Intensified Calf Feeding Programs for Purebred and Crossbred Calves

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(Abstract)

In the first experiment, 132 Jersey calves were assigned to one of three diets on three farms. Diet 20/20, 28/25, and 28/20 were milk replacers (MR) consisting of 20%, 28%, and 28% CP, and 20%, 25%, and 20% fat, respectively. Diet 20/20 was reconstituted at 10% DM solids, whereas diets 28/25 and 28/20 were reconstituted at 12.5% DM solids. Body weight, body length, hip height, wither height, heart girth, and hip width were measured weekly. An initial plasma sample was analyzed for IgG concentration to test for passive immunity. Calves remained on study for 8 wk.

Body weight gain, ADG, total weight gain, and stature measurements were greatest for calves fed 28/25 and lowest for calves fed diet 20/20, whereas calves fed 28/20 were intermediate.

In the second experiment, 70 calves were assigned to one of two treatments. Calves included purebred Holsteins, Jerseys, and crossbred reciprocals. Calves were assigned to diet 20/20, which was reconstituted to 10% DM solids or diet 28/20, which was reconstituted to 13% DM solids. Body weight, body length, hip and wither heights, heart girth, and hip width were measured weekly. Plasma samples were collected weekly for analysis of PUN, glucose, and total proteins. Body weight gain, ADG, and total weight gain were greatest for calves fed 28/20 and least for calves fed diet 20/20. Therefore, feeding calves a 20/20 MR at 10-15% of their BW results in lower BW gain, ADG, total weight gain, and stature measurements.

Keywords: **Calves, Milk Replacer, Growth, and Crossbreds.**

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Chapter One

Introduction

The National Animal Health Monitoring System (NAHMS, 1993, 1995, 2002) reported 8.4%, 11.0%, and 8.7% mortality in preweaned calves in the years of 1991, 1995, and 2002, respectively and represented 78% of the dairy herds in the US. Considering that a well managed herd can achieve mortality rates below 5% this indicates that the dairy industry has difficulty managing preweaned calves. Conversely, death loss for heifers after weaning until calving in comparable years was 2.2%, 2.4%, and 1.9% (NAHMS, 1993, 1995, 2002).

As a result of the high cost of milk replacer, increased labor involvement of feeding calves individually, and increased cost of replacements total cost per day for heifers is highest during the first 3 months of life (Smith, 1991). Kertz (1998) demonstrated relative increases of both BW and wither height are most rapid and cost-efficient during the first 6 months of life. Hence, improved management, which allows better growth, has the potential to decrease cost of replacement animals and decrease age at first calving. Therefore, as demand for replacements increase, more emphasis should be placed on practices that enhance calf performance and reduce calf mortality.

Increasing emphasis on intensified calf feeding programs makes early growth and health important. These programs require maximal growth rates from birth to calving and require expert management skills. Economic advantages are gained from improved feed efficiency, ADG, and promotion of lean tissue growth at this critical preweaned stage of life. Intensified programs involve MR feeding rates of (0.68 to1.13 kg of powder); approximately double that of the conventional programs (0.45 kg of powder). Crude protein in MR should be similar of that in whole milk to meet amino acid requirements of the rapidly growing bone and muscle. Intensified programs capitalize on the rapid and efficient early lean growth potential of calves, which allows greater frame growth without fattening. Target rates of gain reach 0.91 kg/day by the second week and continue through weaning.

Other favorable consequences of intensified feeding systems include changes in body composition, early endocrine development, immune system development and function, and possible subsequent increases in milk production. Health of intensely fed calves is improved due to enhanced development and function of the immune system. Increased levels of growth hormone and insulin-like growth factors are present because of the improved plane of nutrition and play a role in the growth, maintenance, repair, and function of the immune system (Clark, 1997).

In addition to improved immune response, researchers (Foldager and Krohn, 1994; Bar-Peled et al., 1997; Foldager et al., 1997) reported increased first lactation milk yield, decreased age at first calving, and increased BW at calving when calves were fed ad libitum intakes during the first 6 weeks of life.

Weaknesses also exist with intensified calf feeding programs, which include increased costs during the milk feeding period, delayed rumen development, and more intense management. To meet specifications of an intensified calf-feeding program, MR must contain more high quality milk proteins (28% - 30%), which will increase cost of MR per 23 kg by $5 to $6 over conventional MR. Moreover, intensified calf programs also call for a reformulated starter containing more protein, which increases cost of the starter program.

Another concern of intensified rearing systems is delayed rumen development. Starter intake is a major stimulus for rumen development, and increased feeding of liquids slows starter intake. Bartlett et al., (2001) showed that increased liquid feeding rates reduced voluntary starter intake. The study showed that starter intake curves are similar to control calves, but experience a 2-week delay.

Success of intensified programs depends on excellent management. Though not a disadvantage to a good manager, management must be exceptional in all phases of calf rearing, including colostrum and disease management at birth, sanitation, water availability, illness detection, and the ability to reduce volume of MR the week prior to weaning.

Objectives:

The objectives of the experiments described in this work were:

1) To examine the relationship between dietary protein, energy, growth, body composition, and feed efficiency in Holstein, Jersey, and crossbred bull calves.
2) To compare breed effects on starter intake, growth, and body composition of Holstein, Jersey, and crossbred bulls.
3) To evaluate the effects of intensified feeding regimens on growth parameters, starter intake in calves under field conditions.

Chapter Two

Literature Review

Nutrient Requirements for Preweaned Calves

Growth and development

Manipulation of genetic and environmental factors can change growth patterns in farm animals. Growth is defined as quantitative changes in the body, while development expresses qualitative changes (Batt, 1980). Growth is an increase in body weight, body length, hip height, wither height, heart girth, and hip width until mature size is reached. This growth is an increase in cell size and cell numbers resulting in protein deposition. More specifically, growth is an increase in the mass of structural tissue (bone, muscle, and connective tissue) and organs accompanied by a change in body form and composition (Taylor and Field, 2001). Owens et al. (1993) explained the primary mechanism of growth as hyperplasia, the accumulation of new cells, and hypertrophy, the enlargement of cells. Development is defined as the directive coordination of all diverse processes until maturity is reached. It involves growth, cellular differentiation, and changes in body shape and form (Taylor and Field, 2001).

Growth can be divided into several phases; prenatal, neonatal, prepubertal, pubertal, and postpubertal. Three phases of prenatal growth occur including the sex cells, the embryo, and the fetus. From conception to birth, fetal mass increases 44 x $10^{\wedge 7}$ times compared with a 20-fold increase from birth to adulthood; length increases 3850 times to term, compared with a three to four-fold increase from birth to adulthood (Greenspan and Strewler, 1997). During embryological development a spherical mass of cells differentiates into specific cell types and eventually into recognizable organs. The endoderm differentiates into the digestive tract, lungs, and bladder; the mesoderm into the skeleton, skeletal muscle, and connective tissue; the ectoderm into the skin, hair, brain, and spinal cord. Growth, development, and differentiation processes, involving primarily protein synthesis, are directed by DNA chains of chromosomes and the organizers in the developing embryo. Thus, the nucleus is a center of activity for different types of cells, directing growth and development processes (Taylor and Field, 2001).

The fetus undergoes marked changes in shape and form during prenatal growth and development. Early in the prenatal period, the head is much larger than the body. Later, the body and limbs grow more rapidly than other parts. The order of tissue growth follows a sequential trend determined by physiological importance, starting with the central nervous system and progressing to bones, tendons, muscles, intermuscular fat, and subcutaneous fat (Taylor and Field, 2001).

During the first two-thirds of the prenatal period, most of the increase in muscle weight is due to hyperplasia (increase in number of fibers). During the last trimester of pregnancy, hypertrophy (increase in size of fibers) represents most of the muscle growth. Individual muscles vary in their rate of growth, with larger muscles (those of the legs and back) having the greatest rate of postnatal growth. Water content of fetal muscle declines with fetal age, and this decline continues through postnatal growth as well. The relative size of the fetus changes during gestation, with the largest increase in weight occurring during the last trimester of pregnancy (Taylor and Field, 2001). In mature animals, unlike prenates, new cells are produced at a steady, but slow rate to maintain cell numbers by replacing cells that are lost (Hafez and Dyer, 1969).

Patterns of growth during development

Transition from prenatal to postnatal life requires maturation of biological systems essential for survival and growth (Mellor, 1988; Silver, 1990). The neonatal period is the most critical phase of postnatal growth and development in mammals. Studies in humans and animals have shown that malnutrition during the neonatal and early weaning periods permanently decreases the postnatal growth rate. In all mammals, body weight increases exponentially between conception and maturity (Burrin et al., 2001). Therefore, the relative rate of growth is higher during the neonatal period than at any time during postnatal life. In regards to composition of growth, fetal growth is dominated by much higher deposition rates of protein than of fat (Mitchell et al., 2001). The relative deposition rates of protein (40-50 g/d) and fat (30-40g/d) are similar in the neonatal pig (Shields et al., 1983). Conversely, subsequent to puberty, between 50 and 100 kg body weight in pigs, the amount of fat deposited (22.6 kg) is approximately fourfold greater than that of protein (5.88 kg) (Shields et al., 1983).

The fractional rates of protein deposition and synthesis are higher during the neonatal period and decline progressively with postnatal age. The rates of whole body protein synthesis (g/kg BW per day) in both pigs and humans are three to four times greater in neonates (31 and 11) and in adults (7 and 3.5), respectively (Reeds et al., 2000). Increased sensitivity of the neonatal skeletal muscle to anabolic stimuli is linked to the increased sensitivity of components of the intracellular signaling pathway that controls translation initiation and insulin action (Davis et al., 2000). The heightened responsiveness of the neonate to anabolic stimuli enables the rapid incorporation of amino acids into protein thereby minimizing their oxidation. This contributes to the relatively high efficiency of protein utilization compared to later stages of postnatal growth (Burrin et al., 2001).

Pattern of nutrition during development

The composition of nutrient supply changes significantly between conception and maturity. During the neonatal phase when maternal milk represents the source of nutrition, the proportion of dietary fat increases dramatically. Mammalian milks are relatively high in fat content, usually representing at least 50% of the caloric content. The proportion of nutrient intake derived from protein is lower than fat, but tends to correlate with the rate of neonatal growth. For instance, the contribution of protein to caloric content of sow's milk (25%) is approximately three times higher than human milk (8%), which correlates with the rate of weight gain in neonatal pigs compared to human infants of 50 versus 15 g/kg per day, respectively. After weaning, the composition of the diet changes again as the relative proportion of carbohydrate to fat increases with domestic animals and humans. In humans, estimates of carbohydrate and fat intake represent approximately 50% and 35% of the dietary energy intake (Burrin, 2001).

Studies in piglets also indicate that output and composition of milk limit growth of suckling pigs (Pluske, et al., 1995). Studies in the piglets show that voluntary energy intake of piglets fed milk replacer is 50% to 100% greater than those suckled by the sow between 8 and 16 days of age. Premature human infant and piglet studies indicate that increasing the protein to energy ratio of the neonatal diet substantially increases the proportion of lean tissue growth and nitrogen retention (Pluske, et al., 1995). Furthermore, growth of the premature infants and neonatal animals is more responsive to higher protein-energy intakes than at later stages of postnatal life.

Survival

Calf mortality is connected in part with failure to consider principles of natural processes. In nature, all mammals nurse their mothers until solid feeds can be consumed in quantities sufficient to maintain normal growth (Wing, 1963). However, in a dairy operation this is not the case, young calves are removed from their dam after birth, which offers the young animal little resistance to disease, due to the lack of nutrients in milk replacers.

In addition to somatic growth and lean tissue deposition, nutrition has a significant impact on the survival and health of the neonate. Rates of morbidity and mortality are high during the neonatal period (Burrin et al., 2001). In swine, the rates of pre-weaning mortality range from 13 to 15%, whereas in human infants the perinatal mortality rate is approximately 1% of all live births (Lay et al., 2001).

The epitheliochorial placentation of ruminants prevents in utero passage of Ig to the bovine fetus, which is born agammaglobulinemic (Mee et al., 1996). Thus, the newborn calf is dependent upon passive immunity from colostrum to prevent neonatal morbidity and mortality, as well as influencing long-term calf performance (Wittum and Perino, 1995). Passive immunity is provided when maternal colostrum containing large amounts of IgG are fed to neonatal calves within the first few hours of birth. This is achieved by the transport of macromolecules found in colostrum through the intestinal epithelium, which remains permeable for approximately 24 hours after birth (Staley and Bush, 1985; Stott et al., 1979). Absorbed Ig is then transferred through the lymphatic system into peripheral circulation; this is an effective mechanism until the specific immune system of the calf matures (Redman, 1979). Therefore, to ensure adequate protection against disease exposure, calves rely entirely on the consumption of an adequate amount of quality maternal colostrum within a few hours of birth.

Several studies in the United States indicate that acquisition of passive immunity in young calves is often inadequate (Besser and Gay, 1994; Donovan et al., 1998; Virtala et al., 1999). Failure of passive transfer may be attributed to colostrum containing an inadequate mass of IgG, poor colostrum feeding methods, and poor efficiency of IgG absorption in calves (Abel Francisco and Quigley, 1993; Lee et al., 1983; Rea et al., 1996; Quigley and Drewry, 1998). The economic impacts of failure to achieve adequate passive immunity are substantial. Griebel (1987) reported that 75% of calf mortality occurs before the age of one year. The National Animal Health Monitoring System (NAHMS, 1993, 1995, 2002) conducted a study of dairy operations in the United States and found that there is substantial loss to the dairy industry due to calf mortality, occurring from birth to weaning. The surveys conducted in 1991, 1995, and 2002 yielded results that the mortality rates were 8.4%, 11.0%, and 8.7% respectively. Therefore, management procedures and products that improve passive immunity in calves are crucial for today's dairy industry.

Kruse (1970) suggested that dairy calves should consume at least 100g of Ig during the first 12 hours of life to ensure adequate serum Ig and protection against disease. Whether adequate serum Ig is obtained also depends on efficiency of Ig absorption by the calf. Dairy producers usually feed a fixed volume of colostrum per calf. In a recent survey of 1811 United States dairy farms, 26% of producers who hand-fed their calves fed less than 2 L of colostrum and 74% fed less than 3.84 L of colostrum (USDA, 1993). Pritchett et al., (1991) reported that 23% of Holstein cows producing less than or equal to 8.5 kg of colostrum at the first milking had colostral IgG_1 concentration of less than 35 mg/ml, and the percentage increased as weight of colostrum increased. Therefore, under current feeding practices, failure of calves to absorb adequate concentrations of Ig should occur frequently, and greater than 40% of US dairy heifer calves have less than 10 mg of IgG/ml of serum (USDA, 1993).

In addition to disease protection, early provision of colostrum is important as a source of nutrients (Davis and Drackley, 1998; Quigley and Drewry, 1998). Because supplies of endogenous fuels are exhausted within hours without feed (Okamato et al., 1986; Rowan, 1992), the carbohydrate, fat, and protein in colostrum are essential as fuels for the newborn. Increasing evidence in calves and other species indicates that colostrum also provides a number of hormones and growth factors necessary to stimulate growth and development of the digestive tract and other organs systems (Hammon and Blum, 1998).

Disease

Calf disease, particularly diarrhea and respiratory disease has significant effects on profitability of every calf raising enterprise. A large proportion of dairy calves in the US develop diarrhea during the first 2 months of life. Diarrhea is the most common ailment in young calves causing more than 52% and 62.1% of preweaning deaths in 1993 and 2002, respectively (NAHMS, 1993; NAHMS, 2002). Diarrhea can be caused by a variety of bacteria or viruses, but the most common pathogens are enterotoxigenic *Eshcerichia coli*, rotavirus, coronavirus, *Cryptosporidium*, and *Salmonellae* (Tromp, 1990). During incidents of diarrhea, 10-12 % of body weight can be lost as water. Water loss in feces carries with it major quantities of electrolytes, sodium, chloride, and potassium (Lewis and Phillips, 1978; Phillips, 1985), which if not rapidly corrected will result in death. Recent evidence indicates that electrolyte disturbances are more important than dehydration itself in causing death from diarrhea (Walker et al., 1998).

At the occurrence of diarrhea, the calf should be started on oral rehydration (Davis and Drackley, 1998). Recent studies suggest that the calf should continue to receive a portion of, or all of its regular feeding of milk or milk replacer with the oral electrolytes (McGuirk, 1992; Garthwaite et al., 1994) as long as the calf is willing to drink.

Proper nutrition is essential in keeping calves healthy. Formulation of diets to provide sufficient amounts of protein (including ruminally available and escape protein), energy (as fat and carbohydrates), vitamins, minerals, and water is essential (Quigley, 2003). Methods of housing and feeding colostrum may also alter the exposure to infectious organisms, which may predispose calves to scours, thereby reducing intake and body weight gain. Housing also affects incidence and severity of scours (Davis et al., 1954; Jorgensen et al., 1970; Waltner-Toews et al., 1986). However, other reports (James et al., 1984; Martin et al., 1975) indicate that overall calf management influences morbidity more than housing systems.

Immunology and its affects on growth

Disease reduces growth. Schmoldt et al. (1979) showed with 341 female dairy preweaned calves that pneumonia alone, diarrhea alone, and both together decreased BW gain daily by 1.3, 3.0, and 4.8 g/kg, respectively, during a 44 to 60 day follow up period. The corresponding relative declines in growth rate were 8, 18, and 29%, respectively. Calves were inspected daily, 14% were treated for pneumonia and 15% for diarrhea, and 11% for both. Van Donkersgoed et al. (1993) followed 325 calves from birth to 1.5 to 6 month of age and reported that calves with pneumonia, either diagnosed and treated by the owner or diagnosed by the semimonthly clinical examinations of calves by the research veterinarian, had reduced girth growth during the 1st month of life.

There is a negative relationship between productivity and the pathogenic environment – as pathogens in the environment increase, productivity decreases. In the 1950s a number of experiments with chicks were published, which indicated an effect of the pathogenic environment on growth. In one study, chicks were hatched and maintained in a Gustafsson germ free apparatus or a conventional environment and fed a diet with or without antibiotics (Coates et al., 1963). Germ-free chicks gained more weight than chicks maintained in conventional environmental pathogens and growth.

Antigens stimulate immune cells to secrete cytokines. Cytokines are immunoregulatory molecules because they reduce inflammation and up-regulate the immune system. Cytokine messages from the immune system to the brain are responsible for sickness behavior, including decreased feeding (Johnson, 2001). If animals do not eat well they obviously cannot grow or produce well. However, feed intake is not the only factor limiting productivity of sick animals. Cytokines released during the immune response are major mediators of metabolism. Klasing et al. (1987) conducted a series of experiments in chicks, which demonstrated that a variety of inflammatory agents reduced food intake and efficiency of gain, increased body temperature, increased plasma corticosterone and altered distribution of zinc, iron, and copper. About 70% of the reduction in weight gain was due directly to a reduction in voluntary food intake- meaning 30% was due to a change in metabolism.

The use of milk replacer containing lower levels of fat and protein results in marked weight loss, nutritional scours, increased susceptibility to infectious diarrhea and pneumonia, and a high mortality (Roy, 1969). In children there is an increased incidence and severity of infectious disease, secondary to protein energy malnutrition (PEM) induced impairment of the immune system (Edelman, 1977; Scrimshaw, 1968; Chandra, 1981). It is possible that a similar effect occurring in neonatal calves contributes to the increased mortality.

In the neonatal calf there are age – related increases in peripheral blood T-cell populations (Outteridge and Dufty, 1981), neutrophil functions (Hauser et al., 1986), complement activation (Renshaw et al., 1978; Renshaw and Everson, 1980), delayed hypersensitivity (Woodward et al., 1979; Woodward et al., 1979b), and lymphocyte proliferation responses (Rossi et al., 1979; Rossi et al., 1981).

Recent studies provide indirect evidence that PEM may decrease the immunocompetence of neonatal calves. Examination of 20 emaciated neonatal calves revealed marked lymphoid depletion in thymus, spleen, lymph nodes, and aggregated lymphoid follicles consistent with cellular immunodeficiency. Precocious thymic involution in malnourished children has been related to decreased immunocompetence (Edelman, 1977; Purtilo and Conner, 1975).

Nutritional deficiency has detrimental immunological effects including decreased cell-mediated immunity, T-cell numbers, helper T-cell function, complement activity and neutrophil bacterial killing capacity (Renshaw and Everson, 1980; Purtilo and Conner, 1975;

Chandra et al., 1982; Chandra, 1983). Many of these functions are already suboptimal in neonatal calves (Osburn et al., 1974). This may make adequate nutrition of critical importance in the prevention of infectious disease during this time.

Gross anatomy of the digestive system

From birth until weaning to dry feed, the calf undergoes tremendous physiologic and metabolic changes (Toullec and Guilloteau, 1989). Early during the embryonic stage, the digestive system of the calf begins to develop (Warner, 1958). At 56 days after conception, the rumen, reticulum, omasum, and abomasum are visible (Warner, 1958). At birth, the calf acts as a monogastric, with the abomasum being the predominant compartment, constituting of 50% of total tissue weight of the stomach. During this period, the abomasum carries out the gastric digestion of proteins similar to that of nonruminants.

The young calf necessitates more digestible nutrients than mature ruminants due to lacking the digestive capability required for digestion of forages. Therefore, the most critical period is the first 2-3 weeks of life, during which time the calf's digestive system is immature, but developing rapidly with regard to digestive secretions and enzymatic activity (Toullec and Guilloteau, 1989).

The major factor influencing development of the forestomach of the neonatal calf is the diet. Dry feed consumption causes the forestomach to increase rapidly in volume, weight of tissue, musculature, and absorptive capacity (Huber, 1969). Dry feed has a high potential for fermentation that allows for more rapid development of the tissues of the forestomach (Brownlee, 1956). Consumption of dry feed with high potential for fermentation to volatile fatty acids (VFA), acetate, butyrate, and propionate, which are involved in development of the forestomach. Butryic and propionic acids are the primary stimulators of tissue growth because ruminal tissues extensively metabolize them during absorption (McGilliard et al., 1965). Their metabolism provides energy for growth of epithelial tissue and for muscular contractions. In addition, butyrate and propionate have direct effects on proliferation and differentiation of gastrointestinal epithelial cells (Velazquez et al., 1996). However, at the neonatal stage of life, the rumen and its microbial population are immature (Anderson et al., 1987) and ruminal cellulose digestibility is limited (Williams and Frost, 1992). As a result, long hay is not as effective as concentrates in developing a functional rumen and limits metabolizable energy intake in young calves (Stobo et al., 1966).

Rumen development

Development of the rumen is critical to successful weaning and good growth rates after weaning. Rumen development encompasses several processes that must be set in motion early in the life of the calf if it is weaned to solid feed at an early age (4-6 weeks). Calves experience three distinct phases in digestive development; preruminant, transitional, and ruminant phases (NRC, 2001). Phase one is the preruminant phase, which consists of highly digestible liquid feeds for the calf. The preruminant calf can digest energy in the form of fat and lactose, but is not capable of digesting starch, cellulose, or hemicellulose and requires a high quality protein source (NRC, 2001). The second phase of rumen development is the transitional phase where the calf is consuming both liquid and dry feed. At this time, the calf gains the ability to digest plant proteins, starch, cellulose, hemicellulose, and synthesize B-complex and K vitamins (NRC, 2001). Initial changes are solely dependent on consumption of dry feed, coupled with microbial fermentation of the organic matter to VFA (Flatt et al., 1958). Butyric and propionic acids have the greatest stimulatory effect on growth and development of the rumen epithelial tissues (Sutton et al., 1963). It has been reported that 50% of the propionic acid produced in the rumen is metabolized during absorption, and up to 90% of butyric acid is oxidized to ketone bodies by the rumen epithelium (Britton and Krehbill, 1993), from which they are carried by ruminal veins to the portal vein and hence to the liver.

Another process that must occur in the development of a truly functional rumen, which is the final phase, is the establishment of a diverse and stable population of microorganisms. These microorganisms must possess growth characteristics and nutritional requirements that can be met by the diet. Bryant et al. (1958) found that calves reared by their dam acquired microorganisms capable of digesting cellulose within 1-3 weeks after birth. Lactate-fermenting bacteria were found in high numbers at 1-3 weeks of age, but declined to levels similar to those found in the adult animals by weeks 9-13. Bacteria capable of growth under aerobic conditions and coliforms were found in highest numbers during weeks 1-3, but these species declined in numbers as the animals aged (Bryant et al., 1958). Animals fed only milk showed high populations of aerobic bacteria in the rumen (Lengemann and Allen, 1959). Type of diet consumed and closeness of the housing of experimental calves to mature animals appear to be major factors influencing the establishment of protozoa in the ruminal population.

In establishing a mature like fermentation, maintaining ruminal pH in an optimal range (6.0-6.8) for the greater part of the preweaning period is a critical factor. The pH values are the highest during the first week of life. The major changes in the rumen occurred after animals start to consume significant quantities of dry feed, during weeks 4-7. Once an active, relatively stable fermentation is established, the molar proportions of the VFA also are more stable (Davis and Drackley, 1998).

During the first three weeks of life, when dry matter intake is relatively low, fermentation activity is low and ruminal pH is high, and predominant microorganisms are aerobic or facultative bacteria (Lengemann and Allen, 1959). As dry feed intake increases, lactic acid becomes a major product of the fermentation, resulting in a drop of ruminal pH. Over the period of 4-6 weeks of age, the total population of aerobic and facultative microorganisms declines. The anaerobic bacterial population increases during this period, resulting in a more diverse population of microorganisms. Bacterial species utilizing starch, protein, and lactic acid increase in numbers (Bryant and Small, 1960; Anderson et al., 1987).

From information available, it is evident that young calves given access to dry feed early in life (1 week of age) will, over the course of 9-12 weeks, develop a population of bacteria that will be similar in every respect to that found in mature animals in that environment.

Because calves fed higher amounts of milk or milk replacer consume less dry feed, rumen development is delayed (Kaiser, 1976), which is seen with intensified calf rearing. Consequently, at the time of weaning, solid feed intake usually is less for calves fed greater amounts of milk relative to calves receiving the lesser amounts of milk (Dalzell and Allen, 1970; Hodgson, 1971; Kaiser, 1976; Le Du and Baker, 1978; Le Du et al., 1978).

Nutrient requirements

Nutrient requirements are predicted upon the expected composition of body weight gain. As body weight increases, energy content of the gain increases. This implies that the animal deposits more fat, which is more costly and less efficient. However, protein requirements do not decrease as fast because efficiency of protein absorption declines (NRC, 2001).

Detailed descriptions of nutritional requirements of the calf are found in the (NRC 2001), and are discussed in the following sections. Current industry standards ignore growth requirements and target growth rates in favor of least cost approach that relies on the maintenance level of milk and milk replacer intakes. Due to limited dry matter offered, traditional feeding practices do not use efficiency of gain possible at a young age. Dry matter intake is the factor most highly correlated with growth rate (Hodgson 1971; Huber et al., 1984; Khouri and Pickering, 1968; Williams et al., 1986; Woodford et al., 1987). Due to cost of milk and milk replacer, traditional feeding systems limits milk intake in the hope that calves will begin consuming less expensive dry feed. Conversely, no other neonatal system attempts to force weaning from birth.

