Orskov, E.R. 1982. Protein Nutrition in Ruminants. Academic Press, London.

Peel, C.J., D.E. Bauman, R.C. Gorewit, and C.J. Sniffen. 1981. Effect of exogenous growth hormone on lactational performance in high yielding dairy cows. J. Nutr. 111:1662.

Pope, L.S., L. Smithson, D.F. Stephens, D.O. Pinney, and M. Velasco. 1968. Factors affecting milk production of range beef cows. Okla. Agr. Exp. Sta. Misc. Pub. MP-70:69.

Poppi, D.P., D.J. Minson and J.H. Terrouth. 1981. Studies of cattle and sheep eating leaf and stem fractions of grasses. III. The retention time in the rumen of large feed particles. Aust. J. Agr. Res. 32:123.

Prokudin, A.V. 1965. Content of free amino acids in sheep rumen. Tr. Inst. F. Ziol., Akad. Nauk. Kaz. SSR 10:59 (Russian). Nutr. Abstr. Rev. 37:755.

Rakestraw, J., K.S. Lusby, R.P. Wettemann, and J.J. Wagner. 1983. Effects of postpartum weight loss on performance of fall calving cows. Okla. Agr. Exp. Sta. Misc. Pub. MP-114:218.

Rittenhouse, L.R., D.C. Clanton, and C.L. Streeter. 1970. Intake and digestibility of winter range forage by cattle with and without supplements. J. Anim. Sci. 31:1215.

Rush, I.G. and R. Totusek. 1976. Supplemental value of feed grade biuret and urea-molasses for cows on dry winter grass. J. Anim. Sci. 42:497.

Russell, A.J.F. and I.A. Wright. 1983. The use of blood metabolites in the determination of energy status in beef cows. Anim. Prod. 37:335.

Rutledge, J.J., O.W. Robinson, W.T. Ahlschwede, and J.E. Legates. 1971. Milk yield and its influence on 205-day weight of beef calves. J. Anim. Sci. 33:563.

Satter, L.D. and Roffler, R.E. 1975. Nitrogen requirement and utilization in dairy cattle. J. Dairy Sci. 58:1219.

Schneider, B.H. and W.P. Flatt. 1975. The Evaluation of Feeds Through Digestibility Experiments. Univ. of Georgia Press, Athens.

Searcy, R.L., G.S. Gough, J.L. Korotzer, and L.M. Berquist. 1961. Evaluation of a new technique for estimation of urea nitrogen in serum. Amer. J. Med. Tech. 27:255.

Shaw, G.H., E.M. Convey, H.A. Tucker, E.P. Reineke, J.W. Thomas, and J.J. Bryne. 1975. Bovine serum thyroxine, prolactin, growth hormone, glucocorticoid and thyroxine binding globulin response to thyroprotein. J. Dairy Sci. 58:703.

Shymala, G. and W.A. McBlain. 1979. Distinction between progestin and glucocorticoid binding sites in mammary glands. Apparent lack of cytoplasmic progesterone receptors in lactating mammary glands. Biochem. J. 178:368.

Sidhu, K.S. and R.S. Emery. 1972. Regulation of blood fatty acids and glycerol in lactating cows. J. Dairy Sci. 55:926.

Smith, J.A.B. and F. Baker. 1944. Utilization of urea in the bovine rumen (IV) isolation of the synthesized material and the correlation between protein synthesis and microbial activities. Biochem. J. 38:496.

Smith, S.W. 1975. A new salting out technique for colorimetric free fatty acids assay. Anal. Bioch. 67:531.

Somers, M. 1957. Salivary secretion and its functions in ruminants. Aust. Vet. J. 33:297.

Steele, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics (2nd Ed.). McGraw-Hill Book Co., New York.

Thompson, J.L., J.J. Robinson, and R. McHattie. 1978. An effect of physiological state on digestion in the ewe. Proc. Nutr. Soc. 37:71A.

Van Soest, P.J. 1983. Nutritional Ecology of the Ruminant. O & B Books, Inc. Corvallis. Oregon.

van't Klooster, A. 1976. Adaptation of calcium absorption from the small intestine of dairy cows to changes in the dietary calcium intake and at the onset of lactation. Z. Tierphysiol. Tierernahrg v. Futtermittelke. 37:169.

Vernon, R.G., R.A. Clegg and D.J. Flint. 1981. Metabolism of sheep adipose tissue during pregnancy and lactation. Biochem. J. 200:307.