Energy requirements

Traditional practices, favoring a least cost approach, comprise growth performance and health. The calf partitions energy in the diet into maintenance or growth requirements. Increased energy intake by calves often is desired for increased growth or maintenance of normal growth in cold weather (Kuehn et al., 1994). Major body energy stores at birth are glycogen, fat, and protein. However, glycogen and fat are much more readily available than protein, yet they offer only a limited energy reserve compared to the daily energy needs (Duee et al., 1996; Herpin and Dividich, 1995). In fasted newborn pigs, liver and muscle glycogen reserves are quickly mobilized and metabolized within the 12 to 24 hours. As a consequence, soon after birth, intake of dietary energy, usually from colostrum is vital for the survival of the neonate (Burrin et al., 2001).

High fat content of colostrum is an excellent source of fatty acids for oxidative metabolism, which increases substantially after birth. Furthermore, oxidation of fatty acids by other peripheral tissues, such as heart and skeletal muscle, spares glucose for use in glucose-dependent tissues, such as the brain, kidney, and erythrocyte (Burrin et al., 2001).

Increased energy intake is accomplished by additional milk or by added fat to milk or starter to increase energy density. Net energy maintenance requirements are 12-24% higher in autumn, spring, and winter than summer. When ambient temperature falls below a lower critical temperature then the calf's maintenance energy requirements increase as the calf must increase its expenditure of dietary energy to maintain body temperature. Thermoneutral zone for calves is reported at 15-25^0 C for young calves, but older calves have a lower critical temperature of –5 to -10^0 C (NRC, 2001). In cold climatic conditions, added fat to milk replacer has increased body weight gains in calves (Jaster et al., 1992). Scibilia et al. (1987) fed milk replacer containing 10, 17.5, or 25% fat to 36 Holstein bull calves housed at -4 or 10^{0}C. Calves housed at -4^{0}C gained more body weight with higher fat in the milk replacer. Schingoethe et al. (1986) observed that body weight gains in winter were higher for calves fed additional milk than for calves fed the same amount of solids in a fat supplement. Calves receiving a starter with a high percentage of fat (6%) did not differ in feed intakes, body weight gains, or ratios of feed to gain compared with those calves fed low fat (2%) and raised in mild winter conditions, ambient temperatures of 25-30^0 C (Stewart et al., 1984).

In addition, feeding supplemental fat can reduce the occurrence of scours. Fowler (1993) reported increased feed efficiency and decreased the incidence of scours when levels of dietary fat increased in diets. Optimum feed efficiency and scour scores were obtained when calves were fed diets containing 20% or more fat.

Moreover, calves fed milk replacers with higher levels of fat deposit more body fat (Gerrits et al., 1996; Donnelly and Hutton, 1976) and increased body fat could be beneficial to the calf in periods of stress (Davis and Drackley, 1998). However, the NRC (2001) states that research on the optimal concentrations of fat in MRs are conflicting.

Fasting metabolism

Fasting or basal metabolism is the starting point in deriving maintenance energy requirement of the animal (Brody, 1945). Fasting metabolism represents the minimum energy cost for maintaining life, that is, maintenance of cellular ion gradients, respiration, circulation, thermal regulation, kidney function, and muscle tone. To measure fasting metabolism the animal is fasted for 15 hours, housed in a thermoneutral environment, and physical activity is limited. As conditions are reached, heat production of the animal can be measured and the quantity of heat produced by the animal is indicative of the maintenance cost of the animal (Davis and Drackley, 1998). Previous studies of energy metabolism in animals noted that basal heat production was not a linear function of body weight of the animal (Brody, 1945 and Kleiber, 1965). Basal heat production expressed per unit of body weight was 20-25 times higher for small animals, such as mice, than for large animals, such as cattle (Brody, 1945). Basal heat production was proportional to surface area (meters squared) of the animal; however, measurement of the surface area of an animal is extremely difficult and highly variable.

Influences of basal metabolic rate

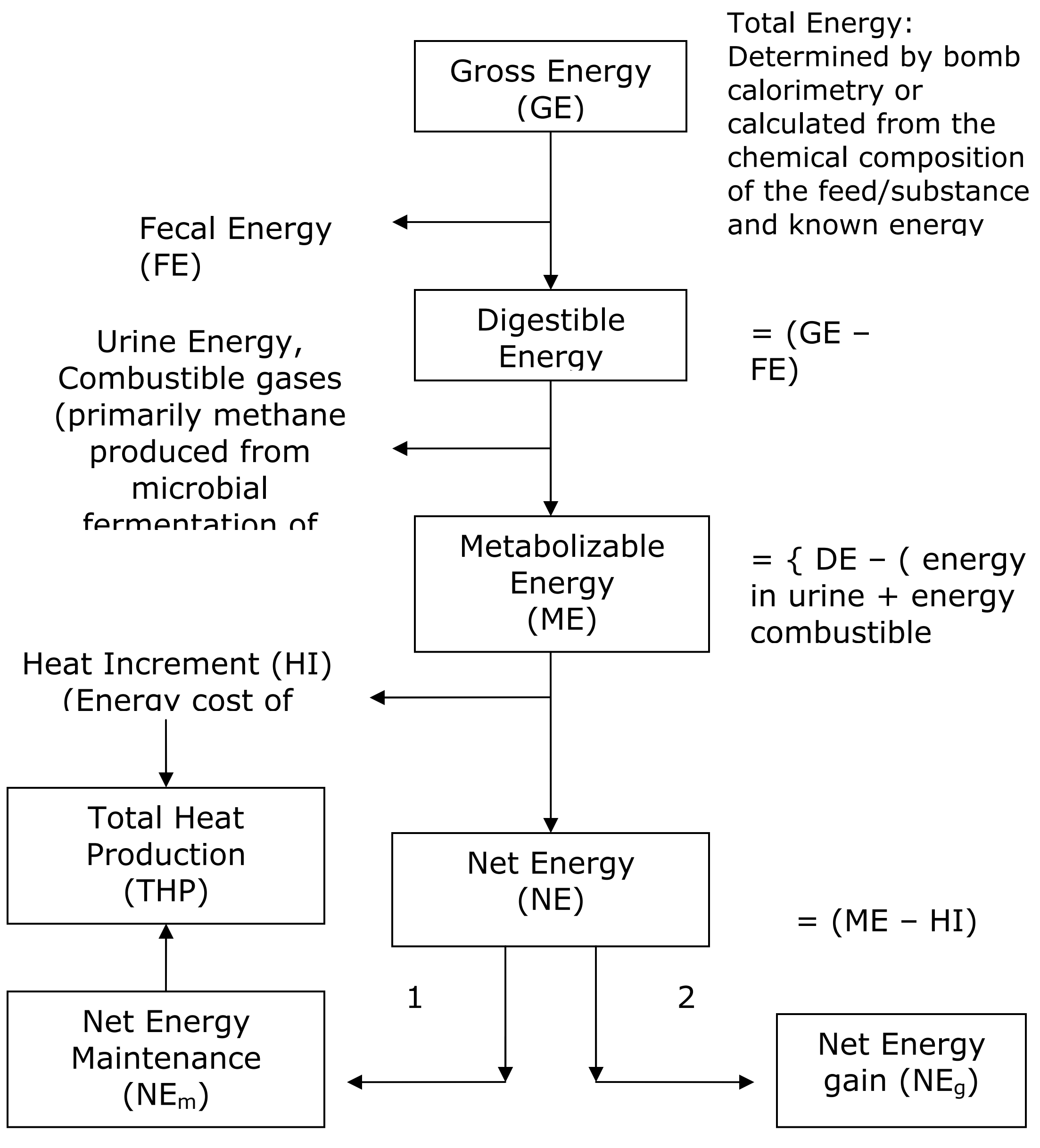
Age of the calf influences the basal metabolic rate of the animal. Calves less than 10 days of age exhibit very high rates of metabolism due to adjusting to a hostile environment, compared with utero conditions. Newborn calves demonstrate their highest rate of heat production within 15 minutes after birth (Thompson and Clough, 1970). Brody (1945) found basal metabolic rate to be highly correlated with heart and respiratory rates. Higher basal metabolic rates in the young calf compared with the mature animal may be linked to differences in relative weights of vital organs whose energy expenditure is high (Baldwin and Bywater, 1984).
Young calves compared with mature cattle, exhibit high physical activity (Van Es, 1972; Ortigues et al., 1994) and high rates of tissue protein turnover (Simmon, 1989). Vermorel et al.

(1983) noted an increase in heat production in response to standing. Heat production at birth was 200 kcal/h for a 45.4 kg calf, approximately 3.2 times the expected rate for older calves under thermoneutral conditions. Heat production declined over a short period of time (17 hours) after birth. The high rate of tissue protein turnover in young calves may be responsible for the low efficiency of use of metabolizable energy (ME) for protein gain (Kirchgessner et al., 1976; Geay, 1984).

Table 2.1 Literature values for fasting basal metabolic rates of young calves.

Age of calves	Basal Metabolic Rates ($kcal/kg^{0.75}$ per 24 h)	Source
Growing cattle	86[a]	National Research Council (1989)
1 mo	123	Agriculture Research Council (1965)
1 mo	122; 153	Blaxter and Wood (1951a)
8 d, 1 mo, 2 mo	172, 137, 122	Ritzman and Colovos (1943)
Veal calves (BW 101-118 kg)	136-146	Webster et al. (1975)
2-14 d	80, 86	Johnson and Elliot, (1972b)
6-14 d	91	Schrama (1993)
Age unknown (BW 35 kg)	112	Blaxter (1952)
3-35 d	100-101	Holmes et al. (1975)
5-13 h	116-131	Carstens et al. (1987)
6 h (held at 20^0C)	120	Thompson and Clough (1970)
1-7 d	86-155	Roy et al. (1957)
2.5 – 15 h	103-104	Okamoto et al. (1986)
15 h (held at 37^0C)	114	Vermorel et al. (1983)

[a] Reported as net energy for maintenance (NE_m).
Davis and Drackley (1998)



1 First priority 2 Occurs only after maintenance needs have been satisfied

Figure 2.2 Classical scheme for energy partitioning in animals.

Adapted from Davis and Drackley, 1998.

Energy requirement for maintenance

The metabolizable energy (ME) requirement for maintenance of the calf is the point in energy status at which the animal is neither losing nor gaining body energy (zero energy balance). Since basal metabolic rate is a function of metabolic body weight ($kg^{0.75}$), the ME requirement for maintenance is a function of metabolic size. Blaxter (1952) reported that efficiency of use of ME in whole cow's milk by the young calf fed at or near maintenance intake level was 85%. The Agricultural Research Council (ARC, 1980) established the equation

$$\text{Efficiency of use of ME} = 0.30q_m + 0.546$$

for the relationship between the metabolizability of the diet for maintenance (q_m) and the efficiency of use of ME. Therefore, efficiency of use of metabolizable energy (ME) from milk or milk replacer to meet maintenance requirements is set at 86%. Consequently, maintenance ME is defined as 0.100 Mcal/$kg^{0.75}$ daily.

Toullec (1989) calculated the ME requirements with this equation

$$\text{ME requirement (Mcal/d)} = 0.1\ LW^{0.75} + (0.84\ LW^{0.355})(LWG^{1.2})$$

where live weight (LW) and daily live weight gain (LWG) are in kilograms. The first portion of the equation sets the ME required for maintenance at 100 kcal/$kg^{0.75}$ per day. The second portion of the equation is used to derive the ME required for LWG, which is a function of both body size (LW) and rate of gain (LWG). This equation was derived on the basis of an efficiency of conversion of ME to NE_g of 69 % for calves fed only milk or milk replacer. Values predicted by the present equation agree well with available experimental data on body composition of dairy calves (Webster et al., 1975; Donnelly and Hutton, 1976; Gerrits et al., 1996). Metabolizable energy requirements for maintenance may be underestimated for calves during the first week of life because of the high and variable basal metabolic rate observed during this time (Roy et al., 1957; Okamoto et al., 1986; Arieli et al., 1995). Due to conflicting research from the 2001 NRC, it is feasible to assume that Jersey calves, owing to their smaller size require more energy per unit of BW for maintenance because they have a greater body surface area per unit of BW, as indicated by their metabolic bodyweight, and thus use more energy to maintain body temperature (Bascom, 2002).

Energy requirement for growth

Growth rate of calves depends on net energy available after maintenance requirements have been met. Starting point for deriving the ME requirement for body weight gain is NE_g, or the energy stored in body tissues. The calf is born with limited body energy reserves and only modest insulation afforded by hair coat and body fat. A newborn calf has enough body energy stores in the form of fat and glycogen to last no more than 1 day under cold conditions (Alexander et al., 1975; Okamoto et al., 1986; Rowan, 1992).

Protein content of body weight gain by the young calf is rather constant and is not greatly influenced by diet, rate of gain, age of animal, or breed (Toullec, 1989), however, energy content of gain is determined by the fat content of the diet. Donnelly and Hutton (1976) stated that energy stored as fat in young milk-fed calves accounts for 50%-70% of the total energy in gain. Holding other factors constant, an increase in ME intake above maintenance results in a linear increase in energy retention in body tissues. Johnson and Elliot (1972) found that efficiency of utilization of ME for body energy gain was approximately 63% and was constant at all levels of ME intake. Efficiency of ME utilization for growth in milk-fed calves is "close to 69%" and is not significantly affected by the age of the animal, live weight, live weight gain, or diet composition; hence "energy allowances can be expressed in terms of metabolism energy" (Toullec, 1989).

Table 2.2 Efficiency of utilization of metabolizable energy (ME) for gain in calves fed either milk or milk replacer.

Source	Efficiency
Gonzalez-Jimenez and Blaxter (1962)	0.77-0.82
Van Es et al. (1969)	0.69
Vermorel et al. (1974)	0.69
Toullec (1989)	0.69
Webster et al. (1975)	0.72
Holmes et al. (1975)	0.67[a]
Johnson & Elliot (1972)	0.63
Donnelly and Hutton (1976)	0.73-0.82
Neergaard (1976)	0.70-0.80[b]

[a] Calculated using ME_m values of 100.

[b] Calculated using ME_m values of 103.

Most researchers agree fairly closely on the ME required for maintenance, but differ widely as to ME requirement for body weight gain.

Table 2.3 Effect of rate of BW gain with constant initial BW (45.4 kg) on protein requirements of pre-weaned dairy calves.

Adapted from Davis and Drackley, 1998.

Rate of gain (kg/d)	ME (Mcal/d)	ADP (g/d)	Required DMI[a] (kg/d)	CP Requirements (% of DM)
0	1748	28	0.381	8.3
0.227	2296	82	0.504	18.1
0.454	3008	136	0.658	22.9
0.680	3798	189	0.830	25.3
0.907	4643	243	1.016	26.6
1.134	5532	297	1.211	27.2

[a]Amount of milk replacer DM containing 4573 kcal ME/kg DM needed to meet ME requirements

Protein requirements

Dietary protein is essential for growth and development of tissues. However, protein receives the most attention because it is the most expensive component of the diet for the young calf (Davis and Drackley, 1998). Calves require amino acids rather than protein but scientists lack sufficient information on amino acid requirements, therefore, the nitrogen needs of the calf are stated in terms of protein. Milk proteins are highly digested and contain the most nearly perfect balance of essential amino acids for maintenance and growth, and are most suitable for the calf less than 21 days of age (Davis and Drackley, 1998).

The 2001 NRC computes the protein requirement of calves weighing up to 100 kg with the factorial method of Blaxter and Mitchell (1948). Maintenance and growth are two components of protein requirement. Maintenance constitutes obligatory nitrogen (N) losses in urine and feces, whereas gain pertains to N stored in the tissues. The requirement is expressed in terms of apparent digestible protein (ADP, g/d).

ADP, g/d = 6.25 [1/BV (E + G + M X D) – M X D]

BV = biological value of milk proteins

Efficiency of N use for growth above maintenance is assigned a value of 0.80 (Donnelly and Hutton, 1976)

E (g/d) = endogenous urinary N

Computed as 0.2 $LW^{0.75}$, LW is live weight and is in kg (Agriculture Research Council, 1980)

G = N in gain

Assumed to be constant at 30 g N/kg LWG, LWG is live weight gain

M = metabolic fecal N

Set at 1.9 g/kg of dry matter consumed from milk or milk replacer

3.3 g/kg of starter DM consumed (Roy, 1980)

D = dry matter consumed

The value of 0.80 for biological value was determined at limiting protein intakes and assumes that the diet being fed is balanced for all essential nutrients and that energy intake is sufficient to support protein synthesis. Protein intake must not be in excess of that required for the targeted gain allowed by energy intake. Donnelly and Hutton (1976) stated that the biological value decreased as protein intake was increased because calves consuming high levels of DM (as a % of BW) or high-energy diets require more dietary protein for lean tissue growth than calves on low energy or restricted levels of intake.

Conversion of CP to apparently digestible protein (ADP) was assumed to be 93 percent for milk proteins (Agriculture Research Council, 1980), which is slightly higher than the value for conversion of dietary CP to absorbable amino acids (91 percent) (National Research Council, 1978). ADP and CP have been established on the basis of diets containing milk proteins with high digestibility and BV; calves might not use alternative nonmilk proteins in milk replacers at these high efficiencies, and appropriate adjustments may need to be made when such protein sources are used to ensure adequate supply of amino acids for growth (Davis and Drackley, 1998).

Protein requirements for maintenance

Protein requirement for maintenance of the preruminant calf is a function of two factors: (1) metabolic fecal N (MFN) losses and (2) endogenous urinary N (EUN) losses (Preston, 1963). Metabolic fecal nitrogen originates from eroded gut tissues resulting from passage of feed materials, bacterial debris, and digestive secretions (mucus and digestive juices). Losses of N via this manner are relatively small in the milk-fed calf compared with more mature animals consuming dry, coarse, fibrous feeds (Roy, 1970; Stobo and Roy, 1973). Calves consuming milk or milk replacer diets show MFN that range from 1.9-to 2.7-g/N kg of DM consumed (Lofgreen and Kleiber, 1953; Cunningham and Brisson, 1957; Roy, 1970; Donnelly and Hutton, 1976).

The EUN loss originates from tissue metabolism. This loss is related to overall metabolism, and is more correctly expressed on the basis of metabolic body size ($kg^{0.75}$). The EUN loss has been shown to decline with age (Roy, 1970). Reported EUN losses, when standardized to metabolic body size ($mg/kg^{0.75}$), range from 168 to 218 $mg/kg^{0.75}$/ d (Blaxter and Wood, 1951; Cunningham and Brisson, 1957; Roy, 1970).

There is also a small amount of protein needed to replace N lost from the surface of the body in addition to the requirements for MFN and EUN. Surface loss of N is proportional to the surface area of the body, which scales approximately to the two-thirds power of body weight. This is equal to approximately 2-3 g of protein a day (Davis and Drackley, 1998).

Another consideration is biological value (BV) of protein consumed. Biological value is a measure of how well the amino acid balance of the protein being fed meets amino acid requirements of the animals. Biological value is determined as percentage of reabsorbed amino acids retained by the body (N retention/N absorption X 100). Maximum tissue protein synthesis during growth requires a high-quality protein in the diet and adequate energy intake to use the absorbed amino acids.

Protein requirements for growth

The total protein requirement for maintenance plus gain of the young calf is primarily a function of the rate of body weight gain. Due to this relationship, the maintenance protein requirement is relatively small fraction of the total protein requirement in a reasonably fast growing calf. As growth rates increase, the calf's CP intake requirement increases (NRC, 1989). Preston (1966) stated that protein required in a ration depends on body weight, average daily gain, and protein digestibility. As growth rate increases, CP requirements increase at a faster rate than energy requirements (Preston, 1966). Therefore, the protein to energy ratio should be higher for rapidly growing heifers than for heifers growing at a standard rate.

A small number of studies have evaluated dietary protein levels for calves less than 6 months of age. These experiments (Schurman and Kesler, 1974; Veira et al., 1980) have shown optimal growth with a 16 to 18% CP diet. The NRC (1989) CP requirements for growing heifers from 2 to 6 months of age are 16% and 12% for heifers older than 6 months of age. The diet energy density recommended for growing heifers decreases linearly from 2 months of age (NRC, 1989). The ensuing CP to metabolizable energy (ME) ratios is 59 to 62:1 g/Mcal for heifers younger than 6 months of age. NRC (2001) states calves consuming milk or MR at or near ad lib intake require a higher level of protein relative to energy than calves fed a restricted level of milk or MR. Table 5 demonstrates at low levels of intake, a MR containing 21% CP and 21% Fat supplies enough energy and protein for similar amounts of energy and protein gain. When feeding rates are increased, energy supplied will support a higher rate of gain than protein, insinuating that added protein would increase the rate of gain. As a result, energy and protein requirements should be balanced for a calf's diet.

Table 2.4 ***Energy and Protein allowable gains for a 22.7 kg calf.***

DM fed	Intake	Allowable gain, kg		%CP
kg	% BW	Energy	ADP	Required in MR
0.30	10	0.21	0.16	23.5
0.34	12	0.29	0.20	28.5
0.40	14	0.41	0.24	32.0
0.45	16	0.5	0.28	34.0
0.51	18	0.6	0.33	36.0

Energy and protein allowable gains for a 22.7-kg calf fed a 21/21 milk replacer at an ambient temperature of 20°C. As the level of DM fed increases, the rate of gain supported by the protein in the diet is far less than the rate of gain supported by the level of energy in the diet. Therefore, a higher level of CP is required to support lean tissue growth. Values calculated using NRC (2001).

The protein to energy ratio may be a more appropriate method to evaluate protein requirements. The protein to energy ratio is more a function of ADG than body weight (Preston, 1966). Furthermore, researchers (Radcliff et al, 1997; VandeHaar, 1997) suggest that insufficient concentrations of dietary CP in rapidly growing prepubertal heifers may impair mammary development and decrease subsequent milk production.

In addition to rate of gain, composition of the gain also influences the protein requirement of the calf. Body weight gain is determined primarily by protein synthesis in the tissues, whereas energy retention is influenced more by fat storage (Davis and Drackley, 1998). The amount of N stored for each kilogram of gain in body weight varies between 26 and 34 g (Roy, 1970). This computes between 16.25 and 21.25 g of protein per 100 g of gain, when using a factor of 6.25 to convert N to protein.

Table 2.5 Nitrogen retention (protein accretion) in young calves fed whole milk or milk protein-based diets.

Source	N Retention (g/kg of gain)	Protein accretion (g/kg of gain)	Comments
Blaxter and Wood (1951)	26.2	164	Whole cow's milk diets fed at different levels
Brisson et al. (1957)	32.2	201	Whole milk-based diets
Roy et al. (1964)	34.1 28.7 33.1	213 (4 wk) 179 (7 wk) 207 (10 wk)	Calves fed milk-Protein-diets; measurements at 4,7, and 10 wk of age
Bryant et al. (1967)	25.6	160	Calves 4-60 d of age; fed skim milk based diets with 0%, 20%, 35%, or 50% of proteins replaced with distiller dried solubles
Roy (1970)	30.0	188	Value used by Roy (1970) in estimating apparently digestible protein requirement
Donnelly and Hutton	26.6-34.4	166-215	Calves fed milk-(1976) protein-based diets from 12 to 61 days of age; protein content of diets ranged from 5.7% to 31.5%

Adapted from Davis and Drackley, 1998.

Intensified calf rearing

Compared to later stages of life, the first weeks of life are critical and there is little recognition of how nutrition and environment during this period are linked to subsequent health and productivity. However, intensified feeding schemes promote rapid growth and development. These systems are designed to provide enough nutrients in the liquid diet to support ADG of 1000 g or more in Holstein calves (Drackley, 2001). Conversely, due to the cost of replacement heifers, cost efficiency has become a major concern of dairy farmers, and expenses associated with rearing heifers can be successfully reduced by early intake of starter. The most effective strategy to reduce these costs is to shorten the rearing period, by encouraging early intake of calf starter (Webb, 1992). Conventional heifer calf rearing schemes rely on restricted feeding of milk or milk replacer (typically 8 to 10% of body weight) to encourage early intake of starter, and gain little during the first weeks of life, but later increasing to rates of 250 to 400 g/d (Drackley, 2001). Drackley (2001) stated that the health of calves has been perceived to improve once calves were weaned from milk, which is likely a factor of the extensive detoxifying ability of the rumen, the bulking effect of solid feeds in the intestine, and improvements in energy balance.

The current convention of raising calves in the US has worked reasonably well and allows producers to wean healthy calves at less than 5 weeks of age and at minimal cost. However, heifer calf mortality in the US is still over 8.5% (NAHMS, 2002), which is not acceptable. It is evident that there is room for conventional systems to decrease mortality and morbidity in preweaned calves. Current feeding practices often do not take advantage of the efficiency of gain possible at this age because of limited amount of dry matter offered (Diaz et al., 2001). When compared to lambs and piglets, the restricted feeding rates of liquid feeding used on the average dairy farm lead to low feed conversion efficiencies.

Species	Gain to Feed Conversion	Reference
Current Calf (Birth to 6 wk)	0.35 - 0.45	Everitt and Jury, 1977
Lambs	0.69 – 0.73	Greenwood, 1997
Piglets	0.69 – 0.73	Harrel, 1998

Table 2.6 Gain to feed conversions of the calf, lamb, and piglet.

Traditional feeding systems supply limited nutrients above maintenance leading to low rates of gain (200g to 400g/d) (Wise and LaMaster, 1968). Restricted growth rates over an extended period of time are known to affect mature size and future performance in piglets (Burt and Bell, 1962; Everitt and Jury, 1977; and Swanson and Hinton, 1964).

Jersey and Holstein calves fed a 20% CP and 20% fat MR reconstituted at 12.5% DM solids at a rate of 31% of metabolic BW were supplied enough energy only to maintain BW (Mowery, 2001). Sufficient energy was provided for 227 g ADG according to NRC (2001), however, calves should have gained 8 kg BW over the duration of the experiment but the Jersey calves gained less than 5 kg BW. Jersey calves showed little or no increase in BW from birth to 22 d. However, BW began to increase in Holstein calves after d 15. This implies maintenance energy requirements of Jersey calves are higher per unit of metabolic BW than Holstein calves and that NRC (2001) equations for maintenance energy may not be appropriate for Jersey calves.

In another study, Holstein calves were fed MR (reconstituted to 12.5% DM) at 10% or 14% of BW and CP in the MR varied from 14% to 26% (Bartlett et al., 2001). In another Bartlett experiment, calves were fed milk at either 8.32% or 11.65% of BW or MR with similar nutrient density to milk at 11.65% of BW. Increasing the rate of feeding resulted in increased feed efficiency and an increase in body fat %. Increasing the level of CP in the diet also increased the level of feed efficiency but decreased body fat %. Calves fed milk and a MR with similar nutrient density to milk had similar feed efficiencies and body fat %. The results are found in Table 7.

Feeding Rate % of bw	CP % of DM	Fat % of DM	Feed efficiency gain/unit of feed	Fat % in body
10.0	14.0	22.0	0.40	6.8
10.0	18.0	20.7	0.48	5.9
10.0	22.0	19.4	0.55	5.6
10.0	26.0	18.1	0.61	5.1
14.0	14.0	22.0	0.52	8.8
14.0	18.0	20.7	0.59	8.1
14.0	22.0	19.4	0.72	7.1
14.0	26.0	18.1	0.71	6.6
8.32[m]	25.4	27.1	0.49	5.4
11.65[m]	25.4	27.1	0.72	6.7
11.65	26.0	28.0	0.65	4.1

Table 2.7 The effect of varying the level of intake and crude protein on feed efficiency and body fat deposition. (Bartlett et al., 2001)
[m]Whole milk.

Studies have shown that calves will consume in excess of 18% BW when fed milk at ad libitum intakes. Khouri and Pickering (1968) fed calves whole milk at rates of 11.3%, 13.9%, 15.9%, or 19.4 % (ad libitum) of body weight. Average daily gains during weeks 2 to 6 of life were 0.41, 0.50, 0.62, and 0.94 kg/d, respectively. As a result, what is referred to as “accelerated growth” is the restoration of biologically normal growth in early life before starter consumption becomes the predominant source of nutrients (Drackley, 2001). Hodgson (1971) and Huber et al. (1984) found that at higher rates of milk or milk replacer feeding, intake of starter decreased. Conversely, lower starter intake slows rate of rumen development, which has been assumed to contribute to calves “hitting the wall” when weaned from milk (Drackley, 2001).

In one experiment, one group of calves were kept with the cow for 2 weeks after birth, and these calves were allowed to suckle freely (Fowler and Weary, 2001). Control calves were separated from the cow within 24 hours and fed milk at 10% of body weight per day. At the end of the 2 weeks, calves kept with the cows gained 16.5 kg, compared with 4.5 kg for conventionally fed calves. Similar weight advantages have been shown in other studies in which the cow and calf are kept together (Metz, 1987).

Enhancing early growth rates has the potential to capitalize on efficiencies of early growth capacity of young calves. Proportional rates of increase in wither height and BW are highest during the first 2 months of life (Kertz et al., 1998). Furthermore, feed cost per increase in wither height is lowest during the first 2 months of age (Kertz et al., 1998). Efficiency of dietary protein use for body protein gain is highest in young calves and decreases with body size (Gerrits et al., 1996). Khouri and Pickering's (1968) study found that feed efficiencies (kg milk DM per kg BW gain) in which calves were fed whole milk at the rates of 11.3%, 13.9%, 15.9%, and 19.4% (ad libitum) of body weight were 1.58, 1.48, 1.34, and 1.23, respectively. These values are favorable with that found in the lamb and piglet. Increasing efficiencies with increasing feeding rate are attributable to increased gain per unit of maintenance (Drackley, 2001).

Calves receiving an ad libitum acidified feeding program demonstrated more rapid body weight gain than the conventionally fed controls in some (Thickett et al., 1983; Nocek and Braund, 1986; Woodford et al., 1987) but not all (Richard et al., 1988) experiments. Feeding ad libitum acidified milk repalcer led to good health of the calves and in some cases improved health (Nocek and Braund, 1986). Furthermore, feed costs per calf and feed cost per kilogram of body weight gain were increased substantially for the acidified, ad libitum program (Nocek and Braund, 1986).

Calves fed ad libitum showed marked improvements in weight gain and feed efficiency to 5 weeks of age, and weight advantages were retained through 8 weeks of age (Thickett et al., 1983). Conversely, Nocek and Braund (1986) and Richard et al. (1988) found that early differences in weight gain between ad libitum fed and conventionally fed calves were not maintained through the remainder of the growth period, resulting in no apparent advantage to justify the greater feed cost.

Recently, there has been increased interest in intensified growth programs for dairy heifers, with the goal to have heifers well grown enough to calve at an age of 18-20 months (Van Amburgh and Fox, 1996). These programs rely on maximal growth rates from birth through calving and require exceptional management. Nonetheless, dairy farmers due not see economic benefit perceived from the greater cost of rearing calves. However, calves in the field raised under more typical and less rigid management conditions might be more likely to benefit from increased liquid feed intake. Leadley and Sojda (1996) noted that a longer liquid-feeding period at higher intakes than recommended results in calves that are better grown, more vigorous, healthier, and suffer less slump in growth at weaning.

Williams et al. (1981) compared two amounts of milk replacer solids (600 and either 300 or 400 g/d) either with ad libitum or restricted access to calf starter. Calves fed the higher amount of milk replacer with ad libitum access to calf starter had the greatest average daily gains and the least mortality. Recent studies (Griebel et al., 1987; Pollock et al., 1993, 1994) demonstrated that a low level of nutrition results in impaired immune responses in young calves.

Diaz et al. (1998) adjusted intake of a MR in an attempt to achieve target ADG of 500 g, 950 g, or 1400 g. Calves were fed a 30% CP MR so that protein would not limit growth. Feed efficiency increased from 0.64 to 0.74 between the diets. Calves fed for a target gain of 1400g/d per d deposited more body fat and less protein than the calves fed for 500g ADG.

Traditional recommendations to feed no more than 8% to 10% of body weight during the first 1-2 weeks of life is based on the belief that feeding greater amounts of milk or milk replacer will cause nutritional diarrhea. Conversely, under good management and sanitation, feeding milk or milk replacer ad libitum does not lead to diarrhea (Mylrea, 1966; Roy, 1980). Conrad and Hibbs (1972) fed whole milk for ad libitum intake once daily beginning at day 3 of life. In 43 calves fed the ad libitum program, there was no difference compared with the restricted-fed controls for number or severity of digestive upsets, despite the consumption of 7.3-13.6 kg of milk daily. The diarrhea is contributed by the level of microbial colonization.

Increasing the rate of feeding of MR increases ADG and feed efficiency regardless of the level of CP in the diet but feeding low CP MR results in a composition of gain that has more fat and less protein than higher CP MR (Bascom et al., 2002; Bartlett et al., 2001; Gerrits et al., 1996; Donnelly and Hutton, 1976; Diaz et al., 2001) . Despite this evidence, most producers continue to feed restricted quantities of milk to calves, perhaps because of the perception that increased milk intake leads to higher incidence of diarrhea, or that it leads to reduced intake of solid feed, resulting in reduced weight gains after weaning.

Body composition

Jacobsen (1969) discussed the concept that nutrient requirements might vary with the intended purpose of the mature animal. Furthermore, Jacobsen (1969) suggested that it is possible to alter body composition of growing calves by nutrition, and this was partially elucidated by Donnelly and Hutton (1976) and Donnelly (1983). Furthermore, manipulation of the carbohydrate:fat ratio in diets of mice and rats influenced body composition (Hunt and Heald, 1970; Hartsook et al., 1973).

Roy (1970) employed comparative slaughter techniques in a study of fat supplementation and concluded that increasing dietary fat from 20 to 30% increased carcass fat without a change in N retention. Donnelly (1983) demonstrated that as the ratio of carbohydrate to fat increased, the crude protein and water content of the gain increased and fat decreased.

Excessive body fat deposition has been negatively correlated with mammary development, and future milk yield (Sejrsen et al., 1982; Radcliff et al., 2000). Thus, minimizing fat in the gain has the potential to be beneficial for long-term productivity.

A recent evaluation of the National Research Council Nutrient Requirements of Dairy Cattle (NRC, 1989) and Cornell Net Carbohydrate and Protein System (Fox et al., 1992) for growing Holstein heifers indicated that neither system adequately accounted for the energy requirements of the lightweight growing Holstein heifers (Van Amburgh et al., 1998). The equations used in the 1989 Dairy NRC and 1996 Beef NRC to predict energy and protein requirements for growth were based on equations developed by Garrett (1980, 1987) and the 1984 Beef NRC committee (NRC, 1984). This indicated a need to reevaluate the nutrient requirements of growing Holstein cattle, particularly at early stages of growth. The 2001 NRC makes a much needed improvement in predicting the requirements for young dairy calves. However, there is still much need for improvement as Bascom et al., (2002) concluded that the nutrient requirements for maintenance were much higher for Jersey calves than predicted by the NRC.

Composition of milk replacers

Various feeding and management practices on dairy farms have a profound impact on overall mortality, morbidity, and growth of the young calf. A wide variety of liquid feed sources are available to nourish the calf once it has been fed first colostrum and transition milk (second and subsequent milkings after first colostrum). Milk replacers are also good source of liquid feed for calves. There are often situations, in which milk replacers are more easily adapted to the labor and facility needs of calf-raising operations than either whole or waste milk (Fowler, 1992; Heinrichs 1994).

Milk replacers must be formulated with ingredients processed for the underdeveloped digestive system of the young calf. Within a few weeks of age, ability of the calf to digest various feedstuffs improves dramatically as its enzyme production increases and diversifies (Aranda et al., 1991; Nousianinen, 1990). The nutritional availability of protein and energy sources used for milk replacers is a key factor in determining the outcome of the feeding program (Schoonderwoerd and Misra, 1989).

Fluctuation in usage likely reflects several economic factors within the dairy industry. Data show that the percentage of farms using milk replacer all or part of the time varied from 72.4% in 1979, to 52% in 1983 (Hoard's Dairyman, 1990), 47.1% in 1987 (Heinrichs et al., 1987), and 55.7% in 2002 (NAHMS).

During the first 3 to 4 weeks of age, the enzymatic system of the calf is still developing, and the calf cannot digest starch sucrose, or maltose (Jenkins, 1982). Also, the calf has difficulty digesting carbohydrates other than lactose and glucose (Heinrich, 1994; Huber et al., 1961; Huber et al., 1961; Tomkins and Jaster, 1991). Growth, development, and digestive tolerance were improved in premature human infants who were fed formulas with ratios of whey to skim milk of 60:40 rather than 20:80. Studies with foals determined that diets predominantly composed of whey caused significant increases in mean body weight over time (Buffington et al., 1992).

Lipids supply greater than 50% of the energy in milk or milk replacer but typically supply only 10 to 15% of the energy from dry diets fed after weaning. In preruminant calves, liquid feeds are shunted to the abomasum via the esophageal groove; therefore, dietary lipids escape alteration by microbes in the developing rumen (Noble, 1980). Dietary triglyerides are hydrolyzed enzymatically to free fatty acids (FFA) and 2-monoglycerides in the abomasum and small intestine. The 2-monoglycerides and FFA are incorporated into micelles for absorption into intestinal epithelial cells. Both 2-monoglycerides and bile salts are necessary for stabilization of the micelles in the small intestine of preruminant calves (Small, 1968). Apparent total tract digestibility of long-chain saturated fatty acids and body weight gains were decreased when FFA replaced triglycerides in milk replacers (Jenkins et al., 1985), possibly because of insufficient formation of 2-monoglycerides for micelle formation.

Milk replacers are widely used in the US for providing nutrients to calves prior to weaning. During this period, replacement dairy calves are susceptible to many pathogens that cause disease. Antibiotics, which are extensively used in milk replacers (Heinrichs et al., 1995) 55.7% in 2002 (NAHMS), have been shown to improve performance and reduce scours in dairy calves (Morrill et al., 1995; Tomkins and Jaster, 1991). These antibiotics include chlortetracylcline, oxytetracycline, oxytetracycline with neomycin, decoquinate, and lasalocid (NAHMS, 2002). Researchers have demonstrated the benefits of adding antibiotics to the feed of young calves. These benefits include increased average daily gains, improved feed consumption, and enhanced phagocytic efficiency. Decreased incidence of scours, lower calf mortality, and decreased protein requirements are other benefits of adding antibiotics to milk replacer (Morrill et al., 1977; Morrill et al., 1995). Conversely, there are downsides to using antibiotics in animal agriculture. There is the possibility of antibiotic resistance as *The New England Journal of Medicine* (May, 1998) suggests with one organism, the link between antibiotic use in animals and antibiotic resistance in human pathogens.

Fat from sources other than milk is used readily, and lactose, the carbohydrate of choice for the young calves, is readily available as a by-product of cheese manufacturing, but milk protein is more difficult to replace. Other sources of fat include butterfat, tallow, choice white grease, and lard. Unsaturated fats such as, most vegetable oils, are unsatisfactory in MR

because they have lower digestiblities and cause diarrhea in calves (Jenkins et al., 1985). However, coconut and palm oils may be used in combination with animal fats in MR, these oils are more digestible (92-96%) than most vegetable oils (Toullec et al., 1980).
Protein ingredients in milk replacer contribute significantly to overall expense of these products. Most protein in milk replacer is provided by ingredients derived from milk, including whey protein concentrate, dried whey, and dried skim milk. Alternative sources of proteins in milk replacer, including soybean (Erickson et al., 1989; Mir et al., 1991), fish (Opstvedt et al., 1987), wheat protein, potato protein concentrate, meat solubles, sprayed dried red blood cells, animal plasma, and others (Otterby and Linn, 1981; Tomkins and Jaster, 1991), have been evaluated in milk replacer in an effort to reduce cost. However, the digestibilities of these alternative protein sources are inferior to skim milk. The reasons for inferior utilization of non-milk protein sources are largely due to differences in the amino acid profile of these proteins.

Several studies (Dawson etal., 1988; Otterby and Linn, 1981; Seegraber and Morrill, 1986) investigated the substitution of nonmilk proteins, particularly soy proteins, for milk proteins. However, results usually are better with replacers containing all milk protein than with replacers containing nonmilk proteins (Otterby and Linn, 1981). Many of these proteins have anti-nutritional factors. Soy proteins contain protease inhibitors that interfere with the ability of digestive enzymes including trypsin and chymotrypsin to digest proteins. Furthermore, soy proteins contain antigenic proteins that result in allergic reactions in young calves (Davis and Drackley, 1998). Other proteins, such as wheat proteins, have lower digestibilities in the young calf (Davis and Drackley, 1998).

Recently, proteins from animal plasma and red blood cells have been used in early weaning starter diets for pigs (Hansen et al., 1993; Kats et al., 1994) and in milk replacer for calves (Morrill et al., 1995; Tomkins et al., 1994) and have been used successfully in the swine industry (Ermer et al., 1992; Gatnau and Zimmerman, 1992; Kats et al., 1992). Plasma proteins may be attractive because of their high digestibility and favorable amino acid profile. Quigley et al. (2000) evaluated red blood cell protein in MR and were able to replace up to 43% of the protein in the MR without affecting weight gain, feed efficiency, starter intake, fecal scores or days scouring, indicating that the red blood cell protein could be an alternative source of protein

for use in MR. The concentration of Ig in plasma may also influence intestinal colonization by enteric pathogens (Drew, 1994).
However, due to the recent discovery of BSE in Washington State, use of animal plasma and red blood cells has been eliminated.

Crossbreeding

Crossbreeding provides a simple method to increase the health and efficiency of many plants and animals, by introducing favorable genes from other breeds, by removing inbreeding depression, and by maintaining the gene interactions that cause heterosis. "The demonstrated commercial success of hybrid corn and hybrid chicks has made it seem biologically possible to make several new breeds, each good in some specific combinations although it is own average phenotypic merit may be only mediocre" (McAllister, 2002). Using rotational crossbreeding might be more profitable for commercial production than would raising any purebreds available. Crossbreeding has been successful with chickens and (to a lesser extent) with pigs.

Most economically important traits in dairy cattle differ among breeds and are influenced by nutritional management (Hohenboken et al., 1995). Dual purpose and beef cattle breeds (Jenkins and Ferrell, 1992) and dairy cattle genotypes (Meyer et al., 1991; Wang et al., 1992) differ in the increase in milk yield in response to increase energy content in the diet.

For dairy cattle breeding, considerations on optimization of genetic improvement have genetic effects. Genetic variation is usually partitioned into additive and nonadditive components. Nonadditive genetic variation can be further divided into dominance variance caused by interaction of genes at the same locus and epistatic variance is due to interactions of genes at two or more loci (Fuerst and Solkner, 1993). Genetic improvement in dairy cattle involves exploitation of within-breed additive genetic variance by selection for milk and milk fat production. Nonadditive genetic factors have been examined in some experiments (Donald et al., 1977; McAllister, 1986; McDowell and McDaniel, 1968; Pedersen and Christensen, 1989; Rincon et al., 1982; Robison et al., 1981; Witt et al., 1973) crossing *Bos taurus* dairy breeds.

Total genetic makeup of crossbreds can include additive effects, dominance, maternal effects (both nuclear and cytoplasmic), maternal heterosis, and recombination effects. Beneficial heterosis of 5% was observed, but large standard errors of crossbred means due to small sample size potentially masked statistically significant differences (McAllister, 1986).

Current interest in crossbreeding in the commercial dairy industry, even though it is quite limited, raises questions of breed utilization. Fewer than 5% of US dairy cattle are other than purebred or grade Holsteins (McAllister, 2002). The large advantage of Holsteins for additive genetic merit for lactation milk yield is apparently responsible for this trend (McAllister, 2002). Young (1984) stated few dairy cattle in the United States are crossbred because high milk yields made purebred Holsteins the preferred breed.

"Crossbreds may not exceed the best purebred for any single trait, yet the net economic merit of crossbreds may be superior to purebreds when all traits of affecting or influencing net income are considered" (Fohrman et al., 1954). Heterosis would have to exceed 25% for the crossbreds to exceed the superior purebred (Nagai and McAllister, 1982) if one assumes a genetic model which includes additive direct breed effects and direct heterosis.

However, designed studies in North American herds indicated that some crossbreds were more profitable than Holsteins (Touchberry, 1992; McAllister et al., 1994). A study of Holstein crossbreds in a commercial herd also showed that some crossbreds may be more profitable than Holsteins (Lesmeiser et al., 2000). Lopez-Villalobos et al. (2000) concluded that rotational crossbreeding is profitable for commercial milk production in New Zealand. Crossbreeding of Jerseys with Holsteins is common in New Zealand (about 20% of milk-recorded cows) and in Australia (about 5% of cows) (VanRaden and Sanders, 2001).

An increasing proportion of the dairy cattle population in New Zealand has been crossbred since 1960, mainly with the aim of changing from straightbred Jerseys to Holstein-Friesians (Ahlborn-Breier and Hohenboken, 1991). This breeding practice resulted in a large number of herds containing cows of both breeds and crossbreds, because the crossbred cows represent 22% of the national dairy cattle population (Ahlborn-Breier and Hohenboken, 1991).

The New Zealand dairy industry's breed structure of the national herd was 57% Holstein-Friesian (H), 16% Jersey (J), 18% crossbred H X J, 2% Ayrshire (A), and 7% other dairy breeds and their crosses (Livestock Improvement, 1997).

Reports on crossbreeding of New Zealand dairy cattle (Ahlborn-Breier and Hohenboken, 1991; Harris et al., 1996) have showed evidence of favorable heterosis for yields of milk, fat, and protein and for body weight and cow survival. Research from other countries (Donald et al., 1977; Ericson et al., 1988; Grosshans et al., 1994; Madgwick and Goddard, 1989; McAllister, 1986; McDowell, 1982; and Touchberry, 1992) have also reported favorable heterosis for viability and the reproductive and productive performance of dairy cows. Only a few studies (McAllister et al., 1994; McDowell and McDaniel, 1968; and Touchberry, 1992) have showed that crossbreeding resulted in sufficient heterosis to provide greater economic returns than did the best of existing breeds.

Crossbreeding of European dairy breeds with Zebu or native breeds from tropical areas has been used widely as a method to improve milk production in the tropics and subtropics. In general, the first generation from crossbreeding has performed well and is accepted by dairy farmers, but continuation of the program by continued upgrading to European breeds may present problems because performance of higher levels of upgrades of crossbred cattle can be disappointing. Milk production per cow may decline, fertility may be lower, and calf mortality may increase after the first cross because of loss of heterosis, recombinant genetic effects, or deterioration of environmental levels (feeding and management) (Freitas et al., 1998).

History of crossbreeding

The USDA crossbreeding study initiated in 1939 (Fohrman et al., 1954) sought to answer Lush's question with a study of two and three-breed crosses involving Holstein, Jersey, Red Dane, and Guernsey using Holstein, Jersey, and Red Dane proved sires. The authors concluded that "there is sufficient evidence presented here to indicate that female progeny of crossbred cows when sired by production proved bulls will develop into very satisfactory dairy animals."

A crossbreeding project involving the Holstein and Guernsey breeds was conducted at the Illinois Agricultural Experiment Station from 1949 to 1969. All surviving female calves born in the first four generations, 723 of the 788 born, were given the opportunity to conceive and produce milk. On a basis of a total of 2015 calves born, crossbreds had a 15.6% greater survival rate to sale or 1 week of age than purebreds. Of the 778 surviving females born in the first four generations, 18.4% more crossbreds than purebreds calved once, and 24.5% more crossbreds than purebreds calved twice. For weight at 18, 24, 30, 36, and 48 month of age, crossbreds exceeded purebreds by 5.0, 7.0, 4.4, 3.6, and 5.3%, respectively. For yield of milk, fat, protein, and SNF, crossbreds exceeded purebreds by 8.0, 8.5, 7.5, and 3.0% respectively. Measures of survival, growth, milk yield, and reproduction were appropriately combined into an index of income produced per cow. On a basis of income per cow per lactation, crossbreds exceeded purebreds by 14.9%. On a basis of income produced per cow per year, crossbreds exceeded purebreds by 11.4% (Touchberry, 1992).

Illinois crossbreeding project, 1949 to 1969

Because the Holstein was the predominant dairy breed and the breed with the highest milk yield, it was decided that the Holstein must be one of the two breeds selected. The Guernsey breed was the second most popular dairy breed; Guernsey milk had a high fat content and, at the time, a higher milk yield than the Jersey.

Basis to compare purebreds and crossbreeds in Illinois Project

The best method for comparing purebreds and crossbreds is total performance. Total performance must be based on the income generated per cow per year. Net merit would be the total income per cow per year minus the costs per cow per year of producing that income (Touchberry, 1970).

Traits of Total Performance

1. The milk yield and fat per lactation were traits considered most important. Price of milk at the time was based solely on pounds of milk and fat percentage.

2. Swine and chicken work showed that survival rates and reproductive performance were major contributors to heterosis in those species. For this reason, records of the numbers of abortions, stillbirths, deaths from birth to calving, the number sold because of failure to breed or other debilitating conditions, and number calved were carefully recorded for each breed group. Records on services per conception, age at first calving, interval from calving to first calving, interval from first service to conception, and calving intervals were reported for each animal.
3. Because of number of animals culled yearly, effects of crossbreeding on size and number of dairy cattle at a given age are important. Weight, wither height, depth of chest, length of body (the horizontal distance from the point of the shoulders to the pin bones), circumference of the chest, and circumference of the paunch were recorded on all animals at the ages of 3, 6, 12, 18, 24, 30, 36, 48, and 60 months. In addition, each animal was weighed 3 days before and after calving to estimate maintenance requirements of the animal during pregnancy.
4. From 1956 to 1968, complete records of all veterinary services were kept to estimate health costs for various groups.
5. Records on rates of milk removal, time required to milk, type classification, degree of fleshiness, and udder palpations were recorded routinely.
6. Some important traits were recorded but only on a few individuals. These records included feed actually consumed by individual animals and complete records on blood antigens (Touchberry, 1970).

Adapted from Touchberry (1992).									
		Male Calves			Female Calves			All Calves	
	Live	Dead	Total	Live	Dead	Total	Live	Dead	Total
Purebreds	462	40	502	400	45	445	862	85	947
Percentages	0.92	0.8		0.899	0.101		0.91	0.09	
Crossbreds	527	32	559	475	34	509	1002	66	1068
Percentages	0.943	0.057		0.933	0.067		0.938	0.062	
All Calves	989	72	1061	875	79	954	1864	151	2015
Percentages	0.932	0.068		0.917	0.83		0.925	0.075	

Table 2.8 Numbers of calves born in various broad categories.

Number of calves born dead or alive classified according to sex of the calf and as purebred or crossbred are shown in Table 6. Of the 947 purebreds born, 85 or 9% were dead at birth or died within 24 hours after birth. Of the 1068 crossbreds born, only 66 or 6.2% were dead at birth or with 24 hours after birth. Therefore, there were less crossbreds than purebreds dead at birth or that died within 24 hours after birth.

The Holsteins and crossbreds reproduced surviving females at a rate of approximately 1.3 females per female per generation, whereas the Guernseys reproduced surviving females at an approximate rate of .92 per female per generation. Therefore, the survival and well-being of the Holsteins and crossbreds are much superior to that of the Guernseys.

The partial regression of the 16 means for percentage of survival on the comparison for heterozygosity was 1.54. This means that survival increased 1.54% for each increase of 1/8 in the heterozygosity. The regression coefficient 1.54 multiplied by 8 equals 12.32, which is an estimate of the difference in survival of purebreds with no heterozygosity from the two-breed cross and the survival rate of the half-Holstein, half-Guernsey crossbreds possessing 100% of the heterozygosity from the cross. It is thus apparent that crossbreds have a higher survival rate than purebreds, (crossbreds – purebreds) = 12.32%, and Holsteins had a higher survival rate than Guernseys, (Holsteins – Guernseys) = 13.36%. From this information, crossbreds have a 15.6%

greater survival rate than purebreds, and Holsteins have a 17% greater survival rate than Guernseys. As a result, of all calves born, 18.4% more crossbreds than purebreds calved once, and 24.5% more calved twice. In addition, crossbreds had a slightly higher rate of survival than purebred Holsteins. From the means of breed groups, it is obvious that Guernseys had a higher mortality rate than Holsteins, 28 versus 14.5%. The higher survival rates of Holsteins and crossbreds result in more animals for sale and more opportunity to cull based on yield.

Crossbred Growth

Weight at a given age is the best measure of growth and size in dairy cattle. In addition, weight is the primary basis on which dollar value of a culled dairy animal is determined. Percentage of heterosis for this study for weight ranged from 3.6% at 36 months to 7.0% at 24 months with an average of 5.1% for the five ages. Average weight of Holsteins exceeded that of Guernseys by a percentage ranging from 20.6 at 30 months to 25.8% at 24 months with an average of 22.9%. It was obvious that the income from the sale of culled animals will be affected by fraction of heterozygosity resulting from crossbreeding and additive genetic differences between Holstein and Guernseys breeds.

Chapter Three

Materials and Methods

Abbreviation key: MR = milk replacer, **20/20 =** treatment in which calves were fed a 20% protein, 20% fat milk replacer**, 28/20** = treatment in which calves were fed a 28% protein, 20% fat milk replacer, **28/25** = treatment in which calves were fed a 28% protein, 25% fat milk replacer.

Field Study

Objectives:

Our objectives were to determine whether a 25% or 20% fat MR should be fed to Jersey calves under field conditions to provide additional energy for times of stress such as disease, environmental stress, or other stresses that would increase maintenance energy requirements.

Animals:

One hundred forty-two Jersey calves were assigned to one of three diets in a restricted randomized block design depending on location. According to gender, each successive calf was assigned to a 20/20 MR or a 28/25 MR. Milk replacer 28/25 was replaced by 28/20 MR, and calves were then assigned to either a 20/20 MR or a 28/20 MR according to gender on all farms. All calves were fed for 8 wk. The study was conducted from September 2002 to May 2003.