Wagner, J.J., K.S. Lusby, and G.W. Horn. 1983. Condensed molasses solubles, corn steep liquor and fermented ammoniated condensed whey as protein sources for beef cattle grazing dormant native range. J. Anim. Sci. 57:542.

Waller, G.R., R.D. Morrison, and A.B. Nelson. 1972. Chemical composition of native grasses in Central Oklahoma from 1947 to 1962. Okla. Agr. Exp. Stat. Bull. B-699.

Weller, R.A., F.V. Gray, and A.F. Pilgrim. 1958. Conversion of plant nitrogen to microbial nitrogen in the rumen of sheep. Br. J. Nutr. 12:421.

Zinder, O., M. Homosh, T.R.C. Fleck, and R.O. Scow. 1974. Effect of prolactin on lipoprotein lipase in mammary gland and adipose tissue of rats. Am. J. Physiol. 226:744.

Zinn, R.A., L.S. Bull, and R.W. Hemken. 1981. Degradation of supplemental proteins in the rumen. J. Anim. Sci. 52:857.

APPENDIX

TABLE IV

CHEMICAL COMPOSITION OF HAY

	1	2	3	4	5	6	7	8	9
Crude Protein, %	4.66	4.54	4.56	4.61	4.62	4.94	4.96	4.74	4.72
Acid detergent fiber, %	43.4	44.9	44.3	42.9	44.9	43.2	42.2	42.3	43.0
Lignin, %	5.45	5.34	5.47	4.79	4.93	5.86	4.72	5.09	4.80
Ash, %	7.16	7.04	6.26	6.85	6.83	7.17	6.52	6.31	6.80
Acid insoluble ash, %	3.90	3.88	3.69	3.94	3.96	3.76	3.50	3.27	3.59

TABLE V

DOSE CONCENTRATIONS OF
YTTERBIUM AND COBALT

	1	2	3	4	5	6	7	8	9
Ytterbium, g/hd	.79	.84	.83	.83	.89	.87	.80	.86	.88
Cobalt, g/hd	1.06	1.12	1.04	1.02	1.05	1.17	1.05	1.05	1.09

TABLE VI

COW WEIGHT AND BODY CONDITION CHANGES DUE TO STATE OF PRODUCTION AND EARLY POSTPARTUM PROTEIN

	-3	-2	-1	0	1	2	3	4	5
Cow weight change, kg									
Control	0	-5.3±4.83	-3.0±4.83	-69.9±4.83	-73.7±4.83	-79.6±4.83	-99.5±4.83	-106.1±4.83	-118.2±5.26
Supplemented	0	-6.3±4.83	-6.3±4.83	-68.8±4.83	-57.5±4.83	-55.7±4.83	-52.9±4.83	-51.6±4.83	-46.7±5.26
Body condition change, units									
Control	0	-.085±.0913	.010±.0913	-.418±.0913	-.373±.0913	-.681±10913	-.777±.0913	-.968±.0913	-1.116±.0995
Supplemented	0	-.036±.0913	.036±.0913	-.063±.0913	-.203±.0913	-.250±.0913	-.157±.0913	-.154±.0913	- .036±.0995

TABLE VII

CALF PERFORMANCE

	1	2	3	4	5
Calf weight gain, kg					
Control	4.6±1.62	10.9±1.37	13.5±1.55	20.6±1.74	24.2±2.11
Supplemented	8.4±1.51	15.4±1.27	19.5±1.43	27.0±1.61	33.9±1.96

TABLE VIII

DIGESTIVE AND METABOLIC CHANGES DUE TO PHYSIOLOGICAL STATUS AND EARLY POSTPARTUM PROTEIN SUPPLEMENTATION

	WEEK								
	-2			1			4		
	ACE	PROP	BUT	ACE	PROP	BUT	ACE	PROP	BUT
Volatile fatty acids, %									
Control	83.89±.675	10.12±.672	6.00±.457	85.30±.604	9.98±.601	4.72±.408	86.63±.604	9.22±.601	4.15±.408
Supplement	84.82±.604	8.93±.601	4.91±.408	85.96±.604	9.72±.601	4.16±.408	86.28±.604	8.82±.601	4.89±.408