The Virginia Tech Animal Care and Use Committee approved the experimental protocol. Jersey calves were studied at three locations: 1) Farm A located at 36° N latitude, and 81° W longitude (n = 14 bulls, n = 60 heifers); 2) Farm B located at 37.875° N latitude, and 80.375° W longitude (n = 4 bulls, n = 42 heifers); 3) Farm C located at the University (n = 12 heifers).

Calf Care Protocols:

A colostrometer (Jorgensen Laboratories, Loveland, CO) was used to determine specific gravity of colostrum and make an indirect assessment of immunoglobulin concentration as described by Fleenor and Stott (1980). Colostrum was considered to have high immunoglobin concentration if the reading was > 50 mg/ml. If high quality colostrum was not available, calves received 454 g of Lifeline™ (American Protein Corp., Ames, IA).

Calves at Farm A received 1.89 L of colostrum at birth, and three more feedings of high quality colostrum (immunoglobulin concentration >50 mg/dl) at 6 h intervals thereafter. Low quality colostrum (< 50 mg/dl immunoglobulin concentration) was mixed with 1.89 L of Lifeline™ (American Protein Corp., Ames, IA). Calves received 1.89 L Lifeline™ (American Protein Corp., Ames, IA) at 6 h intervals if no colostrum was produced. Calves were housed in individual pens inside a non-ventilated barn with sawdust as bedding. Vaccinations for these calves were for bovine rhinotracheitis and parainfluenza 3 (2 ml intranasally, TSV-2, Pfizer Animal Health, Exton, PA), rota-virus and corona-virus diarrhea (3 ml orally, Calf Guard, Pfizer Animal Health, Exton, PA), *Clostridium chauvoei, septicum, novyi*, *sordelli, perfringens* Types C and D plus *Haemophilus somnus* (2 ml subcutaneously, Vision 7 Somnus, Intervet Inc., Millsboro, DE), and *Escherchia coli* (10 ml orally, Bar Guard 99, Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO).

Farm B calves were fed 1.89 L of colostrum at birth, and two more feedings of high quality colostrum at 12 h intervals. Calves were housed in individual hutches with sawdust as bedding. The hutch area was frequently covered in mud due to inclement weather. Calves received antibodies for K99 *Escherchia coli* and corona-virus (1 capsule orally, First Defense, Immucell Corporation, Portland, ME) and vaccinations for bovine rhinotracheitis, bovine viral diarrhea, parainfluenza 3, and bovine respiratory syncytial virus (2 ml intramuscularly, Bovi-Shield® Gold 5, Pfizer Animal Health, Exton, PA).

Farm C calves received 1.89 L of colostrum and an additional 1.89 L of high quality colostrum 12 h later. Calves were housed individually in hutches on coarse gravel with sawdust and straw as bedding. At birth, vaccinations at Farm C included bovine rhinotracheitis and parainfluenza 3 (2 ml intranasally, TSV-2, Pfizer Animal Health, Exton, PA).

All three farms used the following protocol: Initial weight was recorded for each individual animal before the first feeding of colostrum.

Calf health was monitored daily. Calves received a scour score on a scale of 4: (1 = firm, 2 = pudding consistency, 3 = pancake batter consistency, and 4 = watery). The following scour protocol was used. When a fecal score was equal to or exceeded 3, calves received 1.89 L oral electrolytes (Entrolyte H.E., Pfizer Animal Heal, Exton, PA) in an open bucket at 12:00 h. If a fecal score of greater than 3 occurred, an additional 1.89 L of electrolytes was fed to calves at 16:00 h. Calves with fecal scores of 3 and above for two consecutive days received 30 g Gammulin ™ (American Protein Corporation, Ames IA) for 6 consecutive feedings.

Diets:

Three MR were fed in this study; 1) 20/20 containing 20% CP, 20% fat, 2) 28/20 containing 28% CP and 20% fat, 3) 28/25 containing 28% CP and 25% fat. The 20/20 MR was reconstituted for 10% DM solids, and the 28/20 and the 28/25 MR were both reconstituted for 12.5% DM solids. Milk replacer was offered to calves in an individual open bucket at 0800 h and again at 1700 h. Fresh water was available ad libitum. Both bull and heifer calves were utilized. Two dry feeds were offered free choice). Calves on the 28/20 and 28/25 MR were fed the "Intense Calf Diet 22 B60" (Table 3.4) to meet standards of an intensified feeding program and calves on the 20/20 MR were fed "Future Cow Starter B90" (Table 3.4) (Land O'Lakes Animal Feed Products Co., St. Paul, MN) to meet standards of a conventional feeding system from day 5 of life.

Farm A calves were assigned to either the 28/25 diet or the 20/20 diet. Forty-three calves were assigned to the 28/25 diet (n = 9 bulls, n = 34 heifers) and thirty-one calves were assigned to the

20/20 diet (n = 4 bulls, n = 27 heifers). Table 3.1 contains the number of calves per diet and season.

Table 3.1 Diets by seasons for Farm A.

Diet	Season	N	Diet	Season	N	Diet	Season	N
20/20 MR	Sept - Nov	13	20/20 MR	Dec - Feb	17	20/20 MR	Mar - May	1
28/25 MR	Sept - Nov	14	28/25 MR	Dec - Feb	20	28/25 MR	Mar - May	2

All three diets were used at Farm B utilizing forty-six calves. Eleven calves were assigned to the 28/25 diet (n = 1 bull, n =10 heifers), 12 calves were assigned to the 20/20 diet (n = 3 bulls, n = 9 heifers), and 19 heifers were assigned to the 28/20 diet. Table 3.2 shows the number of calves per diet and season.

Table 3.2 Diets by seasons for Farm B.

Diet	Season	N	Diet	Season	N	Diet	Season	N
20/20 MR	Sept - Nov	3	20/20 MR	Dec - Feb	6	20/20 MR	Mar - May	3
28/25 MR	Sept - Nov	3	28/25 MR	Dec - Feb	5	28/25 MR	Mar - May	3
						28/20 MR	Mar - May	19

Twelve heifer calves were assigned to two diets at Farm C. Five calves were assigned to diet 28/20 and the other seven calves were assigned to diet 20/20 from March to May.

Table 3.3 contains nutrient analysis for MR. Table 3.5 contains feeding rates for 28/25 and 28/20 MR treatments. Table 3.6 contains feeding rates for 20/20 MR treatment.

Table 3.3 Milk replacer on an as fed (powder) basis.

Variable	20/20[a]	28/20[b]	28/25[c]
Dry Matter	97.3%	97.3%	97.3%
Crude Protein %	20.0	28.0	28.0
Crude Fat %	20.0	20.0	25.0
Crude Fiber %	0.15	0.15	0.15
Calcium %	1.0	1.0	1.0
Phosphorus %	0.70	0.70	0.70
Potassium %	2.66	2.57	2.40
Magnesium %	0.13	0.12	0.12
Vitamin A IU/kg	9072	9072	9072
Vitamin D_3 IU/kg	2268	1134	2268
Vitamin E IU/kg	45.36	22.68	45.36
Thiamine mg/kg	6.61	3.31	6.61
Riboflavin mg/kg	6.61	3.31	6.61
Niacin mg/kg	2.65	1.32	2.65
d-Panthothenic Acid mg/kg	13.23	6.61	13.23
Biotin mg/kg	0.11	0.06	0.11
Ascorbic Acid mg/kg	110.23	55.12	110.23
Pyridoxine Hydrochloride mg/kg	6.61	3.31	6.61
Folic Acid mg/kg	0.55	0.28	0.55
Vitamin B_{12} mg/kg	0.07	0.03	0.07
Choline Chloride mg/kg	1323	661	1323
Iron PPM	100	50	100
Manganese PPM	40	20	40
Zinc PPM	40	20	40
Copper PPM	10	5	10
Iodine PPM	0.5	0.5	0.5
Cobalt PPM	0.11	0.055	0.11
Selenium PPM	0.30	0.15	0.30

[a]20/20 = 20% Protein, 20% Fat MR.
[b]28/20 = 28% Protein, 20% Fat MR.
[c]28/25 = 28% Protein, 25% Fat MR.
[d] Land O'Lakes Animal Feed Products Co., St. Paul, MN

Table 3.4 Nutrient analysis of calf starter grain.

	As Fed	Future Cow Starter B90	Intense Calf Diet 22 B60
Dry Matter	%	87.47	90.00
NFC	%	42.77	50.55
Crude Protein	%	18.00	22.00
Rumen Undegradable Protein	(CP%)	36.46	38.40
Rumen Degradable Protein	(CP%)	63.54	61.60
Soluble Protein	(CP%)	24.63	24.00
Acid Detergent Fiber	%	4.92	8.75
Neutral Detergent Fiber	%	14.06	15.00
Fat	%	2.85	2.45
Calcium	%	2.64	2.67
Phosphorus	%	1.05	1.10
Potassium	%	0.50	0.55
Sulfur	%	0.46	0.45
Magnesium	%	0.23	0.27
Salt	%	0.24	0.40
Sodium	%	0.40	0.45
Chloride	%	0.27	0.42
Zinc	ppm	0.36	0.45
Iron	ppm	199.00	233.00
Copper	ppm	111.00	111.00
Manganese	ppm	23.60	30.90
Cobalt	ppm	0.36	0.44
Iodine	ppm	1.26	1.42
Selenium	ppm	0.48	0.30
Vitamin A	IU/kg	2835	2835
Vitamin D	IU/kg	5667	5667
Vitamin E	IU/kg	1134	1134
Bovatec	g/kg	22.68	27.21
Total Digestible Nutrients	%	90.00	88.86
Net Energy for gain	Mcal/kg	750	520
Net Energy for maintenance	Mcal/kg	560	800
Lignin	%	1.39	1.55

[a] Land O'Lakes Animal Feed Co., St. Paul, MN.

Table 3.5 Feeding rates for 28/25 and 28/20 MR on a powder basis.

Days of Age	Powder (kg/d)	Water (kg/d)
1-7	0.57	3.90
8-49	0.68	4.81
50-56	0.34	2.40

Table 3.6 Feeding rates for 20/20 MR on a powder basis.

Days of Age	Powder (kg/d)	Water (kg/d)
1-49	0.45	3.90
50-56	0.23	1.95

Growth Measurements

Calves were weighed weekly and measurements for body length, hip height, wither height, heart girth, hip width were obtained at birth and once a month thereafter. Body length was measured from the point of the shoulder to the tail head, and hip width was measured from the outer sides of the tuber coxae using a rigid meter stick. Hip and wither heights were obtained using a height stick. Measurements were obtained Tuesdays at 1300h at Farm C, Thursdays at 1300h Farm A, and Fridays at 1400h Farm B.

Blood Samples

Blood samples were obtained by jugular venipuncture during the first week of life to measure IgG levels to indicate passive transfer. Samples were collected in a vacutainer (Becton Dickinson, Franklin Lakes, MN) treated with Potassium EDTA. Centrifugation at 3200 x g for 15 min was used to isolate plasma, and samples were stored at -20^{0} C for later analysis. Levels of IgG were tested at the Virginia-Maryland Regional College of Veterinary Medicine using the radial immunodiffusion procedure. Levels of gamma globulins (GG) were tested at Sure Tech Laboratories (Fort Dodge, IA) using radial immunodiffusion procedure.

Statistical design and analysis

Calves were assigned alternately to opposite diets within gender at each location.
Each farm was analyzed separately due to confounding of location and season. Additionally, all farms did not feed the same diet during the same season.

For measurements taken throughout the experiment the following model was used;

$$Y_{ijklmn} = \mu + D_i + G_j + DG_{ij} + S_k + DS_{ik} + DG_{ij} + DGS_{ijk} + F_l + FD_{li} + FG_{lj} + FS_{lk} + FDGS_{lijk} + C_{(ijklp)m} + B_n(A_o - A) + W_p + WD_{pi} + WG_{pj} + WS_{pk} + WDGS_{pijkl} + E_{ijklmnop}$$

Where:

$B_n (A_o - A)$ = the covariate term for measurement at time 0

D = Diet (i = 1, 2); fixed effect
G = Gender (j = 1, 2) fixed effect
S = Season of birth (k = 1…4) fixed effect
F = Farm (l =1, 2, 3) fixed effect
C = Calf within diet, gender, season of birth, and farm (m= 1, 2, 3) (total of 143 calves); random effect
W = Week after birth (p = 1…8); fixed effect
E = residual
Significance was determined to be $P < 0.05$.
Trends were determined to be $P<0.15$.

Data measured weekly were analyzed using Proc GLM with week as a repeated measure (SAS, 2002). Deaths per treatment were analyzed using Proc Freq in (SAS, 2002).

Chapter Four

Results and Discussion

Diets:

Calves fed 28/25 or 28/20 MR received 99.6 g more protein per d than 20/20 calves, and 28/25 calves received 79.2 g, and 34.0 g more fat per d than calves fed 20/20 or 28/20, respectively. In addition, the experiment was designed to deliver higher amounts of protein to calves on the 28/20 or 28/25 MR in the calf starter. Intensified calf rearing programs have traditionally fed a 28/20 MR; however, research performed by Bascom et al., (2002) determined that a 28/25 MR was more desirable for Jersey calves. Bascom et al., (2002) entered calf weight at 30 kg, and nutrient densities for gross energy (GE) in MR: 3.95, 5.86, and 9.21 per g of lactose, protein, and fat, respectively into the NEm equation and back calculated to find adequate fat percentage in MR to support 500g ADG. When the GE values were used 25% fat MR was adequate to support 500g of gain. However, when bomb calorimetery values were used, 20% fat in MR was determined to be adequate.

Growth Farm A:

Although diet 28/25 calves weighed more during wk 1 through 8, no differences in total weight gained or BW were detected. However, there was a trend ($p<0.15$) that 28/25 MR fed calves had higher total gains and BW than calves consuming diet 20/20 (Figures 4.1, and 4.2, and Tables 4.1 and 4.2). Given that calves fed 28/25 MR consumed 99.6 g more protein and 79.2 g more fat, it is reasonable to expect calves fed 28/25 MR would exceed growth of calves fed 20/20 MR. According to NRC (2001), Jersey calves fed a 20/20 MR at 10% DM solids have the potential to gain 463 g per day, whereas calves fed a 28/25 MR at a rate of 12.5% DM solids have the potential to gain 875 g per day. However, Jersey calves fed at 10% DM solids gained 610 g per day throughout the nine-month field study, and calves fed 28/25 at 12.5% DM solids gained 670 g/d. Therefore, it is reasonable to suspect that NRC (2001) underestimates maintenance requirements for Jersey calves.

Fifteen out of 74 calves had gamma globulin (GG) concentrations of less than 3.0 g/dl, indicating failure of passive transfer (FPT) (Figure 4.3). In addition to FPT, calves at Farm A also experienced a mortality rate of 30%, with 22 of 74 calves dying between wk 2 and 3. Over the duration of the study, difference in weight between calves fed 20/20 MR and 28/25 MR increased. Calves on 20/20 MR gained less weight ($p<0.15$), indicating that feeding Jersey calves a 20/20 MR was adequate to maintain BW but support only a modest rate of gain. Jones (2004) reported that feeding Jersey calves a 20% CP, 20% fat MR at 8 to 10% of BW supported only modest rates of ADG.

No differences in hip height were detected between diets (Figure 4.4). However, the trend ($p<0.15$) was that 28/25 calves were taller in wk 4 and gained 1.4 cm more hip height than calves fed 20/20 over the 8 wk period. Bartlett et al. (2001) showed that preweaned diets affect growth after weaning. Therefore, continuing to track these calves may show the importance and impact of the preweaned diet.

Differences ($p<0.05$) were detected for wither height during wk 4 and total wither height gain (Figure 4.5 and Table 4.3). Calves on diet 28/25 gained 0.9 cm more wither height than calves on diet 20/20. A trend ($p<0.15$) was detected that 28/25 calves were taller in wk 8 than 20/20 calves.

Heart girth measurements were also found to be different (Figure 4.6 and Table 4.4). Diet 28/25 calves had greater heart girth ($p<0.04$) for wk 8 and total gain. Calves on diet 28/25 gained 3.9 cm more in heart girth than 20/20 calves.

Calves had similar body lengths and hip widths across diets (Figures 4.7 and 4.8). No differences were detected, however, 28/25 MR calves gained 5.0 cm more body length and 1.4 cm more hip width than 20/20 MR calves. Calves fed 20/20 MR appear to have slower rates of gain in body length and hip width, but were uniform in growth curves. However, calves on 28/25 MR made much more rapid growth at the end of the trial.

Observations

The high mortality rate was attributed to substandard dry cow-feeding program, poor calving environment, low quantity of colostrum produced, disease, and calf housing. Mortality was the highest from December 2002 to February 2003, with a mortality rate of 15% for calves on diet 28/25 and a mortality rate of 35% for calves on diet 20/20. Average body condition of close-up and far off dry cows was less than 3.0. Upon further investigation, the dry cows were receiving poor quality corn silage and hay, which was inadequate for the environmental conditions present. Researchers (Myer, 1976; Dennis, 1980; Rakestraw et al., 1986) concluded colostrum from animals receiving inadequate nutrition is poor in quantity and quality. Therefore, the poor dry cow feeding program could have contributed to the cows producing low quality colostrum. Twenty-two calves at Farm A received Lifeline™ (American Protein Corp., Ames, IA), as colostrum was not available. However, the low quantity and poor quality colostrum did not affect GG levels. In addition, necropsy analyses were performed and death was attributed to PI_3 and BVD. In addition, high coliforms counts (>300,000 CFU/g) were found in the water. Moreover, calves were housed in a non-ventilated barn, which facilitated respiratory disease. However, Farm A had an excellent calf manager that worked everyday throughout duration of this study. Calves always had clean, fresh water and free-choice calf starter grain. Calf stalls were clean and well-bedded at all times. Furthermore, the calf manager kept meticulous records and calves were fed recommended amounts of powder every feeding and were treated immediately at the first signs of illness. With proper facilities and lower incidences of morbidity and mortality, it is speculated that gains for all calves would have been much higher.

Table 4.1 Total gain for Farm A by treatment and season.

	Total Gain, kg (n)		
Diet	Sept - Nov	Dec - Feb	Mar - May
20/20 MR	13.71 (13)	16.74 (17)	16.02 (1)
28/25 MR	20.55 (14)	15.21 (20)	18.53 (2)
Mean SE	1.62	2.25	1.43
Overall P	0.15		

Table 4.2 Weekly body weight for Farm A by treatment and season.

			Body Weight (kg)							
Diet	Season	N	Birth	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
20/20 MR	Sept - Nov	13	25.96	25.80	26.59	28.14	30.20	33.58	36.48	39.67
20/20 MR	Dec - Feb	17	25.25	25.60	27.55	29.64	32.58	35.40	38.43	41.99
20/20 MR	Mar - May	1	29.39	26.00	29.39	31.39	34.52	38.19	40.64	45.41
28/25 MR	Sept - Nov	14	25.58	27.63	30.31	33.00	36.48	39.01	42.65	46.13
28/25 MR	Dec - Feb	20	25.54	23.34	22.87	29.08	32.14	31.73	38.98	40.75
28/25 MR	Mar - May	2	25.65	26.92	26.35	30.25	31.89	37.6	35.29	44.18
Mean SE			3.40	4.00	3.87	2.93	3.17	3.37	3.75	4.13
P			0.64	0.09	0.11	0.31	0.11	0.12	0.21	0.12

Table 4.3 Wither heights for Farm A by treatment and season.

			Wither Height (cm)			
Diet	Season	N	Birth	Week 4	Week 8	Total Gain
20/20 MR	Sept - Nov	13	70.32	72.04	76.20	5.88
20/20 MR	Dec - Feb	17	69.40	74.07	77.44	8.04
20/20 MR	Mar - May	1	72.39	75.57	79.70	7.31
28/25 MR	Sept - Nov	14	69.78	75.18	78.47	8.69
28/25 MR	Dec - Feb	20	69.29	73.41	76.60	7.31
28/25 MR	Mar - May	2	71.37	72.39	78.75	7.38
Mean SE			1.40	1.51	1.31	1.59
P			0.98	0.05	0.09	0.003

Table 4.4 Heart girth for Farm A by treatment and season.

			Heart Girth (cm)			
Diet	Season	N	Birth	Week 4	Week 8	Total Gain
20/20 MR	Sept - Nov	13	69.71	74.94	83.75	14.04
20/20 MR	Dec - Feb	17	70.44	76.94	86.32	15.88
20/20 MR	Mar - May	1	71.12	74.94	83.10	11.98
28/25 MR	Sept - Nov	14	71.41	78.98	89.24	17.83
28/25 MR	Dec - Feb	20	69.72	75.76	85.37	15.65
28/25 MR	Mar - May	2	70.25	77.16	90.49	20.24
Mean SE			1.79	2.34	2.18	2.26
P			0.62	0.09	0.04	<.0001

Figure 4.1 Total weight gain for Farm A by season of birth and treatment.

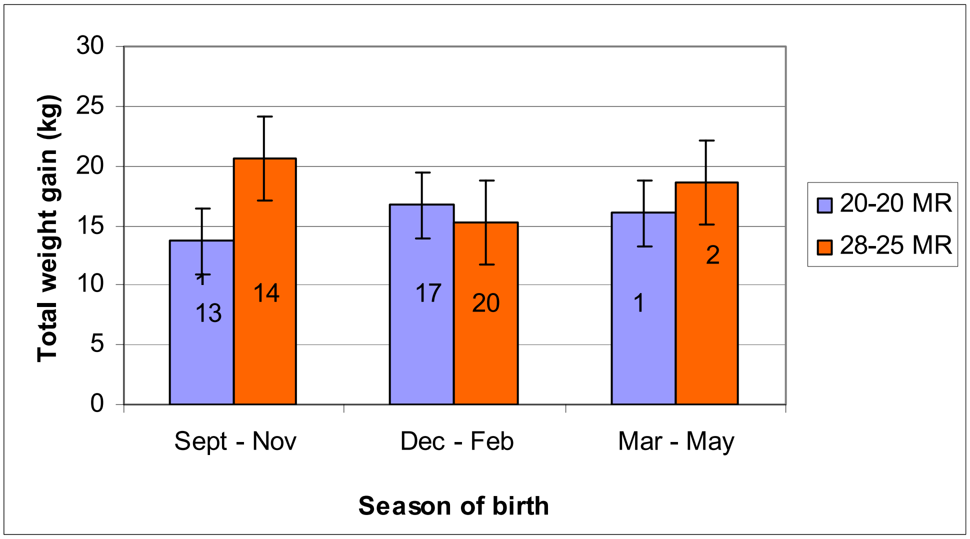


Figure 4.2 Weekly body weights for Farm A.

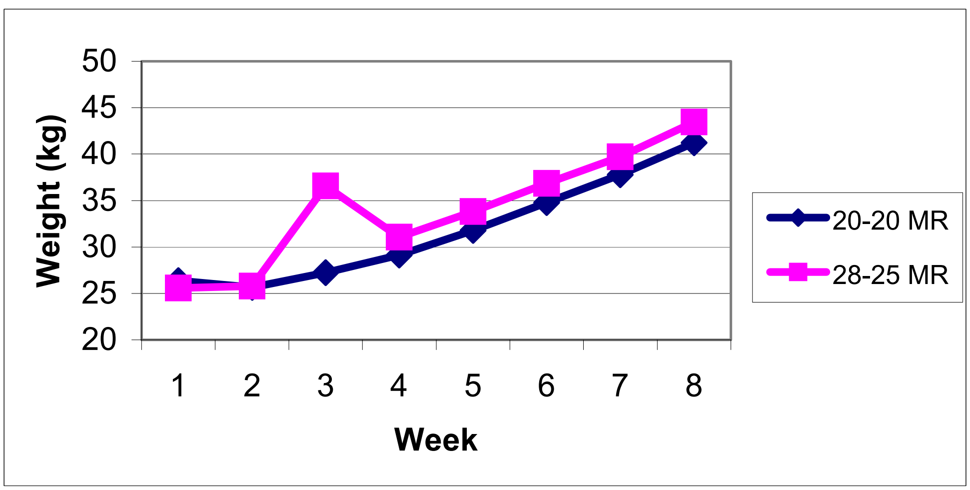


Figure 4.3 Number of calves with gamma globulin levels (g/dl) indicating FPT.

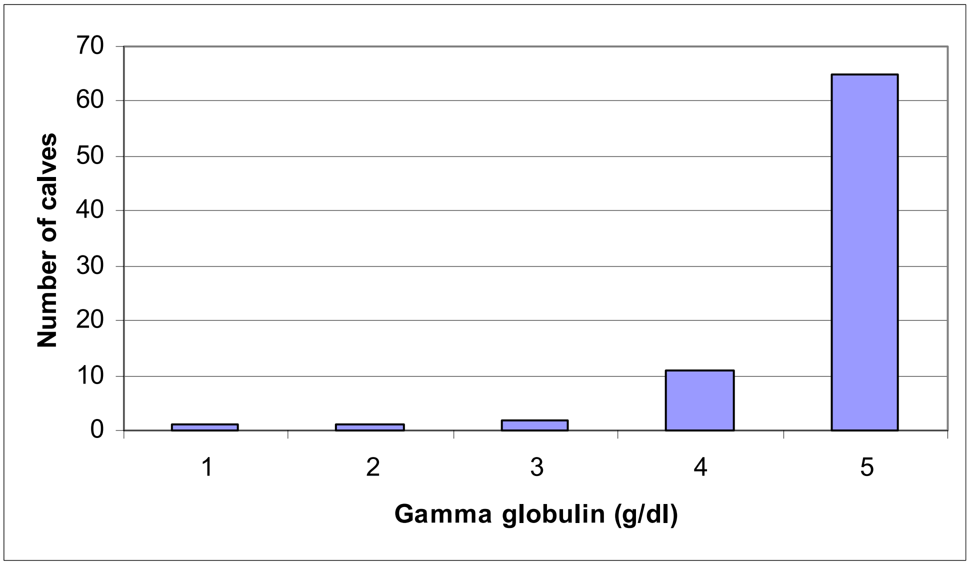


Figure 4.4 Hip height measurements for Farm A by week and treatment.

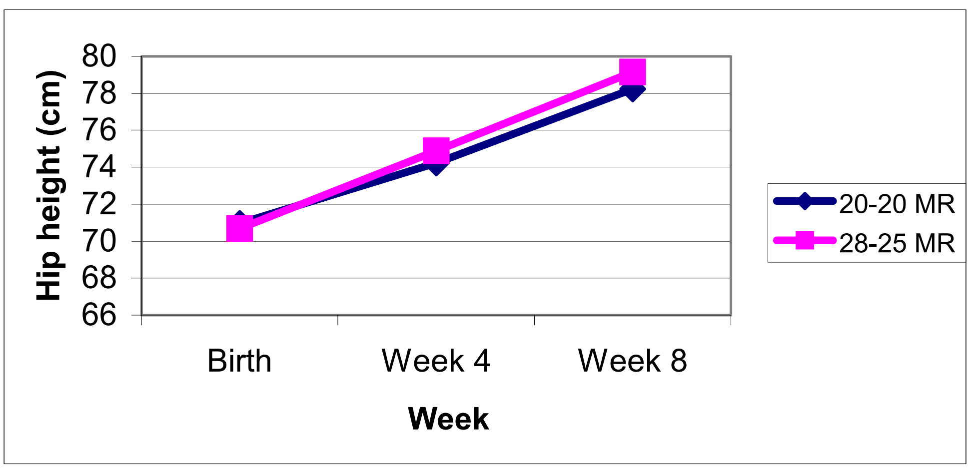


Figure 4.5 Wither height measurements for Farm A by week and treatment.

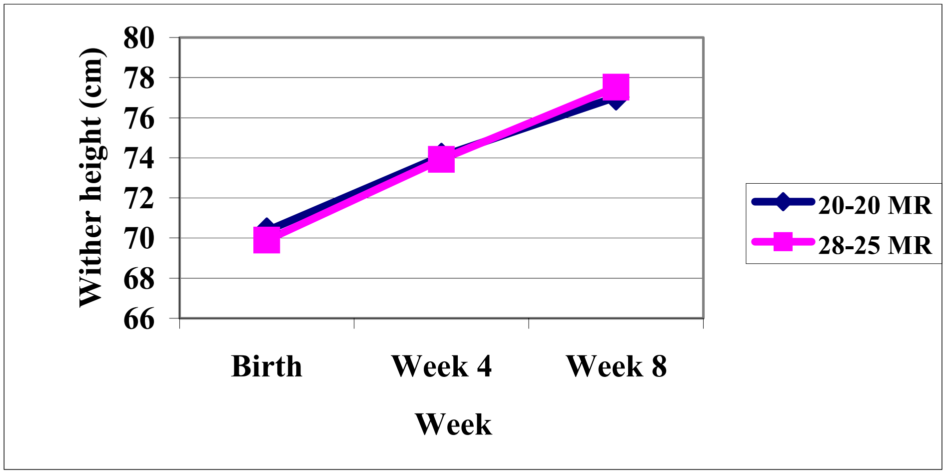


Figure 4.6 Heart girth measurements for Farm A by week and treatment.

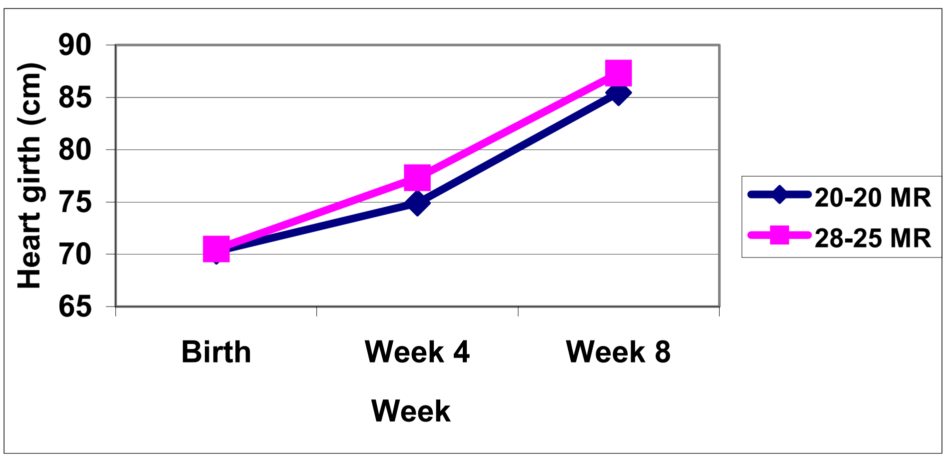


Figure 4.7 Body length measurements for Farm A by week and treatment.

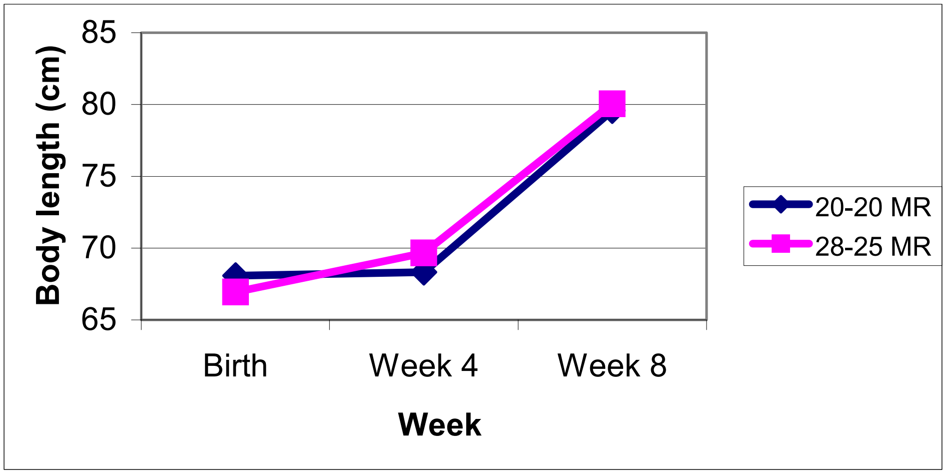
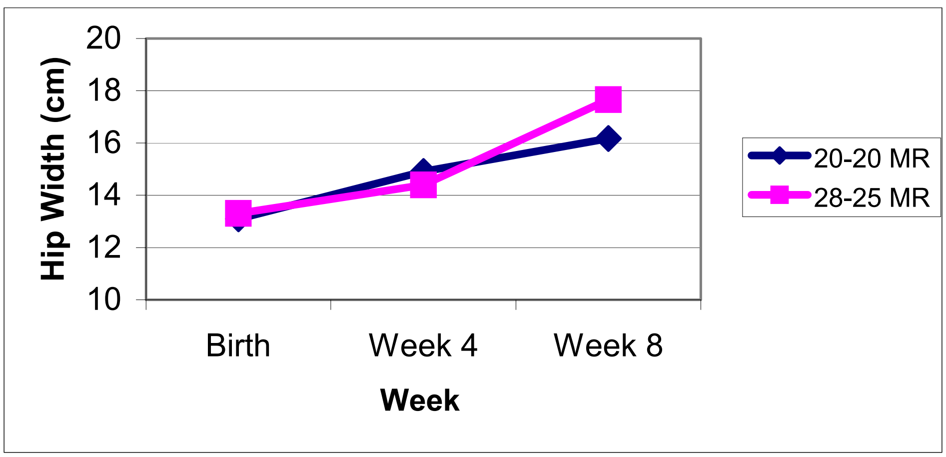


Figure 4.8 Hip width measurements for Farm A by week and treatment.



<u>Growth Farm B:</u>

No differences in total weight gained, ADG, or BW were detected on Farm B (Figures 4.14 and 4.15 and Table 4.9). Given that calves fed 28/25 and 28/20 MR consumed 99.6 g more protein and 79.2 g and 45.2 g more fat, it is reasonable to expect calves fed these diets would exceed growth of calves fed 20/20 MR. Colostrum quality and availability was not a problem as GG concentrations were below 3.0 g/dl for only 12 out of 63 (20%) indicating failure of passive transfer (Figure 4.16). Farm B had a mortality rate of 5%.

In wk 4 through 8 calves fed 20/20 MR were lighter than calves fed other diets (Figure 4.16 and Table 4.10). A significant diet by week interaction ($p<0.05$) was detected for wk 3 and 7, and a trend ($p<0.07$) was detected for wk 5. Over the duration of the study, differences in weight between calves fed 20/20 MR, 28/20 MR, and 28/25 MR decreased.

No differences in hip height were detected between diets (Figure 4.17). A trend ($p<0.15$) was detected during wk 4, showing calves fed 28/20 were taller than calves fed other diets. Calves fed 28/25 and 20/20 diets were similar. The 28/20 fed calves gained the most hip height (11 cm), whereas 28/25 gained the least (5cm). The 20/20 calves were intermediate (7.1 cm).

No differences were detected for wither height (Figure 4.18). However, total wither height gain showed that 28/20 calves gained the most wither height (12.8 cm), whereas 20/20 calves gained an intermediate amount (7.1 cm) , and 28/25 calves gained the least (7.0 cm).

No differences in heart girth measurements or heart girth total gain were found (Figure 4.19).

Calves had similar body lengths and hip widths across diets (Figures 4.20 and 4.21). A difference ($p<0.009$) was detected during wk 8 and a trend was detected for overall gain ($p<0.10$) for body length. The 20/20 MR calves were longest in body length, 28/25 calves were intermediate, whereas 28/20 calves were shortest. However, 28/20 calves gained the most body length (17.20 cm), whereas 20/20 calves were intermediate (17.00 cm), and 28/25 gained the least (10.00 cm). Calves fed 20/20 MR appear to have had faster rates of gain in body length and hip width, but leveled off as the study progressed. Calves on 28/25 and 28/20 MR had much more rapid growth at the end of the trial. No differences were detected for hip width or hip width gain. Body length and hip width had large standard errors indicating that they were not precise indicators of growth.

Observations

Calves on Farm B displayed the results that were hypothesized, 28/25 calves grew best (ADG, BW, and total gain) followed by 28/20 and 20/20. Total weight gain had numerical differences, but not statistical differences. Interrupting these results were difficult because of small numbers of calves (17) from September to February, and the unbalanced number of calves from March to May. Mortality was low and deaths were accidents. However, Farm B experienced an outbreak of *Salmonella* in January of 2003, which negatively affected growth of calves. Furthermore, calves were housed on a hillside, where mud and water collected in the front of the hutches and many calves had mud-covered coats that increased maintenance requirements. In addition, several different workers fed calves daily, possibly affecting the consistency of feeding time, rates, and amounts. Many Fridays, calves were without water and calf starter. If more attention was paid to detail, results would have been more consistent with those expected. No scour scores, respiratory scores, grain intake, or milk refusal records were kept. In addition, calves were not visibly labeled as to what treatment or powder amount was to be fed. Several Hispanic workers and their children fed calves, which created a language barrier and altered results.

Table 4.5 Total weight gain for Farm B by treatment and season.

	Total Gain, kg (n)		
Diet	Sept - Nov	Dec - Feb	Mar - May
20/20 MR	19.20(3)	25.82 (6)	14.18 (3)
28/20 MR			24.34 (19)
28/25 MR	18.45 (3)	27.72 (5)	20.06(3)
Mean SE	3.25	7.27	5.14
P	0.30		

Table 4.6 Weekly body weight for Farm B by treatment and season.

			Body Weight (kg)							
Diet	Season	N	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
20/20 MR	Sept - Nov	3	26.08	19.17	27.48	29.49	33.87	36.44	41.58	45.28
20/20 MR	Dec - Feb	6	29.43	35.80	39.47	39.46	44.23	42.18	51.94	55.25
20/20 MR	Mar - May	3	27.85	28.49	31.48	33.20	36.38	34.75	45.72	42.03
28/20 MR	Mar - May	19	24.84	28.86	31.52	33.81	38.70	40.51	41.74	49.18
28/25 MR	Sept - Nov	3	27.90	20.50	30.17	34.99	38.90	39.75	49.50	46.35
28/25 MR	Dec - Feb	5	26.94	24.79	30.88	34.26	40.48	44.69	46.13	54.66
28/25 MR	Mar - May	3	26.73	30.06	33.14	36.02	40.73	41.84	47.57	47.33
Mean SE			4.01	4.51	3.81	4.19	4.73	4.52	4.26	4.56
P			0.98	0.24	0.03	0.31	0.07	0.48	0.04	0.49

Figure 4.9 Total weight gain for Farm B by treatment and season.

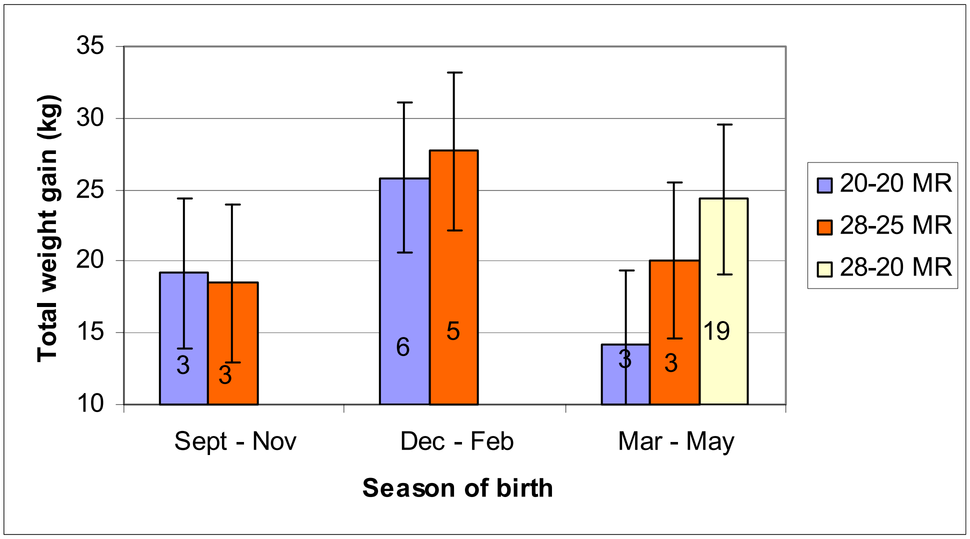


Figure 4.10 Weekly body weights for Farm B by treatment.

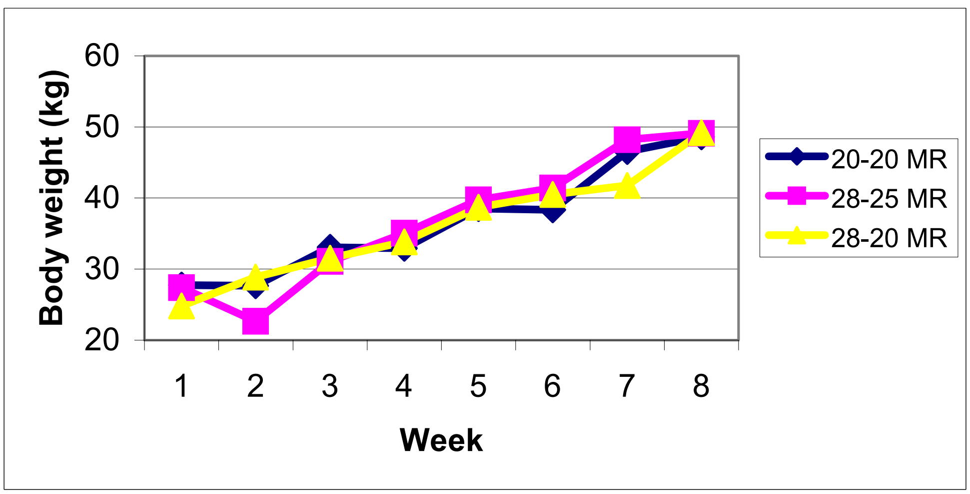


Figure 4.11 Number of calves with gamma globulin levels (g/dl) indicating FPT.

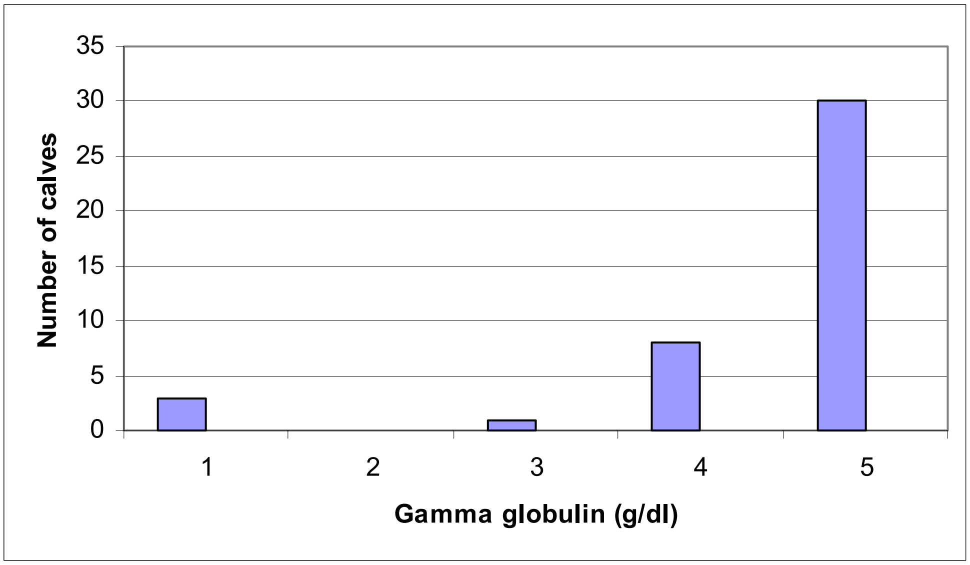


Figure 4.12 Hip height measurements for Farm B by week and treatment.

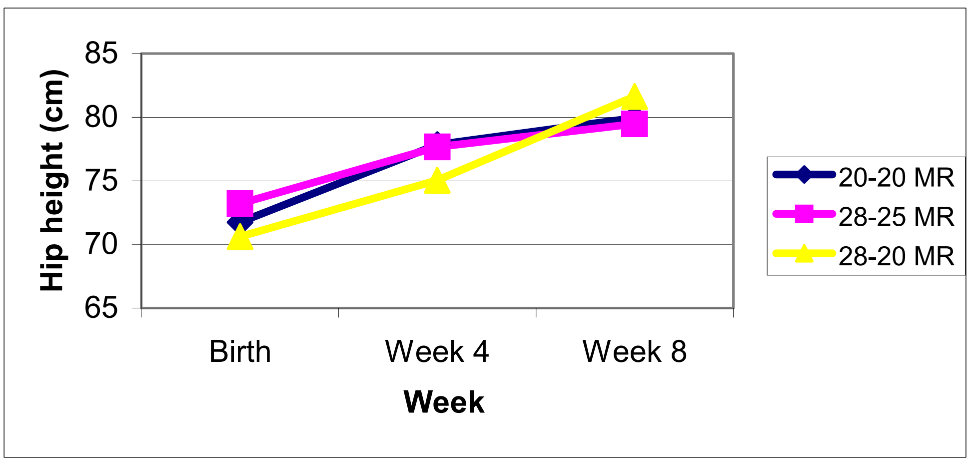


Figure 4.13 Wither height measurements for Farm B by week and treatment.

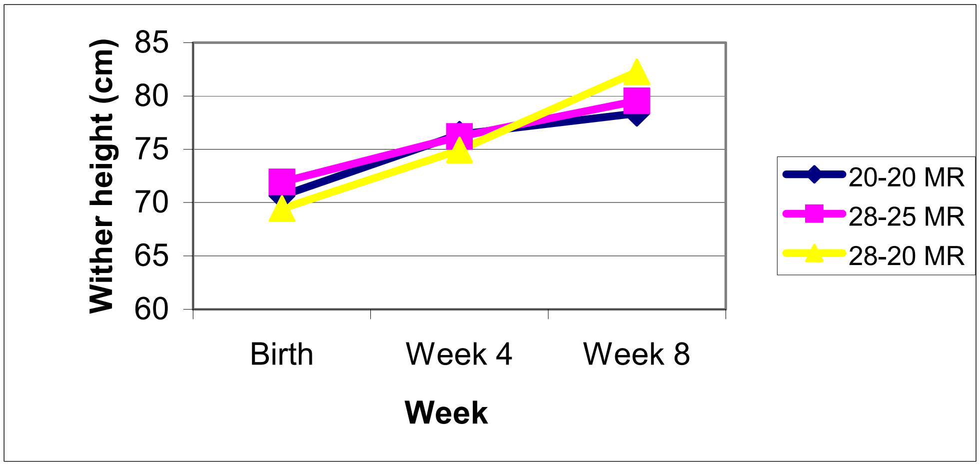


Figure 4.14 Heart girth measurements for Farm B by week and treatment.

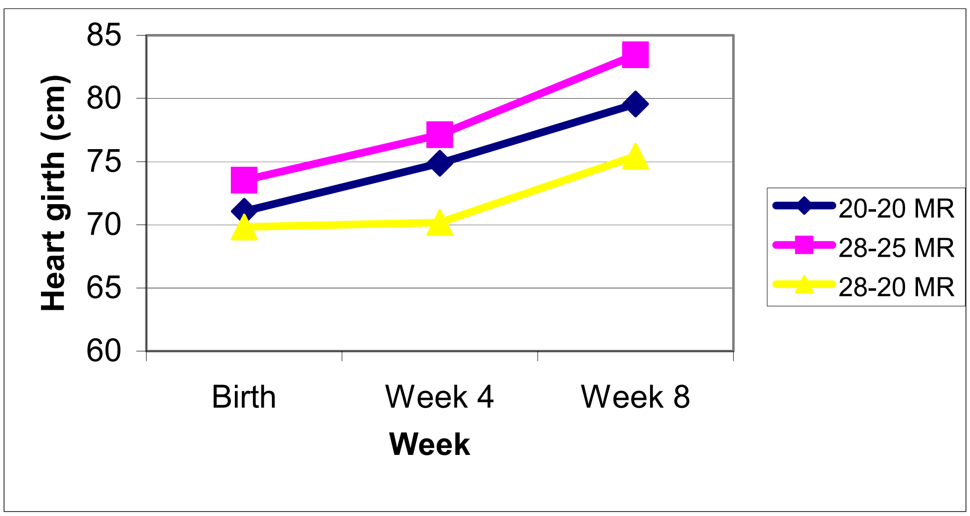


Figure 4.15 Body length measurements for Farm B by week and treatment.

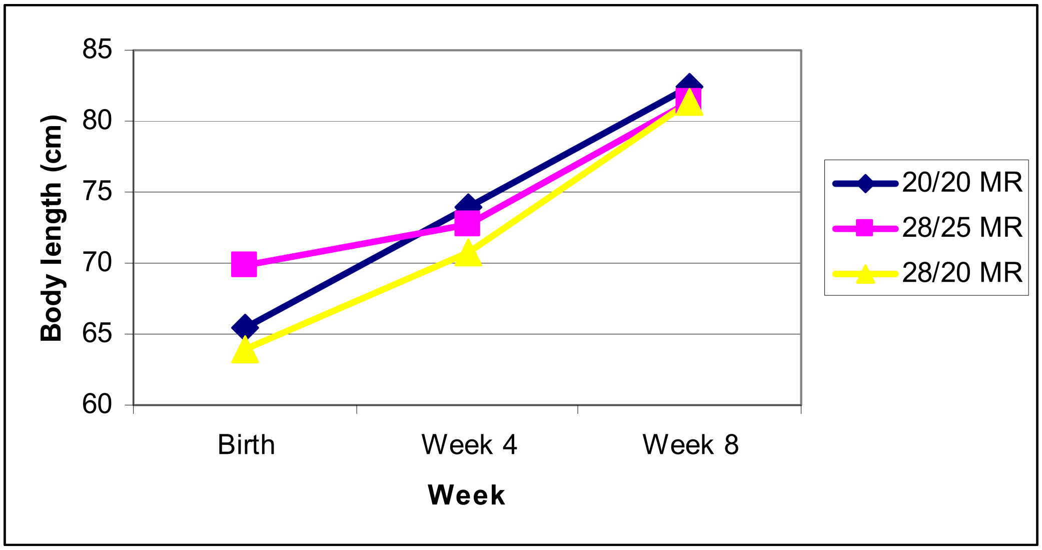
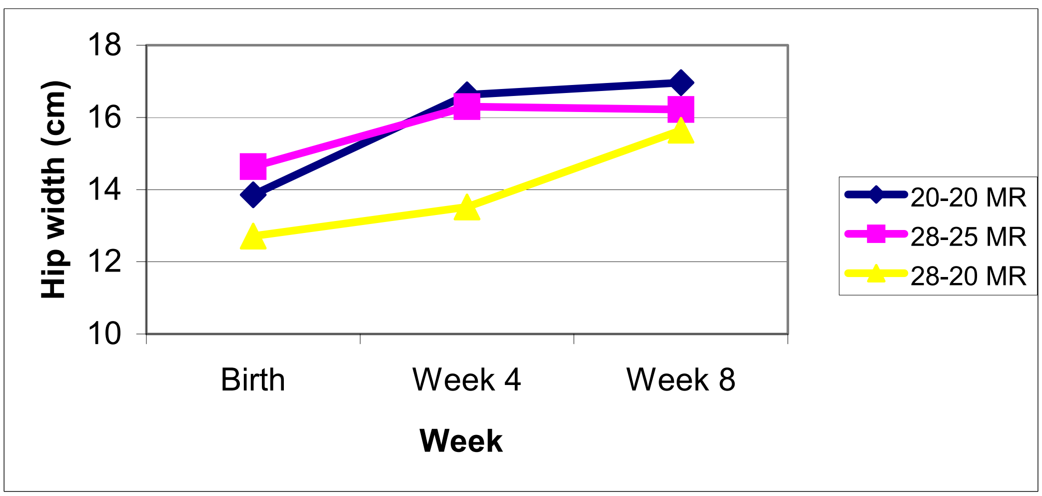


Figure 4.16 Hip width measurements for Farm B by week and treatment.



<u>Growth Farm C</u>:

No differences in total weight gained, BW, or ADG were detected on Farm C (Figures 4.22 and 4.23 and Tables 4.11 and 4.12, respectively). In wk 2 through 8 calves fed 20/20 MR were lighter than the calves fed diet 28/20, however differences were not significant. Given that calves fed 28/20 MR consumed more grams of protein and fat, it is reasonable to expect calves fed these diets would exceed growth of calves fed 20/20 MR. Colostrum quality and availability did not seem to be a problem as GG concentrations were below 3.0 g/dl for only two out of 12 calves indicating failure of passive transfer (Figure 4.24). Farm C had a mortality rate of 0%.

No differences in hip height, wither height, or heart girth were detected between diets (Figures 4.25, 4.26, and 4.27).

Calves had similar body lengths, body length gain, and hip widths across diets (Figures 4.28, and 4.29). A trend ($p<0.07$) was detected for hip width gain. Calves fed 20/20 MR appear to have had a consistent rate of gain in body length and hip width. However, calves on 28/20 had a much more rapid growth from birth to wk 4.

Observations

Farm C had no mortality or morbidity. However, there were only 12 calves on this study. In addition, Farm C was the University; therefore, there were more workers and veterinarian assistance available for this study. Calves were fed by the calf manager twice daily, which ensured consistency of management. Calves had fresh, clean water, calf starter grain, and a well-bedded calf hutch at all times.

Table 4.7 Total gain for Farm C by season and treatment.

Total Gain, kg (n)	
Diet	Mar - May
20/20 MR	23.82 (7)
28/20 MR	25.90 (5)
Mean SE	1.11
P	0.88

Table 4.8 Weekly body weights for Farm C with treatment by week interactions.

		Body Weight (kg)							
Diet	N	1	2	3	4	5	6	7	8
20/20 MR	7	26.94	29.29	30.77	34.34	38.27	42.78	48.31	50.76
28/20 MR	5	25.63	29.44	31.94	35.32	39.10	43.67	48.22	51.53
Mean SE		1.16	1.26	1.30	1.41	1.45	2.19	2.64	2.50
P		0.41	0.93	0.51	0.62	0.70	0.76	0.98	0.81

Figure 4.17 Total gain for Farm C by treatment.