	WEEK								
	-3	-2	-1	0	1	2	3	4	5
Nonesterified fatty acids, µmol/l									
Control	2046±182.9	1807±126.1	1870±126.1	1922±126.1	1794±115.1	2135±115.1	1994±115.1	1675±115.1	1510±138.9
Supplement	1826±138.8	1784±125.6	2125±115.1	1673±125.4	1338±125.6	1100±115.1	1002±125.4	778±115.1	983±138.8
Plasma urea nitrogen, mg/dl									
Control	3.17±.514	4.58±.354	3.78±.354	4.53±.354	3.54±.323	2.83±.323	2.94±.323	3.48±.323	4.31±.390
Supplement	2.94±.390	3.29±.352	3.62±.323	5.04±.352	3.87±.353	4.73±.323	4.54±.352	3.98±.323	4.80±.390
Ruminal ammonia, mg/dl									
Control	0.148±.4661	0.232±.3213	0.293±.3213	0.239±.3213	0.171±.2932	0.195±.2932	0.101±.2932	0.097±.2932	0.103±.3539
Supplement	0.062±.3538	0.127±.3200	0.306±.2932	1.013±.3196	2.347±.3200	2.609±.2932	2.443±.3196	2.811±.2932	2.960±.3538
Liquid passage rate, %/hr									
Control	5.25±1.09	3.87±.752	4.41±.752	4.24±.752	5.47±.687	5.84±.687	5.50±.687	5.56±.687	4.79±.829
Supplement	6.73± .828	4.84±.749	4.98±.687	6.43±.748	5.20±.749	8.43±.686	5.90±.748	7.05±.687	8.15±.828
Particulate passage rate, %/hr									
Control	3.05±.589	2.95±.406	3.23±.406	3.96±.406	3.29±.370	3.69±.370	2.99±.370	2.49±.370	2.76±.446
Supplement	3.92±.447	2.97±.404	3.35±.370	4.23±.404	4.22±.404	4.12±.370	4.01±.404	4.57±.370	6.14±.447
Dry matter digestibility, %									
Control	49.94±3.93	49.18±3.52	48.95±3.34	41.99±1.86	37.72±1.93	38.93±2.08	40.32±2.77	43.35±3.04	42.07±3.77
Supplement	46.40±3.34	46.78±2.85	47.61±2.85	50.47±2.37	44.93±1.97	47.48±1.93	50.74±1.86	52.61±1.84	50.59±2.15
Organic matter digestibility, %									
Control	52.47±3.99	51.82±3.57	52.18±3.39	45.37±1.89	40.19±1.96	41.04±2.11	42.83±2.81	45.65±3.09	44.50±3.82
Supplement	48.81±3.39	49.41±2.89	50.89±2.89	53.52±2.40	47.40±2.00	49.79±1.95	53.25±1.89	55.02±1.86	53.11±2.18
Hay OM digestibility, %									
Control	52.47±4.23	51.82±3.79	52.18±3.60	45.37±2.00	40.19±2.08	41.04±2.24	42.83±2.98	45.65±3.28	44.50±4.05
Supplement	49.03±3.59	49.54±3.06	51.01±3.07	41.89±2.55	36.38±2.12	40.13±2.07	44.45±2.00	46.85±1.98	44.52±2.31
ADF digestibility, %									
Control	42.96±4.55	43.79±4.08	41.18±3.87	36.84±2.16	33.16±2.24	32.57±2.41	33.65±3.21	36.51±3.53	36.08±4.36
Supplement	39.52±3.86	43.41±3.30	46.85±3.30	39.91±2.74	38.80±2.28	39.06±2.23	41.14±2.16	43.59±2.13	43.71±2.49

TABLE VIII (Continued)