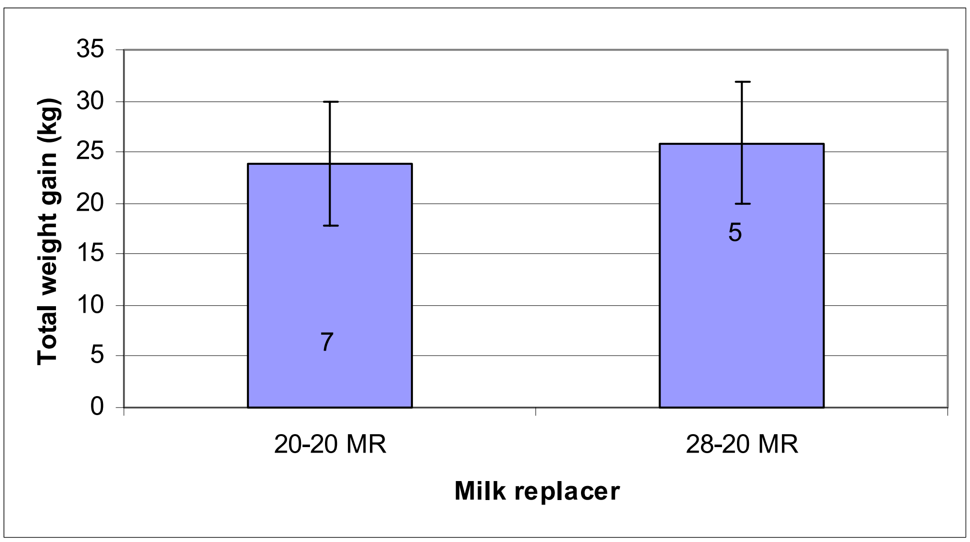


Figure 4.18 Weekly body weights for Farm C by treatment.

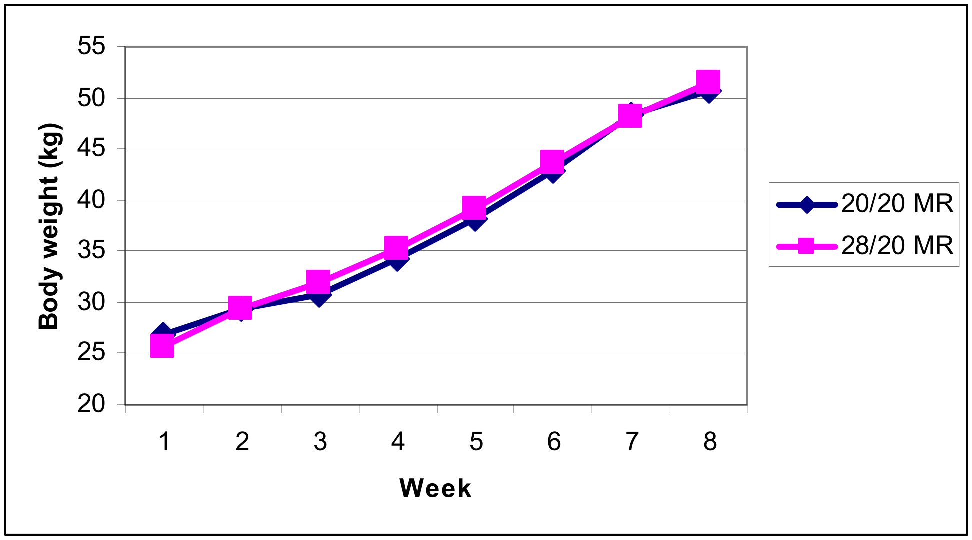


Figure 4.19 Number of calves with gamma globulin levels (g/dl) indicating FPT.

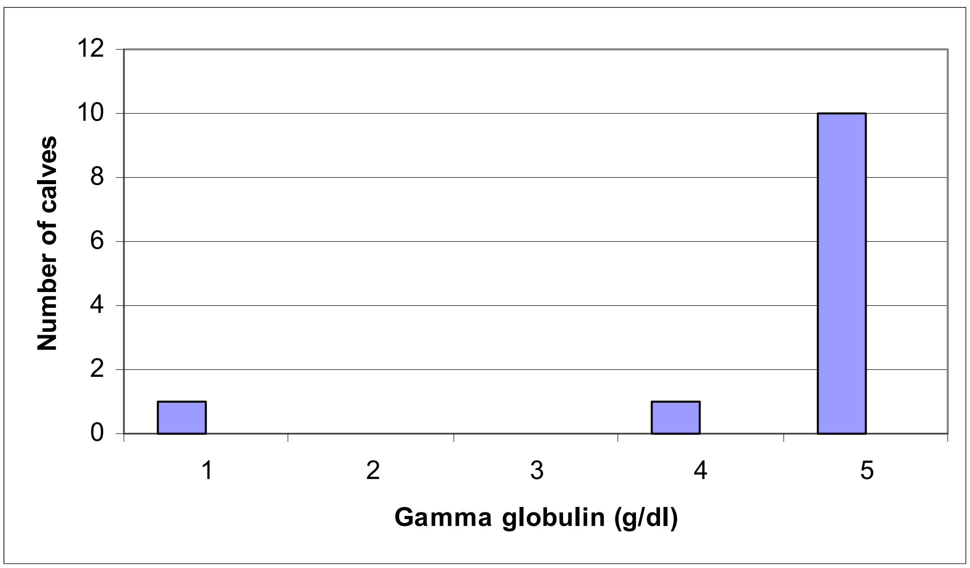


Figure 4.20 Hip height measurements for Farm C by week and treatment.

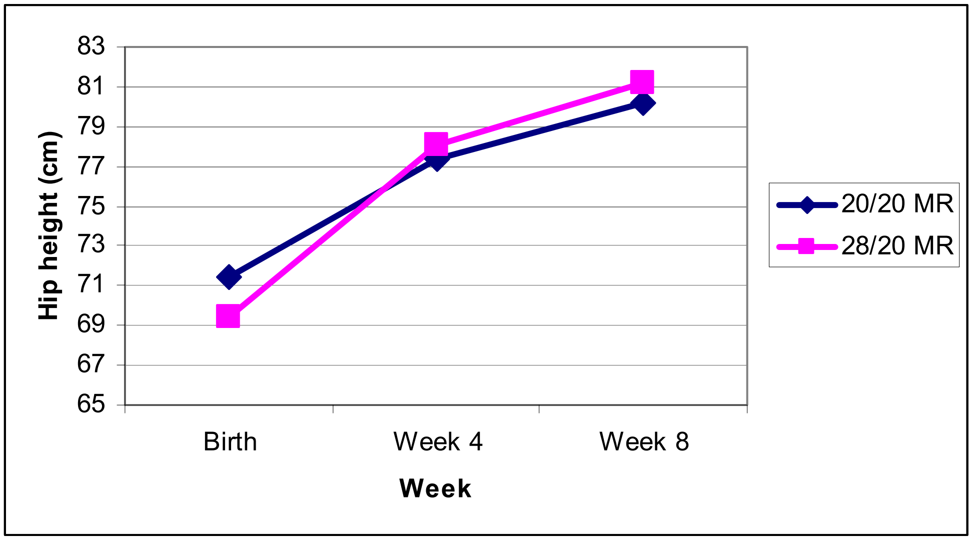


Figure 4.21 Wither height measurements for Farm C by week and treatment.

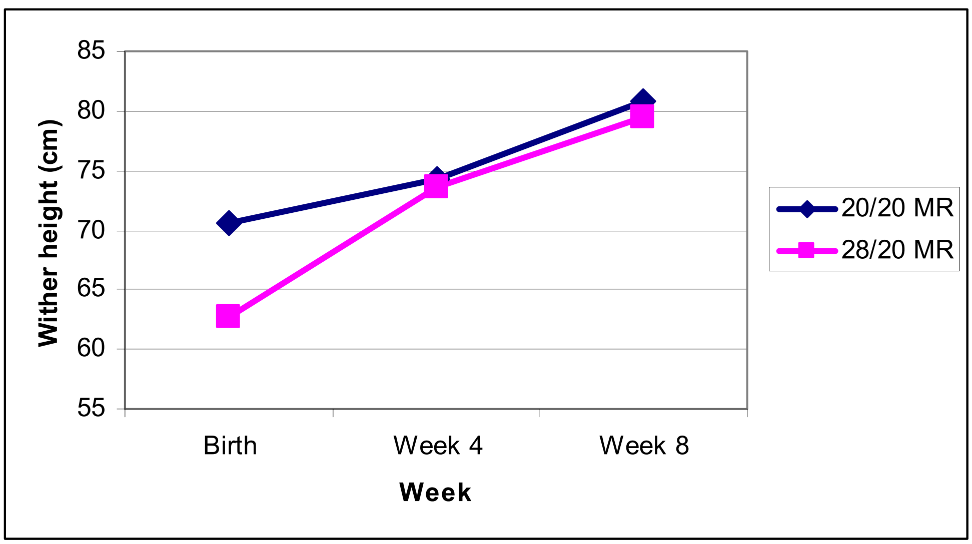


Figure 4.22 Heart girth measurements for Farm C by week and treatment.

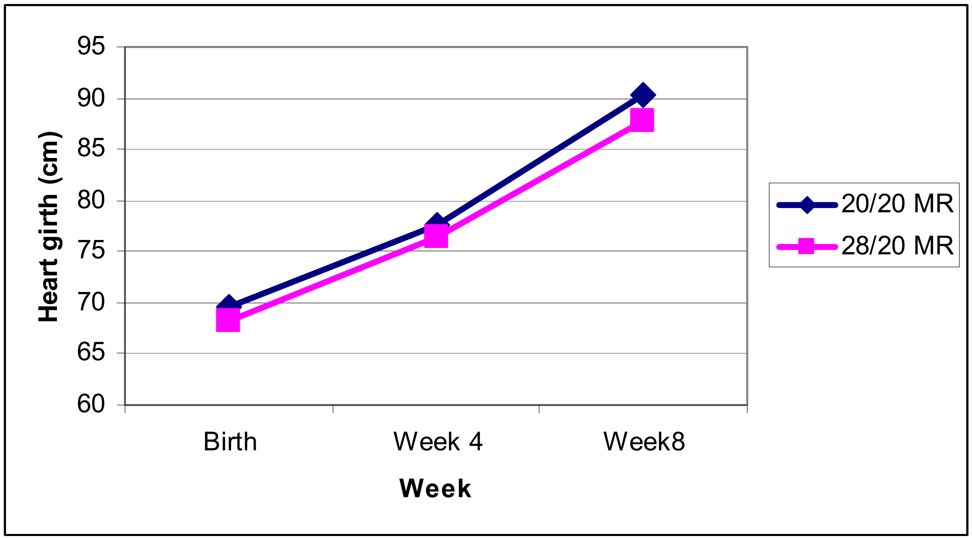


Figure 4.23 Body length measurements for Farm C by week and treatment.

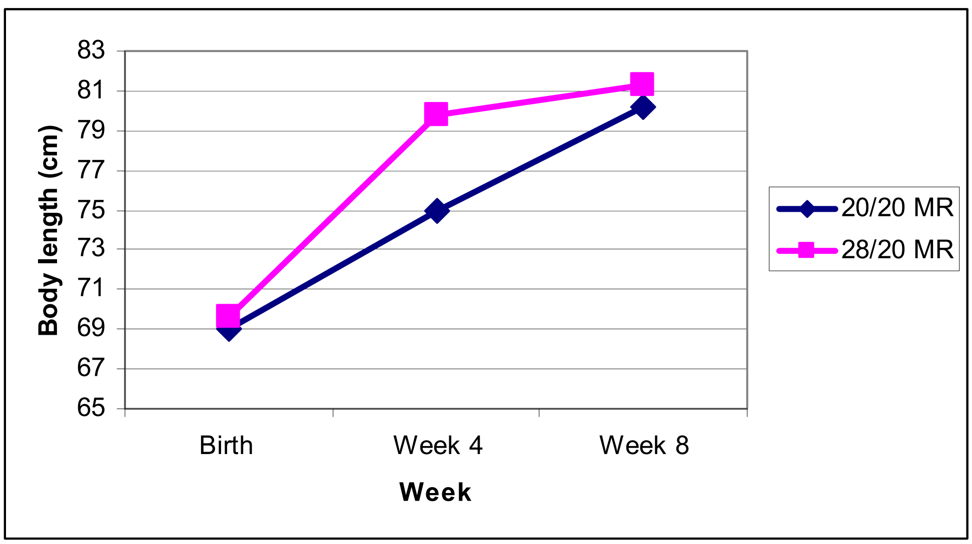
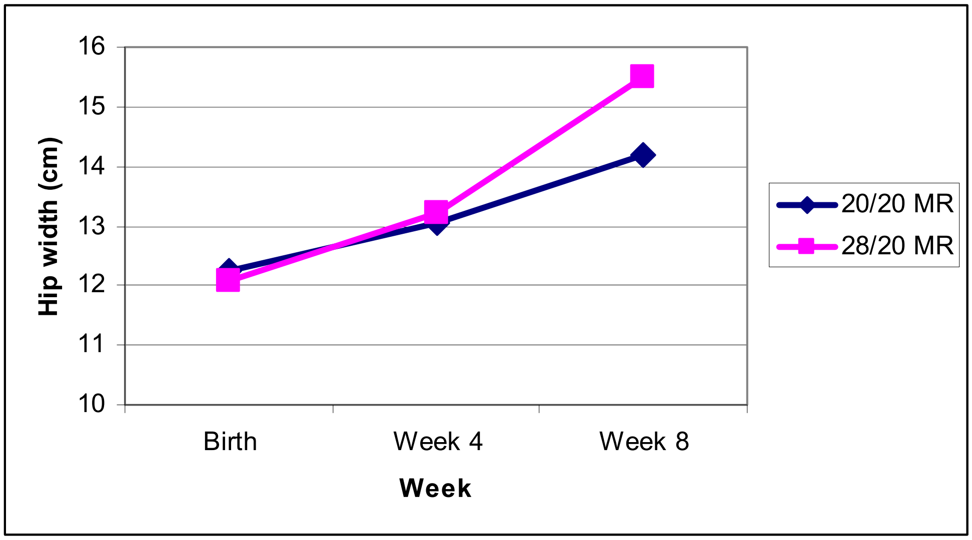


Figure 4.24 Hip width measurements for Farm C by week and treatment.



<u>Conclusions:</u>

Differences were not as expected. There were numerical differences in farms; however, differences were frequently not significant. However, the higher CP and increased feeding rates resulted in lower mortality during the first wk of life and trends for greater body frame measurements.

Calves fed 28/25 MR showed superior performance (BW, ADG, and total gain) to calves on other diets. Diet 28/20 showed intermediate performance, whereas diet 20/20 was inferior. Moreover, 28/25 and 28/20 MR calves were also superior to 20/20 calves in stature and frame gained from birth through wk 8. No differences in overall ADG were detected; however, there were differences in BW detected during wk 2, 3, and 4 and ADG. Added BW explains the lower levels of mortality seen throughout the study for calves on 28/25 and 28/20 because these calves had more body reserves to utilize in times of cold, illness, and stress.

Jersey calves fed a 20/20 MR at 10% DM solids have the potential to gain 463 g per day, whereas calves fed a 28/25 MR at a rate of 12.5% DM solids have the potential to gain 875 g per day. Calves fed a 28/20 MR at 12.5% DM solids have the potential to gain 825 g per day (NRC, 2001). However, Jersey calves fed a 20/20 MR at 10% DM solids gained 610 g per day throughout the nine-month field study, and calves fed 28/25 and 28/20 at 12.5% DM solids gained 670 g and 640 g per day, respectively. Therefore, it is reasonable to suspect that NRC (2001) under-estimates the maintenance requirements for Jersey calves.

Field studies provide important tests of products for practical uses on a dairy. However problems can arise. From first observations, Farm A looked superior to Farm B in management skills, and gains were hypothesized to be higher for Farm A. Farm A had one person feeding calves twice daily; indicating that there would be feed consistency, whereas Farm B had six people feeding calves daily. The calf manager on Farm A was meticulous concerning feeding rates, feed, and records. Additionally, calves on Farm A always had fresh water and calf starter grain, whereas several times calves on Farm B were without water and calf starter. Farms A and B both housed calves individually. However, Farm B housed calves outside in hutches bedded with sawdust and straw, while Farm A housed calves on sawdust in a non-ventilated barn. Calves on Farm B were exposed to inclement weather, while calves on Farm A were in a barn. Nevertheless, the lack of ventilation in the barn on Farm A facilitated respiratory disease. Several times on Farm B, calves were housed together and not clearly identified. Furthermore, problems with disease arose on both farms. Farm A experienced an outbreak of PI_3 and BVD, whereas Farm B dealt with salmonella.

Farm C, the Virginia Tech Dairy Cattle Center, experienced fewer problems. There were fewer calves on this farm, more veterinarian assistance, resources, and employees to watch for illnesses. In addition, the calf manager fed calves twice daily, guaranteeing consistency of feed. Calves were housed individually in hutches, with sawdust and straw bedding on coarse gravel.

Chapter Five

Intensified Growth of Calves

Introduction

Calf mortality has a significant negative economic impact on the dairy industry. In recent years, the price of replacement dairy heifers has increased, indicating that heifers are in short supply; therefore, more emphasis is placed on practices that enhance calf performance and reduce calf morbidity and mortality.

Current conventional systems for raising calves obscures the distinction between normal biological growth for the animal and what is imposed from a management standpoint. Calf performance differences from nutritional alterations are usually measured as differences in ADG. However, ADG can be influenced by the counteracting effects of gut fill due to differences of calf starter intake and may not reflect changes in growth. For instance, increased liquid feeding increases growth of lean carcass, but the corresponding decrease in starter intake decreases rumen size and gut fill. As a result, differences in ADG of BW may be minimal despite substantial improvements in growth of frame and muscle of the calf. Therefore, it is important to understand how nutritional alterations may change body composition of young calves.

In comprehending some of the changes in body composition, researchers made suggestions leading to the development of new calf feeding programs called "Intensive calf rearing" (NRC, 2001). Intensive calf feeding programs are defined as the rearing of replacement heifer calves in a manner that more closely approximates that found in nature when a calf is allowed to suckle ad libitum from the cow.

Researchers have studied intensified feeding regimens and have shown beneficial effects (Bartlett et al., 2001). The first 3 mo of a heifer calf's life is a safe time to increase her growth rate without excess deposits of udder fat. Hardsell et al., (2002) has shown no effect of high rates of gain on mammary development before the animal is 6 wk old.

Bar-Peled et al., (1997) found that calves allowed to suckle three times daily for 6 wk were 5.08 cm taller, calved 30 d earlier and produced over 450 kg more milk than calves fed restricted amounts of milk replacer. Calves allowed to suckle consumed on average 14% more energy than calves fed milk replacer. They typically nursed six to 10 times daily, consuming 16% to 24% of their BW as milk.

This data would suggest that an increased nutrition level during the liquid feeding period has a beneficial effect on lifetime milk production. However, it is becoming more obvious that current recommendations restrict optimum growth of the calf.

Crossbred dairy cattle are gaining popularity across the US because of perceived benefits of increased health and efficiency. Crossbreeding introduces favorable genes from other breeds, removes inbreeding depression, and maintains the gene interactions that causes heterosis.

Recent crossbreeding studies have shown improved longevity of herd life and milk components for dairy cattle (VanRaden and Sander, 2003).

Objectives

The objectives of this experiment were:

1) To determine relationship of dietary protein concentrations to ADG, feed efficiency, calf mortality, body weight and length, hip and wither heights, heart girth, and hip width.
2) To determine breed effects on starter intake and growth of purebred Holstein and Jersey calves and the reciprocal crosses.
3) To evaluate the effects of intensified feeding regimens on growth parameters, and starter intake

Chapter Six

Materials and Methods

Calf Feeding Trial

Experimental Procedure

Seventy calves were assigned to two diets in a restricted randomized block design. Twenty-seven bull calves and 43 heifer calves were used. Calves were fed for 8 wk. At the end of the 8^{th} wk, bull calves were sacrificed for analysis of body composition.

Animals

The Virginia Tech Animal Care and Use Committee approved the experimental protocol. Calves for this trial were from the Virginia Tech Dairy herd (Blacksburg, VA) born between May 29, 2003 and January 2, 2004. Holsteins, Jerseys, and reciprocal crosses were used in this study as shown in Table 6.1.

Table 6.1 Number of calves by gender and breed.

Gender	H X H	J X J	Crossbred
Male	17	2	8
Female	22	8	12

Calves were fed 1.89 L of high quality colostrum (>50 g of IgG) within an hour of birth. Colostrum originated from cows in the Virginia Tech Herd. Quality was measured using a colostrometer (Jorgensen Laboratories, Loveland, CO) to determine specific gravity of colostrum and make an indirect assessment of immunoglobin concentration as described by Fleenor and Stott (1980). Twelve hours later an additional 1.89 L of colostrum was fed, and 24 hr after the first feeding 454 g of Lifeline™ (American Protein Corp., Ames, IA) were fed. Calves were housed in individual calf hutches with sawdust and straw as bedding material.

At birth, vaccinations were administered for bovine rhinotracheitis and parainfluenza 3 (2 ml intranasally, TSV-2, Pfizer Animal Health, Exton, PA). Each individual animal's initial weight was recorded at birth and once a week thereafter (Thursday).

Calf health was monitored daily. Calves received a scour score on a scale of 4: (1 = firm, 2 = pudding, 3 = pancake batter, and 4 = watery). The following scour protocol was used. When a fecal score was equal to or exceeded 3, calves received 1.89 L oral electrolytes (Entrolyte H.E., Pfizer Animal Heal, Exton, PA) in an open bucket at 12:00 h. If a fecal score of greater than 3 occurred, an additional 1.89 L of electrolytes were fed to the calf at 16:00 h. Calves with fecal scores of 3 and above for two consecutive days received 30 g Gammulin ™ (American Protein Corporation, Ames IA) for 6 consecutive feedings.

Diets

Calves were assigned randomly to one of two treatments at 2 d of age according to gender and body weight. Thirty-three calves were assigned to a 28% CP and 20% fat MR (28/20), (Holstein male (n = 9), female (n= 9); Jersey sired male crossbred (n = 4), female (n = 3); Holstein sired crossbred male (n = 1), female (n = 2); Jersey male (n = 2), female (n = 3). Thirty-seven calves were assigned to a 20% CP and 20% fat MR (20/20), (Holstein male (n = 8), female (n = 13); Jersey sired crossbred male (n = 3), female (n = 3); Holstein sired crossbred male (n = 1), female (n = 4); Jersey male (n = 0), female (n = 5). All calves fed the 28/20 MR (Land O'Lakes Animal Milk Products Co., Fort Dodge, Iowa) received 13% DM solids reconstituted, where as all calves fed the 20/20 MR (Land O'Lakes Animal Milk Products Co., Fort Dodge, Iowa) received 10% DM solids reconstituted. Calves on the 20/20 MR served as the control for the experiment. Table 6.1 contains nutrient analysis for MR. Table 6.2 contains nutrient analysis for calf starter grain. Table 6.3 contains feeding rates for 28/20 MR treatment. Table 6.4 contains feeding rates for 20/20 MR treatment.

Feeding rates for this experiment matched known intensified feeding programs for Holsteins and Jerseys. The 28/25 MR was not used in this experiment to simplify experimental design and allow sufficient observations of each breed. Feeding rates for crossbreds were calculated from the differences of maintenance requirements for Jerseys and Holsteins. Feeding rates for diet 20/20 were based on a gain of 454 g per day. Feeding rates for diet 28/20 were based on a gain of 670 g per day.

Table 6.2 Milk replacer on a powder basis.

Variable	20/20 MR[a]	28/20 MR[b]
Dry Matter	97.3%	97.3%
Crude Protein %	20.0	28.0
Crude Fat %	20.0	20.0
Crude Fiber %	0.15	0.15
Calcium %	1.0	1.0
Phosphorus %	0.70	0.70
Potassium %	2.66	2.57
Magnesium %	0.13	0.12
Vitamin A IU/kg	9072	4536
Vitamin D_3 IU/kg	2268	1134
Vitamin E IU/kg	45.36	22.68
Thiamine mg/kg	6.61	3.31
Riboflavin mg/kg	6.61	3.31
Niacin mg/kg	2.65	1.32
d-Panthothenic Acid mg/kg	13.23	6.61
Biotin mg/kg	0.11	0.06
Ascorbic Acid mg/kg	110.23	55.12
Pyridoxine Hydrochloride mg/kg	6.61	3.31
Folic Acid mg/kg	0.55	0.28
Vitamin B_{12} mg/kg	0.07	0.03
Choline Chloride mg/kg	1323	661
Iron PPM	100	50
Manganese PPM	40	20
Zinc PPM	40	20
Copper PPM	10	5
Iodine PPM	0.5	0.5
Cobalt PPM	0.11	0.055
Selenium PPM	0.30	0.15

[a] 20/20 = 20% protein, 20% fat MR
[b] 28/20 = 28% protein, 20% fat MR
[c] Land O'lakes Milk Products Co., (Fort Dodge, IA)

Table 6.3 Nutrient analysis of calf starter grain.

	As Fed	Intense Calf Diet 22 B60
Dry Matter	%	90.00
NFC	%	50.55
Crude Protein	%	22.00
RUP	(CP%)	38.40
RDP	(CP%)	61.60
Sol P	(CP%)	24.00
ADF	%	8.75
NDF	%	15.00
Fat	%	2.45
Calcium	%	2.67
Phosphorus	%	1.10
Potassium	%	0.55
Sulfur	%	0.45
Magnesium	%	0.27
Salt	%	0.40
Sodium	%	0.42
Chloride	%	0.42
Zinc	ppm	0.45
Iron	ppm	233.00
Copper	ppm	111.00
Manganese	ppm	30.90
Cobalt	ppm	0.44
Iodine	ppm	1.42
Selenium	ppm	0.30
Vitamin A	IU/kg	2835
Vitamin D	IU/kg	5667
Vitamin E	IU/kg	1134
Bovatec	g/kg	27.21
TDN	%	88.86
NEg	Mcal/kg	520
NEm	Mcal/kg	800
Lignin	%	1.55

[a] Land O'Lakes Animal Feed Co., (St. Paul, MN)

Table 6.4 Feeding rates for 28/20 MR on a powder basis.

Birth Weight (kg)	d 1-7 (kg of powder)	kg of water	d 8- 49 (kg of powder)	kg of water	d 50 – 56 (kg of powder)	kg of water
23 to 27	0.54	3.63	0.73	4.81	0.36	2.40
28 to 36	0.73	4.81	0.91	5.90	0.45	2.95
> 36	0.82	5.44	1.18	7.89	0.59	3.95

Table 6.5 Feeding rates for 20/20 MR on a powder basis.

Birth Weight	d 1-49 (kg of powder)	kg of water	d 50-56 (kg of powder)	kg of water
All calves	0.45	3.90	0.23	1.95

Milk replacer was offered to calves in an individual open bucket at 0800 h and again at 1600 h. Fresh water was available ad lib. Dry feed, “Intense Calf Diet 22 B60” (Land O’Lakes Animal Milk Products Co., Fort Dodge, Iowa), was offered from day 5 of life. Two hundred thirty g of starter was offered, when the calf consumed 230 g for 3 consecutive d, then the amount was increased by 450 g/ d. Weighbacks were measured on Monday, Wednesday, and Friday. All calves were housed in individual hutches on a layer of coarse gravel with sawdust and straw as bedding.

<u>Weekly Measurements</u>

Calves were weighed and measured for body length, hip height, wither height, heart girth, hip width, and blood samples were obtained within 24 h of birth, and thereafter, every Thursday at 1300 h. Body length was measured from the point of shoulder to the tail head and hip width was measured from the outer sides of the tuber coxae with a rigid meter stick.

Blood Samples

Blood samples were obtained by jugular venipuncture in a vacutainer (Becton Dickinson, Franklin Lakes, MN) treated with Potassium EDTA. Centrifugation at 3200-x g for 15 min was used to isolate plasma that was stored at -20^0 C for later analysis. Samples were analyzed for plasma glucose (Glucose Autokit, C2, Wako Chemicals GmbH, Neuss, Germany), and plasma proteins (Total Plasma Protein Autokit, Wako Chemicals GmbH, Neuss, Germany). Samples were analyzed for PUN using the urease and indophenol reaction (Weatherburn, 1967; Chaney and Marbach, 1962). Absorbance of samples was read on a Microplate Autoreader (Bio-tech instruments, Fredrick, MD) at dual wavelengths of 405 nm and 625 nm.

Sacrifice procedure

All bull calves were sacrificed the Saturday after 56 d of age. Calves were restricted from all feed on Friday morning; however water was offered ad lib. All procedures occurred in the necropsy room of the Virginia-Maryland College of Veterinary Medicine by captive bolt and exsanguination. A tared plastic bag was used to collect blood. The calf was separated into three components. 1) head, hide, feet, and tail (HHFT); 2) Blood and internal organs (BO); and 3) carcass (CAR). The gastrointestinal tract was removed, weighed, stripped of its contents, and reweighed. The carcass fraction was divided longitudinally, both halves were weighed and the lighter half was discarded. Each component was weighed and bagged at the College of Veterinary Medicine and later reweighed at the Virginia Tech Dairy Center, where it was frozen (-20^0 C) and later transported to Cornell University for additional processing. At Cornell, each component was further processed by grinding seven times in a grinder (Model 8016, Autio Co., Astoria, OR, 10 mm, 12 mm screens). Random samples of each component were collected, bulked, subsampled, reweighed, and frozen (-20^0 C) for later analyses.

Analysis of tissue samples

Samples were placed in a freeze drier set at a temperature of 24^0 C (VirTus 20 SRC-X; The VirTus Co., Inc., Gardiner, NY) for 72 h. Twenty-four h after being placed in the freeze drier samples were turned to ensure drying in 72 h.

Statistical design and analysis

Calves were assigned to one of two diets within each gender and body weight. Table 6.6 lists the blocks of weights.

Table 6.6 Division of calf weights for grouping of diets.

Birth Weight (kg)
23 to 27
28-36
>36

For measurements taken weekly throughout the experiment the following model was used;

$$Y_{ijklmn} = \mu + D_i + G_l + DG_{ij} + C_{(ij)k} + W_l + DW_{il} + GW_{jl} + DGW_{ijl} + E_{ijkl}$$

Where:

D = Diet (i = 1, 2); fixed effect

G = Gender (j = 1, 2) fixed effect

C = Calf within diet and gender (k = 1, 2) (total of 70 calves); random effect

W = Week (l = 1…8); fixed effect

E = residual

Diet, gender, and interaction differences were tested by calf, and significance was declared for $P< 0.05$ with trends established at $P<0.15$.

Holstein sired and Jersey sired crosses were analyzed separately, however, no differences were detected. Therefore, crossbred calves were combined into one category.

Data measured weekly were analyzed using Proc GLM with repeated measures (SAS, 2002). Data measured only one time during the experiment were analyzed using Proc GLM (SAS, 2002). Frequency of death by treatment was analyzed using Proc Freq in (SAS, 2002) and tested for differences by Chi Square.

Chapter Seven

Dietary Fat and Protein Ratios and their influences on Growth of calves.

Abbreviation key: MR = milk replacer, **20/20 =** treatment in which calves were fed a 20% protein, 20% fat milk replacer**, 28/20** = treatment in which calves were fed a 28% protein, 20% fat milk replacer, **H X H** = Holstein sire and dam, **J X J** = Jersey sire and dam, **Crossbred** = Jersey sire and Holstein dam, or Holstein sire and Jersey dam**, HHFT** = head, hide, feet, and tail, **BO** = blood and organs, **CAR** = total weight of carcass, **Stomach =** rumen, reticulum, omasum, abomasum, **BMI** = body mass index.

Results and Discussion

Diets:

The experiment was designed to deliver 99.6 g, 146.0 g, and 240.4 g more protein and 45.2 g, 92.0 g, and 164.8 g more fat to Jersey, crossbred, and Holstein calves, respectively fed diet 28/20 compared to diet 20/20, and to support 825 g of gain. Calves on diet 20/20 received 90 g of CP and 90 g of fat to support 450 g of gain.

Growth:

Calves fed 28/20 had higher total gain, ADG, and BW gains than calves fed diet 20/20 (Figures 7.1, 7.2, and 7.3, and Tables 7.1, and 7.2, respectively). Diet 28/20 had higher ADG in wk 1, 2, and 3, which is noteworthy. This extra gain may decrease mortality because it supplies extra fat during times of stress. As expected, H X H had the largest body weights and J X J had the smallest body weights, whereas the crossbreds were intermediate. A significant treatment effect was noted for wk 2 through 6. However, there were no overall differences between genders, but differences were reported during wk 2 and 3.

Jersey, crossbred, and Holstein calves fed a 20/20 MR at 10% DM solids should gain 259 g, 340 g, and 463 g, respectively (NRC, 2001). However, actual gains for calves were 274 g, 440 g, and

442 g, respectively. Jersey, Crossbred, and Holstein calves fed a 28/20 MR at 13.0% DM solids had predicted gains of 640 g, 789 g, and 826 g, respectively. Actual gains experienced were 508 g, 523 g, and 696 g, respectively, indicating that NRC (2001) underestimates maintenance requirements for the young calf as suggested by Bascom et al., (2002).

In wk 1 through 8, calves fed 20/20 were lighter than calves fed diet 28/20 and gained less weight (Figure 7.2 and Table 7.2). The 28/20 calves consumed more calf starter than hypothesized (Figures 7.4).

Differences ($p<0.05$) in hip height, wither height, and heart girth were detected between diets for wk 1 through 8 and overall gain (Figures 7.6, 7.7, and 7.8 and Tables 7.4, 7.5, and 7.6, respectively). In addition, gender was not included in the figure if not different. Calves fed 28/20 were taller and had more heart girth and total gain for these measurements than calves fed 20/20. As expected, there were significant breed differences for all weeks for all measurements; however, most would expect that J X J to be smaller than H X H, with crossbreds being intermediate. The "Penn State Growth Chart" (Heinrichs, 2004) appeared to overestimate the wither heights of calves in this study.

Treatment differences for body length were detected for wk of 3 through 7 ($p<0.05$). Trends ($p<0.15$) were detected for wk 8 and overall gain. Differences ($p<0.05$) for hip width by treatment were reported for wk 7 and 8 and a trend ($p<0.15$) was reported for overall gain.

Diet of the preweaned calf might affect rate of growth after weaning. Following growth of calves fed these diets after weaning might enhance our understanding of the impact of protein and fat in the preweaned calf's diet on growth and development.

<u>Plasma indications of protein and energy metabolism</u>

Feeding a MR that supplies more protein than the calf can utilize should result in elevated PUN (Bascom et al., 2002). Calves fed 28/20 had PUN similar to 20/20 calves in wk 1 to 8 (Figure

7.10 and Table 7.7), indicating that feeding diet 28/20 did not greatly exceed the calf's ability to utilize protein.

Differences in blood glucose were detected, calves fed 20/20 had lower levels of blood glucose during weeks 1 to 8 than calves fed 28/20 (Figure 7.11 and Table 7.8). Treatment differences were detected during wk 1, 2, 7, and 8. Expected blood glucose levels for calves are 90 to 120 mg/dl (Wako Chemicals, Wako, Texas; Bascom et al., 2002), which are similar to levels determined on this study (80 to 160 mg/dl).

Total plasma proteins were measured for week 1 to indirectly measure passive immunity. There was a significant difference for breed by gender, as can be seen in (Figure 7.12). The crossbred calves seem to have higher plasma protein levels during week 1. Normal ranges of total proteins for one-week-old calves are 25 to 50 mg/dl, which were recorded in this study (20 to 47 mg/dl).

Health

Average days scouring (days when calves had a fecal score that exceeded 2) were higher for calves fed 28/20 (4.1 d) and were lowest for 20/20 (3.1 d), but differences were not significant. However, the average fecal score for calves fed 28/20 was less than 2 in wk 1, and 3 to 8, indicating that the calves had looser feces but were not scouring. Overall, health of the calves was similar among diets.

Body Components

Differences ($p<0.05$) were detected for total carcass weight, liver, full intestine and empty intestine weight.

Calves fed 28/20 had greater total carcass, liver, full intestine, and empty intestine, than calves fed 20/20 (Figures 7.13, 7.14, 7.15, and 7.16, and Tables 7.9, 7.10, 7.11, and 7.12, respectively).

Body Mass Index

BMI is an indirect measure of body condition because it correlates highly with body fat. Calves on diet 28/20 had higher BMI ($p<0.05$) than calves on diet 20/20 (Figure 7.16 and Table 7.13). Body mass index was calculated using the following equation:

$$BMI = [(kg\ of\ BW) / (cm\ of\ height)^2] \times 1000$$

Holstein and Jersey calves on diet 28/20 had greater BMI than calves on diet 20/20. However, crossbred calves had similar BMI on both treatments. Calves on diet 28/20 had higher BMI's during the first 2 wk of life than 20/20 calves, which indicates that 28/20 calves had added body fat. This added body fat provides reserves for the calf in times of illness and stress.

Feed Efficiency

Feed efficiency has been the successful benchmark of profitability for the poultry, beef, and swine industries. However, feed efficiency has not been used in the dairy industry, but this is changing. With lower milk prices, one way to maintain calf growth and health is to enhance feed efficiency.

Feed efficiency determines the cost of inputs that a producer must invest to get a unit of output (gain). More efficient producers realize a lower feed cost to gain in their animals, which means spending less money to achieve a level of productivity.

Calves on diet 28/20 displayed better feed efficiency ($p<0.05$) than calves on 20/20 (Table 7.14). Feed efficiency was calculated using the following equation:

$$Feed\ efficiency = kg\ of\ feed\ consumed\ DM / kg\ of\ BW\ gained$$

Holstein and Jersey calves on diet 28/20 displayed improved feed efficiency over diet 20/20. Whereas, crossbred calves on diet 28/20 had poorer feed efficiencies compared to diet 20/20.

Conclusions

Calves fed 28/20 displayed greater ADG, total weight gain, BW gain, BMI, and feed efficiency than calves fed 20/20. Feeding higher percent protein MR to calves has a positive impact on growth. However, the gains estimated by NRC (2001) and the "Penn State Growth Chart" (Heinrich, 2004) were not achieved. NRC and "Penn State Growth Charts" estimate higher gains; therefore requirements for young calves must be higher than recorded. Moreover, feeding calves a 20/20 MR at 10% of BW is not advisable given that these calves were substandard to diet 28/20 in ADG, total weight gain, BW gain, body components, BMI, and feed efficiency and stature.

Calf starter is an integral part of any calf rearing program. Even a small amount consumed in the first d is enough to provide important benefits to the rumen. Dry feed increases the rumen's functionality, and population of microbes. Previous researchers (Bartlett et al., 2002) noted that increased liquid feeding rates reduces the intake of starter, and therefore might delay rumen development. In turn delayed rumen development will delay weaning age. However, calves on 28/20 had similar starter intakes to calves on diet 20/20. Furthermore, there were no differences detected in gross rumen size. This indicates that utilizing an intensified feeding program does not delay rumen development or cause calves to "stall" after weaning.

Table 7.1 Body weight gain by treatment and breed.

Total Gain (kg)								
Breed	20/20 Heifer	N	28/20 Heifer	N	20/20 Bull	N	28/20 Bull	N
HXH	36.06	13	37.07	9	39.83	9	40.93	8
JXJ	24.30	3	26.04	4	29.12	1	30.66	2
Crossbred	23.59	7	26.85	7	27.81	4	30.57	3
Mean SE	2.75		5.00		6.75		5.84	
P (effect of diet)	<0.001							

Table 7.2 Weekly body weight by treatment.

Weekly Body Weight (kg)									
Diet	N	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
20/20	37	33.14	34.17	34.52	37.35	40.65	45.02	49.20	53.58
28/20	33	36.45	40.25	43.09	47.57	51.93	56.53	62.03	65.38
Mean SE		0.95	0.99	1.12	1.27	1.34	1.45	1.69	59.48
P (effect of diet)		0.02	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table 7.3 Weekly body length measurements by treatment.

Diet	N	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Total Gain
20/20 MR	37	68.86	70.89	72.12	73.67	77.02	78.98	80.88	83.27	14.43
28/20 MR	33	69.77	72.3	75.11	77.13	88.04	82.45	84.64	86.58	16.42
Mean SE		0.93	1.08	0.92	0.94	0.98	1.03	1.21	1.27	3.15
P (effect of diet)		0.49	0.36	0.03	0.01	0.03	0.02	0.03	0.07	0.15

Table 7.4 Weekly hip height measurements by treatment.

		Weekly Hip Height (cm)								
Diet	N	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Total Gain
20/20 MR	37	75.62	77.54	78.55	79.42	80.68	81.98	83.51	85.42	9.56
28/20 MR	33	77.6	79.48	80.47	82.26	83.67	85.83	87.42	89.09	10.64
Mean SE		0.78	0.71	0.66	0.63	0.62	0.62	0.67	0.66	1.95
P (effect of diet)		0.08	0.06	0.04	0.002	0.001	0.001	0.0001	0.0002	0.003

Table 7.5 Weekly wither height measurements by treatment.

Weekly Wither Height (cm)										
Diet	N	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Total Gain
20/20 MR	37	73.57	75.56	76.41	76.89	78.22	79.03	80.43	82.23	8.73
28/20 MR	33	75.57	77.13	78.35	79.67	81.33	82.65	84.48	85.79	10.06
Mean SE		0.61	0.55	0.56	0.54	0.56	0.55	0.60	0.58	0.61
P (diet)		0.02	0.05	0.02	0.0007	0.0003	<.0001	<.0001	<.0001	0.02

Table 7.6 Weekly heart girth measurements by treatment.

Weekly Heart Girth (cm)										
Diet	N	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Total Gain
20/20 MR	37	73.2	74.73	75.97	78.25	80.44	82.5	86.01	88.11	15.06
28/20 MR	33	76.13	79.05	81.78	83.86	87.34	90.38	93.10	94.88	18.98
Mean SE		0.78	0.73	0.89	0.88	1.01	0.88	0.89	1.01	0.97
P (effect of diet)		0.01	0.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.01

Table 7.7 Weekly plasma urea nitrogen by treatment.

		Weekly Plasma Urea Nitrogen							
Diet	N	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
20/20 MR	37	11.23	11.89	11.46	13.33	10.73	13.13	13.82	14.68
28/20 MR	33	18.92	13.70	11.53	13.32	11.65	11.79	14.56	16.62
Mean SE		4.52	2.89	3.96	2.06	3.24	2.02	2.66	2.57
P (effect of diet)		0.16	0.32	0.75	0.44	0.89	0.60	0.51	0.21

Table 7.8 Weekly plasma glucose levels by treatment.

		Weekly Plasma Glucose (mg/dl)							
Diet	N	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
20/20 MR	37	74.74	72.73	104.47	81.79	104.78	88.52	92.93	85.54
28/20 MR	33	157.82	104.58	104.29	90.87	120.8	95.58	125.27	99.12
Mean SE		15.7	13.36	26.73	7.59	14.30	10.81	8.81	7.62
P (effect of diet)		<.0001	0.01	0.97	0.43	0.32	0.83	0.0003	0.02

Table 7.9 Carcass weights including right and left carcass halves.

Carcass Weight (kg)				
Breed	20/20 MR	N	28/20 MR	N
H X H	37.58	9	45.01	8
J X J	27.21	1	33.29	2
Crossbred	25.58	4	29.96	5
Mean SE	2.75			
P	0.02			

Table 7.10 Liver weights by breed and treatment.

Liver Weights (kg)				
Breed	20/20 MR	N	28/20 MR	N
H X H	1.44	9	1.76	8
J X J	1.22	1	1.60	2
Crossbred	1.13	4	1.37	5
Mean SE	0.18			
P (diet)	0.06			

Table 7.11 Full intestine weights by breed and treatment.

Full Intestine (kg)				
Breed	20/20 MR	N	28/20 MR	N
H X H	5.27	9	7.12	8
J X J	4.45	1	7.33	2
Crossbred	4.50	4	5.63	5
Mean SE	0.65			
P	0.003			

Table 7.12 Empty intestine weights by breed and treatment.

Empty Intestine (kg)				
Breed	20/20 MR	N	28/20 MR	N
H X H	3.02	9	3.74	8
J X J	2.24	1	4.20	2
Crossbred	2.26	4	2.95	5
Mean SE	0.33			
P	0.001			

Table 7.13 Body mass index by breed and treatment.

	20/20		28/20	
Breed	MR	N	MR	N
H X H	81.28	18	91.33	17
J X J	58.27	4	75.81	6
Crossbred	75.79	6	78.26	6
Mean SE	1.54			
P (diet)	<.0001			

Table 7.14 Feed efficiencies by breed and treatment.

	20/20		28/20	
Breed	MR	N	MR	N
H X H	3.32	18	3.01	17
J X J	4.01	4	2.83	6
Crossbred	3.15	6	3.86	6
Mean SE	1.23			
P (diet)	0.05			

Figure 7.1 Total weight gained by diet, breed, and gender.

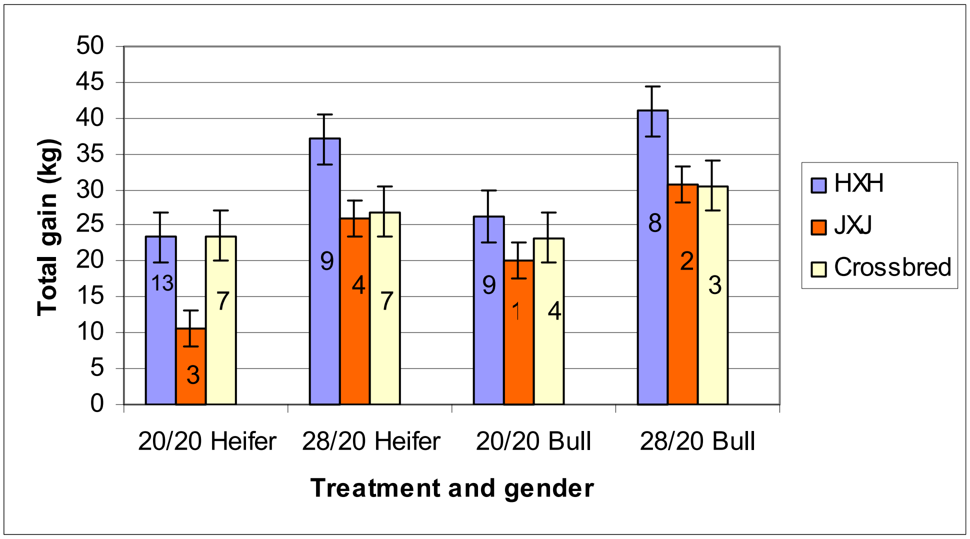


Figure 7.2 Weekly body weights by treatment.

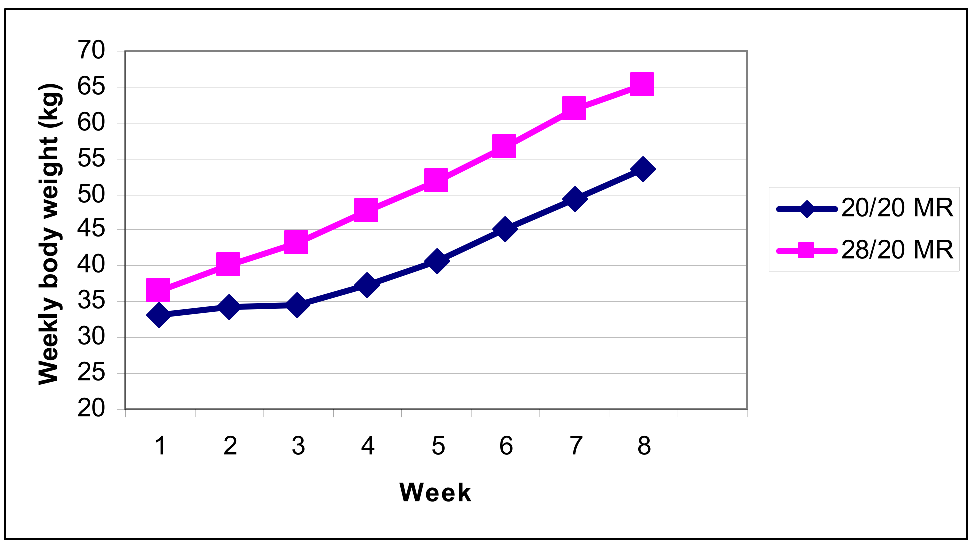


Figure 7.3 Average daily gain by breed, treatment, and gender.

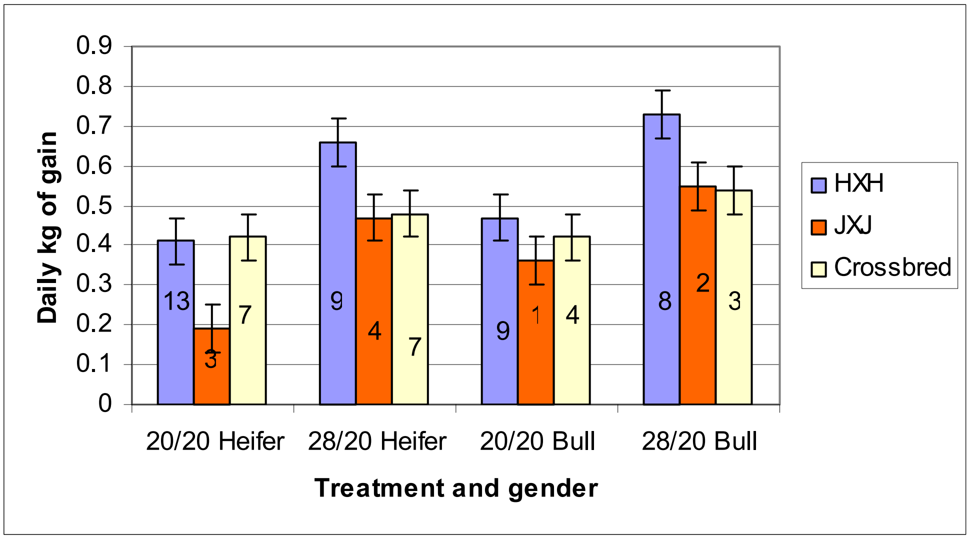


Figure 7.4 Weekly calf starter intake by breed, gender, and treatment.

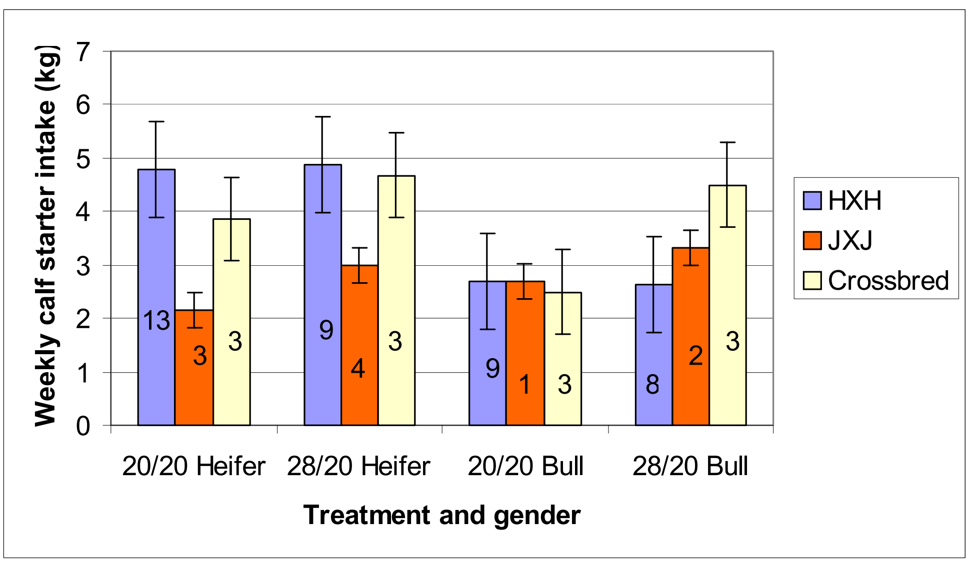


Figure 7.5 Weekly body length measurements by treatment.

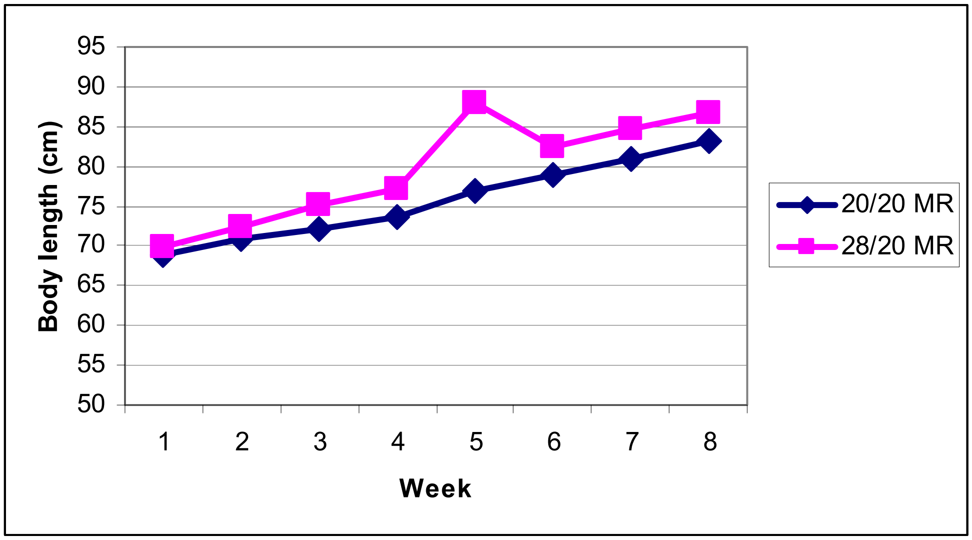


Figure 7.6 Weekly hip height measurements by treatment.