	WEEK								
	-3	-2	-1	0	1	2	3	4	5
Cellulose digestibility, %									
Control	56.42±4.75	48.54±4.26	46.57±4.04	51.05±2.25	47.60±2.34	37.37±2.52	40.38±3.35	47.96±3.68	50.69±4.56
Supplement	50.95±4.04	47.71±3.44	45.69±3.45	53.73±2.86	52.22±2.38	43.76±2.33	47.70±2.25	54.09±2.22	57.44±2.60
Hay DM Intake, g/d									
Control	8214±610.8	7097±547.4	6858±519.4	6408±289.6	7758±300.8	8116±323.4	8074±430.4	7770±473.1	7823±585.4
Supplement	7212±518.5	6281±442.6	5864±443.1	6467±367.7	8981±306.6	10744±299.5	11554±289.5	12114±285.7	13121±333.9
DM Intake, g/d									
Control	8214±610.8	7097±547.4	6858±519.4	6408±289.6	7758±300.8	8116±323.4	8074±430.4	7770±473.1	7823±585.4
Supplement	7212±518.5	6281±442.6	5864±443.1	7613±367.7	10127±306.6	11890±299.5	12700±289.5	13260±285.7	14267±333.9
OM Intake, g/d									
Control	7631±562.5	6639±504.0	6433±478.2	5997±266.6	7247±277.0	7577±297.8	7579±396.4	7297±435.6	7350±539.1
Supplement	6712±477.4	5880±407.6	5504±408.0	7100±338.6	9425±282.3	11063±275.7	11862±266.5	12393±263.0	13308±307.4
Crude Protein Intake, g/d									
Control	367.3±32.49	306.9±27.11	299.6±27.62	282.7±15.40	355.6±16.00	384.2±17.20	377.7±22.89	350.1±25.16	347.9±31.14
Supplement	314.2±27.58	267.9±23.54	255.3±23.57	796.0±19.56	924.7±16.31	1026.2±15.93	1067.1±15.40	1076.1±15.19	1117.5±17.76
Hay DM Intake, % of body weight									
Control	1.61±.121	1.40±.108	1.35±.103	1.30±.057	1.59±.059	1.67±.064	1.70±.085	1.64±.094	1.71±.116
Supplement	1.48±.103	1.31±.088	1.24±.088	1.26±.073	1.80±.061	2.16±.059	2.33±.057	2.44±.056	2.65±.066
Hay DM Intake, g/kg$^{.75}$									
Control	76.74±5.70	66.79±5.10	64.45±4.84	61.19±2.70	76.65±2.80	78.34±3.01	79.27±4.01	76.54±4.41	78.71±5.46
Supplement	69.78±4.83	61.44±4.13	57.83±4.13	60.12±3.43	85.02±2.86	102.01±2.79	109.90±2.70	115.24±2.66	125.18±3.11
OM Intake, % of body weight									
Control	1.49±.112	1.31±.101	1.27±.095	1.21±.053	1.48±.055	1.56±.059	1.60±.079	1.54±.087	1.61±.108
Supplement	1.40±.096	1.25±.082	1.18±.082	1.39±.067	1.89±.056	2.22±.055	2.39±.053	2.49±.052	2.69±.061
OM Intake, g/kg$^{.75}$									
Control	71.31±5.269	62.46±4.721	60.43±4.480	57.28±2.497	69.75±2.595	73.14±2.790	74.43±3.713	71.89±4.081	73.97±5.050
Supplement	65.62±4.472	58.15±3.818	54.89±3.822	66.21±3.172	89.26±2.645	105.05±2.583	112.85±2.497	117.88±2.464	126.94±2.880
Hay OM Intake, g/d									
Control	7631±562.5	6639±504.0	6433±478.2	5997±266.6	7247±277.0	7577±297.8	7579±396.4	7297±435.6	7350±539.1
Supplement	6712±477.4	5880±407.6	5504±408.0	6043±338.6	8368±282.3	10006±275.7	10804±266.5	11335±263.0	12251±307.4
Hay OM Intake, % of body weight									
Control	1.50±.112	1.31±.101	1.27±.095	1.21±.053	1.48±.055	1.56±.059	1.60±.079	1.55±.087	1.61±.107
Supplement	1.39±.095	1.23±.081	1.16±.081	1.18±.067	1.67±.056	2.01±.055	2.18±.053	2.29±.052	2.48±.061
Hay OM Intake, g/kg$^{.75}$									
Control	71.31±5.258	62.46±4.712	60.43±4.471	57.29±2.493	69.76±2.590	73.15±2.784	74.43±3.705	71.90±4.072	73.97±5.039
Supplement	64.95±4.463	57.50±3.810	54.25±3.814	56.17±3.166	79.21±2.640	94.99±2.578	102.79±2.492	107.83±2.460	116.87±2.874

TABLE VIII (Continued)

	WEEK								
	-3	-2	-1	0	1	2	3	4	5
Digestible DM Intake, g/d									
Control	4080±351.9	3520±315.3	3385±299.2	2679±166.8	2940±173.3	3171±186.3	3250±247.9	3373±272.5	3292±337.2
Supplement	3344±298.7	2983±255.0	2817±255.2	3745±211.8	4561±176.6	5662±172.5	6458±166.7	6943±164.5	7212±192.3
Digestible OM Intake, g/d									
Control	3984±346.4	3469±310.4	3381±294.6	2712±164.2	2927±170.6	3123±183.4	3244±244.1	3338±268.3	3273±332.0
Supplement	3282±294.0	2954±251.0	2828±251.3	3708±208.6	4476±173.9	5522±169.8	6329±164.2	6787±162.0	7065±189.4
Digestible OM Intake, % of body weight									
Control	0.79±.073	0.69±.066	0.67±.063	0.55±.035	0.60±.036	0.64±.039	0.68±.052	0.71±.057	0.72±.071
Supplement	0.69±.062	0.63±.053	0.61±.053	0.73±.044	0.89±.037	1.11±.036	1.28±.035	1.37±.034	1.43±.040
Digestible OM Intake, g/kg$^{.75}$									
Control	37.39±3.402	32.72±3.048	31.89±2.892	25.99±1.613	28.14±1.675	29.98±1.801	31.75±2.397	32.83±2.634	32.89±3.260
Supplement	32.25±2.887	29.28±2.465	28.22±2.468	34.64±2.048	42.27±1.708	52.47±1.668	60.39±1.612	64.77±1.591	67.36±1.859
Digestible Hay OM Intake, g/d									
Control	3984±347.6	3469±311.5	3381±295.5	2712±164.8	2927±171.2	3123±184.0	3244±244.9	3338±269.2	3273±333.1
Supplement	3313±295.0	2979±251.8	2853±252.1	2420±209.2	3052±174.5	4028±170.4	4813±164.7	5269±162.5	5450±190.0
Digestible Hay OM Intake, % of body weight									
Control	0.79±.073	0.69±.065	0.67±.062	0.55±.035	0.60±.036	0.64±.039	0.68±.051	0.71±.057	0.72±.070
Supplement	0.67±.062	0.61±.053	0.59±.053	0.47±.044	0.61±.037	0.81±.036	0.98±.035	1.07±.034	1.10±.040
Digestible Hay OM Intake, g/kg$^{.75}$									
Control	37.39±3.394	32.72±3.042	31.89±2.886	25.99±1.609	28.14±1.672	29.98±1.797	31.75±2.392	32.83±2.629	32.90±3.253
Supplement	31.67±2.881	28.67±2.459	27.61±2.462	22.47±2.044	28.75±1.704	38.27±1.664	45.99±1.609	50.35±1.587	51.95±1.855
Indigestible Hay OM Intake, g/d									
Control	3647±524.1	3170±469.7	3051±445.7	3285±248.4	4320±258.1	4453±277.5	4334±369.4	3958±405.9	4076±502.3
Supplement	3399±444.8	2900±379.8	2650±380.2	3622±315.5	5315±263.1	5977±256.9	5990±248.4	6066±245.1	6800±286.5
Indigestible Hay OM Intake, % of body weight									
Control	0.71±.105	0.62±.094	0.60±.089	0.66±.050	0.89±.052	0.92±.056	0.92±.074	0.84±.081	0.89±.101
Supplement	0.71±.089	0.62±.076	0.57±.076	0.71±.063	1.07±.053	1.20±.052	1.20±.050	1.22±.049	1.38±.057
Indigestible Hay OM Intake, g/kg$^{.75}$									
Control	33.92±4.948	29.74±4.434	28.54±4.207	31.29±2.346	41.61±2.437	43.17±2.620	42.68±3.487	39.06±3.832	41.07±4.742
Supplement	33.28±4.200	28.83±3.585	26.64±3.589	33.70±2.979	50.46±2.484	56.72±2.426	56.80±2.345	57.48±2.314	64.92±2.705
Albumin, mg/dl									
Control	5.54±.172	5.42±.156	5.75±.143	4.52±.156	4.42±.143	4.47±.143	5.09±.156	5.20±.156	5.36±.172
Supplement	5.17±.156	5.43±.143	5.53±.143	4.06±.143	4.18±.143	4.10±.143	4.66±.143	5.17±.143	5.09±.172

VITA

Juan Manuel Gonzalez

Candidate for the Degree of

Master of Science

Thesis: DIGESTIVE AND METABOLIC CHANGES IN FALL-CALVING COWS DUE TO STAGE OF PRODUCTION AND EARLY POSTPARTUM PROTEIN SUPPLEMENTATION

Major Field: Animal Science

Biographical:

Personal Data: Born in Bogota, Colombia, August 27, 1957, the son of Bernardino Gonzalez and Lucia Amaya de Gonzalez.

Education: Graduated from Bolivar High School, Cali Colombia, May 1975; received the Bachelor of Science degree from Oklahoma State University, with a major in Animal Science, May 1984; completed requirements of the Master of Science degree at Oklahoma State University, December, 1987.

Experience: Family import-export bussiness, Colombia, 1975; assistant herdsman, Klassen Bros., Kansas, 1978; student employee, Oklahoma State University Swine Barn, 1983; research assistant, U.S.D.A., A.R.S, Stillwater, 1984.

Professional Organizations: Phi Kappa Phi.