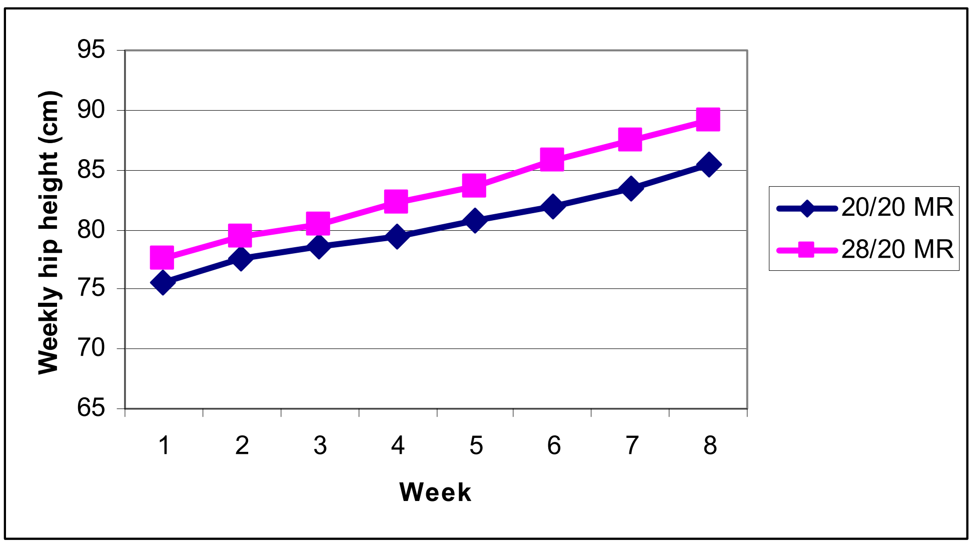


Figure 7.7 Weekly wither height measurements by treatment.

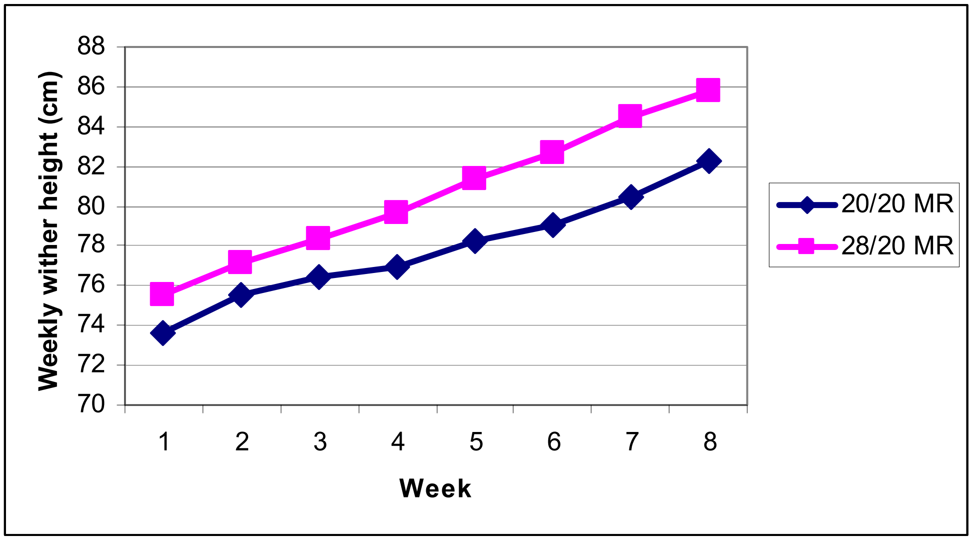


Figure 7.8 Weekly heart girth measurements by treatment.

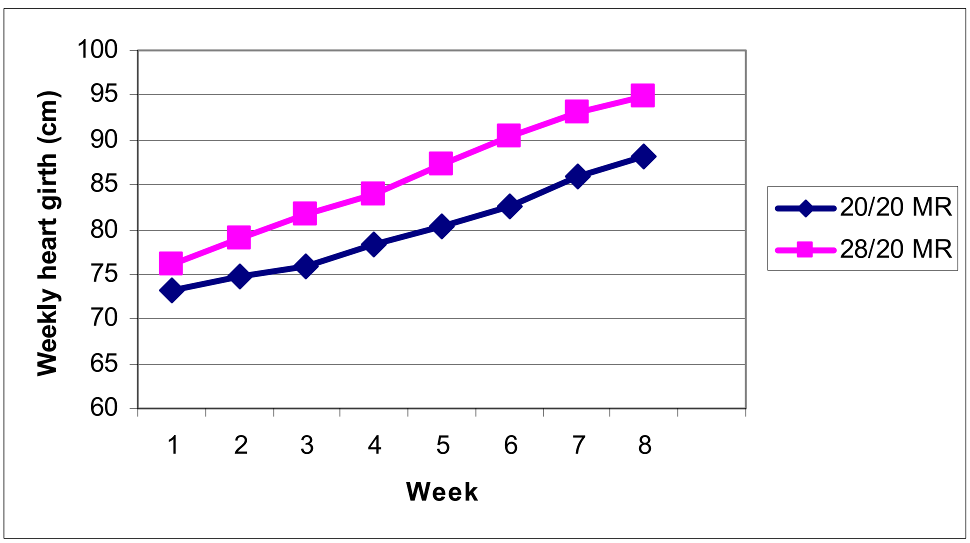


Figure 7.9 Weekly hip width measurements by treatment.

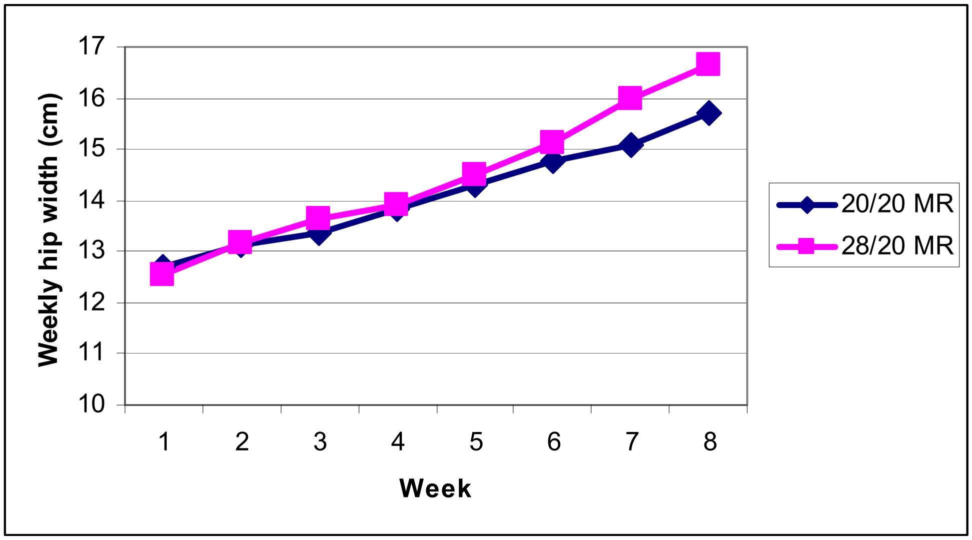


Figure 7.10 Weekly plasma urea nitrogen by treatment.

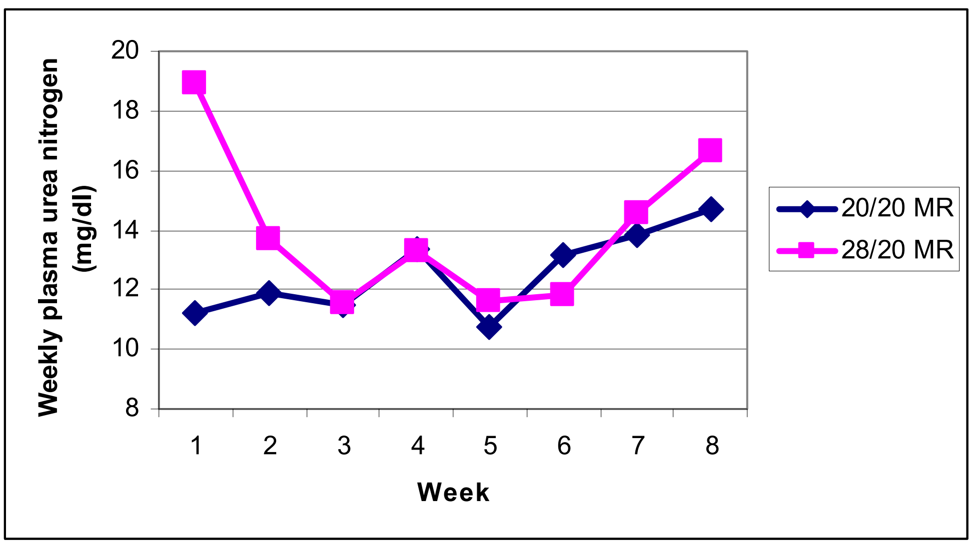


Figure 7.11 Weekly plasma glucose by treatment.

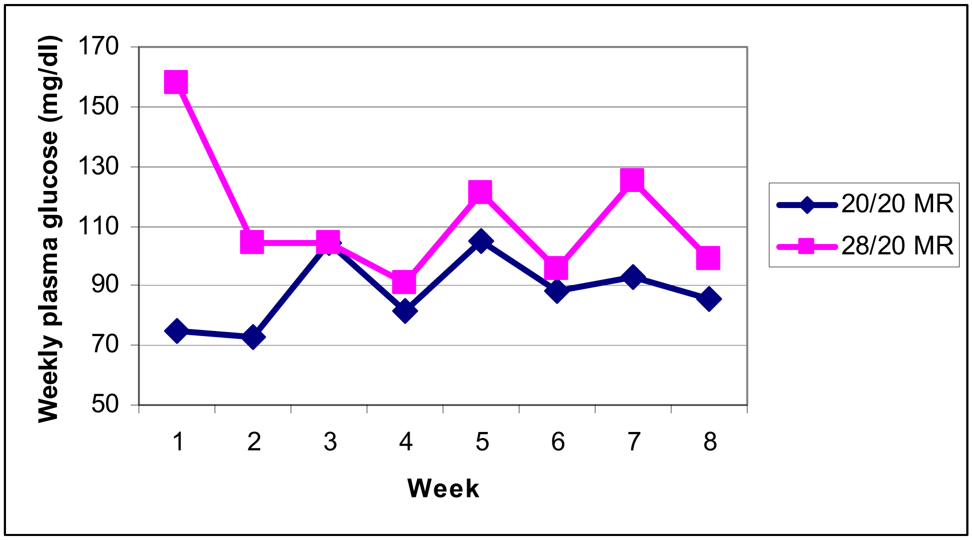


Figure 7.12 Week 1 total proteins by treatment, gender, and breed.

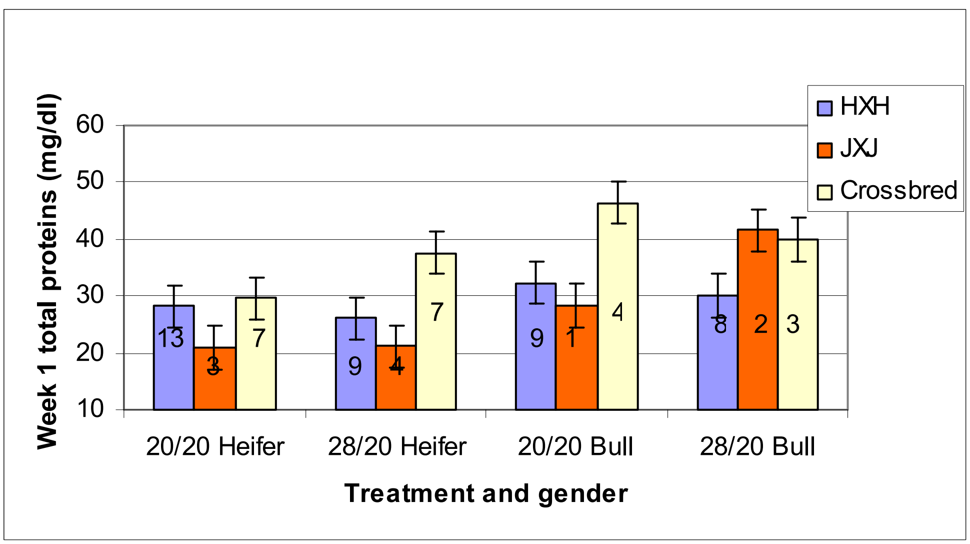


Figure 7.13 Total carcass weight by breed and treatment.

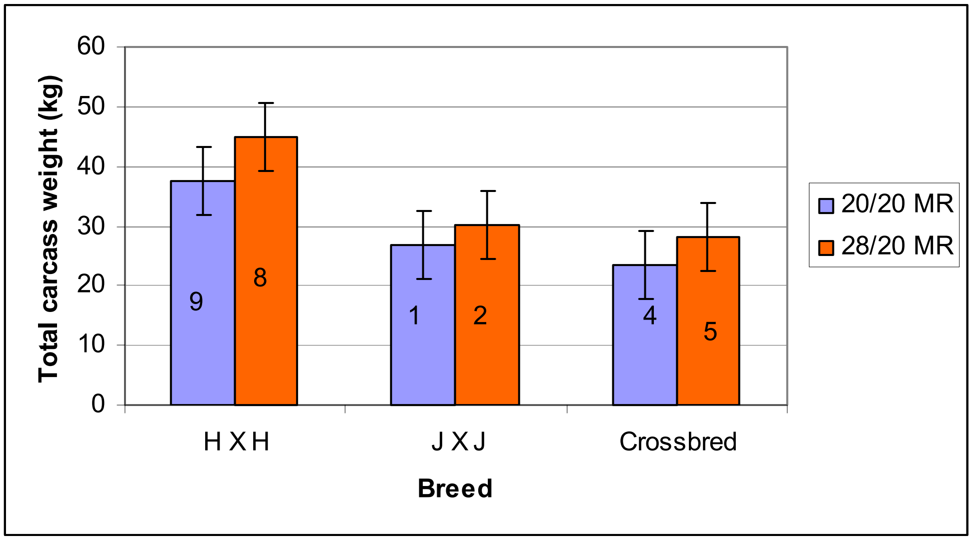


Figure 7.14 Liver weights by breed and treatment.

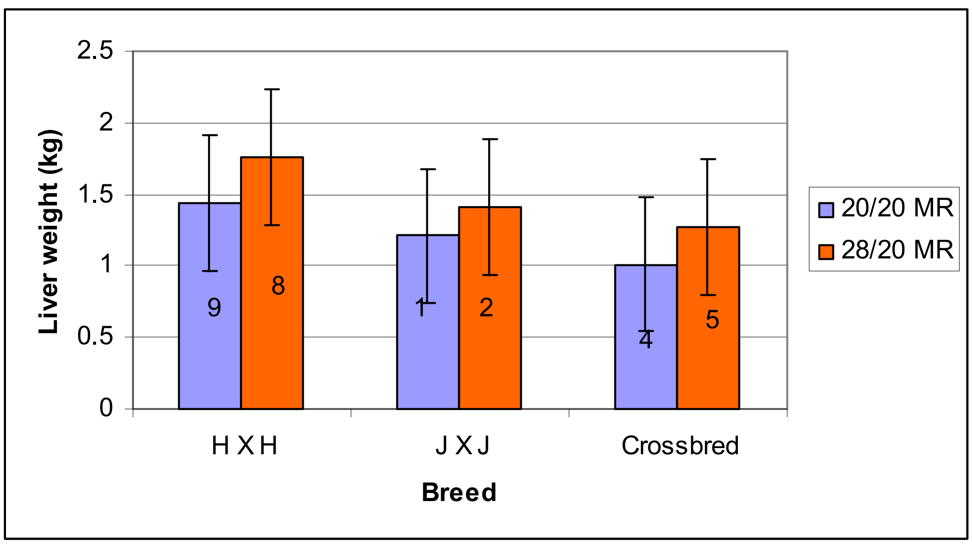


Figure 7.15 Full intestine weight by breed and treatment.

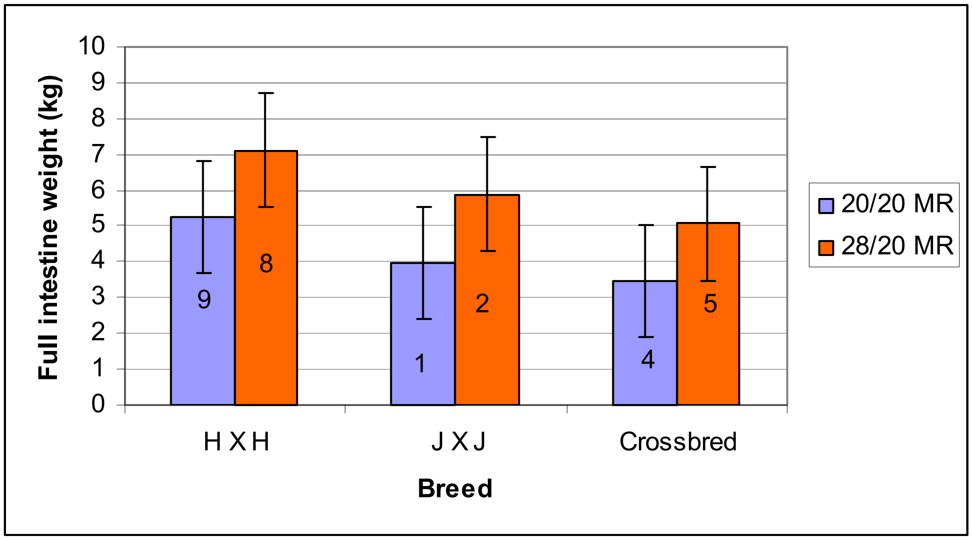


Figure 7.16 Empty intestine weight.

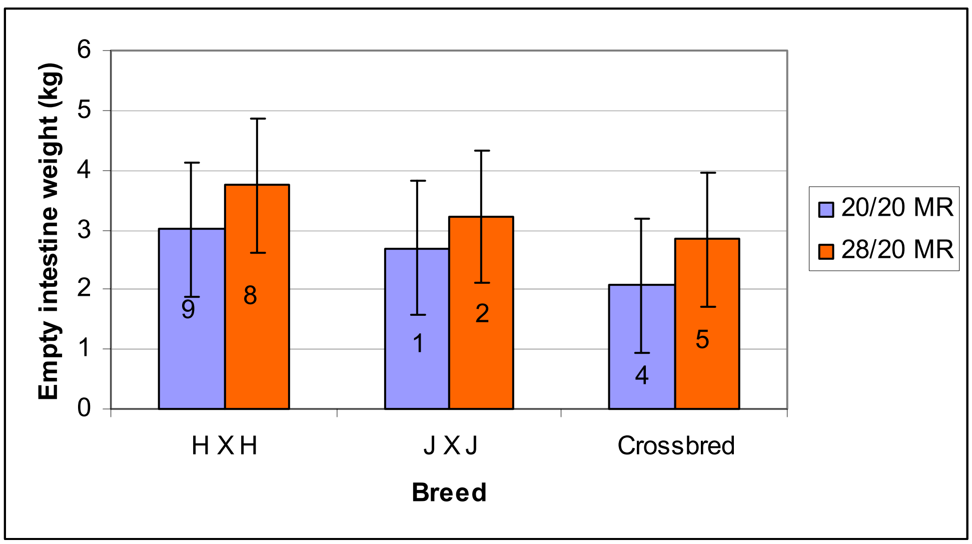
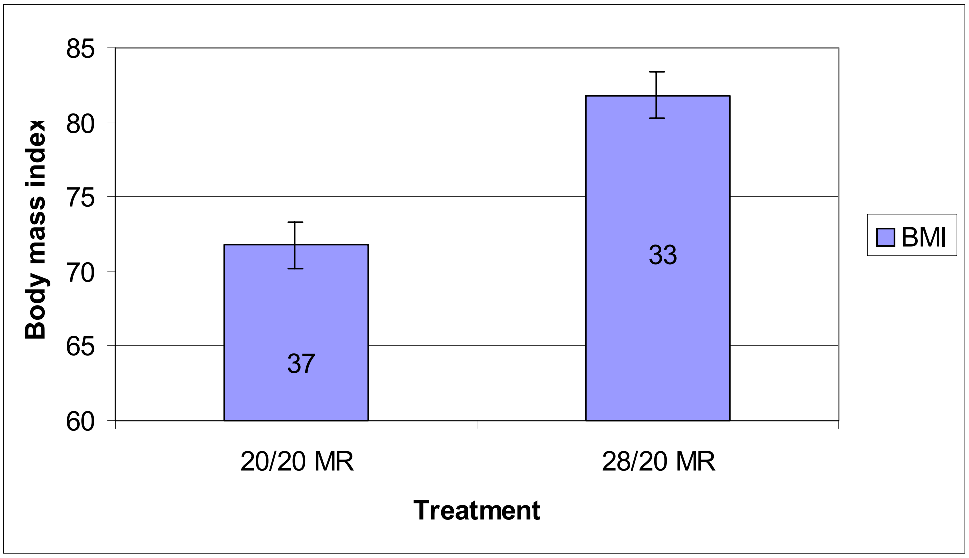


Figure 7.17 Body mass index by treatment.



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Appendix A

Table A.1 Average daily gain for Farm A by season and treatment.

			Average Daily Gain (kg)							
Diet	Season	N	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
20/20 MR	Sept - Nov	13	0.17	0.00	0.10	0.16	0.27	0.15	0.42	0.34
20/20 MR	Dec - Feb	17	0.15	-002	0.08	0.25	0.34	0.43	0.45	0.82
20/20 MR	Mar - May	1	0.11	0.00	0.11	0.14	0.30	0.23	0.60	0.25
28/25 MR	Sept - Nov	14	0.20	0.02	0.14	0.37	0.46	0.37	0.49	0.42
28/25 MR	Dec - Feb	20	0.05	-.001	0.13	0.52	0.28	0.12	0.27	0.42
28/25 MR	Mar - May	2	0.16	0.01	0.13	0.44	0.35	0.22	0.44	0.44
Mean SE			0.35	0.51	0.38	0.31	0.49	0.42	0.52	2.03
P			0.22	0.92	0.64	0.02	0.56	0.01	0.18	0.58

Table A.2 Hip heights for Farm A with treatment and season interactions.

			Hip Heights (cm)			
Diet	Season	N	Birth	Week 4	Week 8	Total Gain
20/20 MR	Sept - Nov	13	70.86	73.12	77.72	6.86
20/20 MR	Dec - Feb	17	69.71	74.79	78.50	8.79
20/20 MR	Mar - May	1	73.66	76.21	80.65	6.99
28/25 MR	Sept - Nov	14	70.60	75.71	79.67	9.07
28/25 MR	Dec - Feb	20	70.18	74.84	78.65	8.47
28/25 MR	Mar - May	2	71.88	73.35	81.44	9.56
Mean SE			1.34	1.64	1.67	1.70
P			0.90	0.08	0.26	0.48

Table A.3 Body lengths for Farm A with treatment by season interactions.

			Body Length (cm)			
Diet	Season	N	Birth	Week 4	Week 8	Total Gain
20/20 MR	Sept - Nov	13	66.43	69.56	82.51	16.08
20/20 MR	Dec - Feb	17	66.93	67.75	76.67	9.74
20/20 MR	Mar - May	1	73.66	73.66	76.20	2.54
28/25 MR	Sept - Nov	14	67.71	73.73	82.99	15.28
28/25 MR	Dec - Feb	20	64.73	67.76	77.11	9.35
28/25 MR	Mar - May	2	63.82	71.44	81.29	17.47
Mean SE			2.26	8.91	2.66	8.88
P			0.13	0.71	0.99	0.65

Table A.4 Hip widths for Farm A with treatment by season interactions.

			Hip Width (cm)			
Diet	Season	N	Birth	Week 4	Week 8	Total Gain
20/20 MR	Sept - Nov	13	13.34	15.43	17.64	4.30
20/20 MR	Dec - Feb	17	13.35	14.65	15.44	2.09
20/20 MR	Mar - May	1	12.38	15.24	15.56	3.18
28/25 MR	Sept - Nov	14	15.24	16.83	18.63	3.39
28/25 MR	Dec - Feb	20	13.03	13.10	16.70	3.67
28/25 MR	Mar - May	2	11.95	12.07	18.21	6.26
Largest SE			0.82	0.96	0.69	0.83
P			0.86	0.37	0.19	0.28

Table A.5 Average daily gain for Farm B by season and treatment.

			Average Daily Gain (kg)							
Diet	Season	N	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
20/20 MR	Sept - Nov	3	0.39	0.39	-0.22	0.38	0.24	0.71	0.44	0.66
20/20 MR	Dec - Feb	6	0.22	0.22	0.47	0.13	0.24	0.16	0.33	0.57
20/20 MR	Mar - May	3	0.93	0.93	0.39	0.43	0.36	0.25	0.37	0.67
28/20 MR	Mar - May	19	0.32	0.32	0.57	0.11	0.45	0.89	0.75	0.42
28/25 MR	Sept - Nov	3	0.16	0.66	-0.03	0.75	0.49	-0.13	0.88	-0.04
28/25 MR	Dec - Feb	5	0.31	0.42	0.27	0.59	0.71	0.58	0.51	0.59
28/25 MR	Mar - May	3	0.36	0.54	0.41	0.38	0.67	0.57	0.68	0.37
Mean SE			0.80	0.64	0.50	0.62	0.34	1.02	0.53	1.29
P			0.32	0.09	0.53	0.02	0.20	0.48	0.25	0.65

Table A.6 Hip heights for Farm B with season and treatment interactions.

			Hip Height (cm)			
Diet	Season	N	Birth	Week 4	Week 8	Total Gain
20/20 MR	Sept - Nov	3	69.59	74.83	77.95	8.36
20/20 MR	Dec - Feb	6	72.49	82.47	83.03	10.54
20/20 MR	Mar - May	3	74.61	74.61	77.79	3.18
28/20 MR	Mar - May	19	70.62	75.04	81.64	11.02
28/25 MR	Sept - Nov	3	72.67	78.15	79.89	7.22
28/25 MR	Dec - Feb	5	73.91	78.58	78.58	4.67
28/25 MR	Mar - May	3	73.55	75.78	79.48	5.93
Mean SE			2.63	2.33	2.78	2.69
P			0.88	0.15	0.31	0.45

Table A.7 Wither heights for Farm B with treatment by season interactions.

			Wither Height (cm)			
Diet	Season	N	Birth	Week 4	Week 8	Total Gain
20/20 MR	Sept - Nov	3	70.06	75.06	78.00	7.94
20/20 MR	Dec - Feb	6	71.63	79.59	80.81	9.18
20/20 MR	Mar - May	3	69.85	72.71	74.30	4.45
28/20 MR	Mar - May	19	69.44	74.92	82.27	12.83
28/25 MR	Sept - Nov	3	70.57	77.12	79.50	8.93
28/25 MR	Dec - Feb	5	73.72	75.99	80.65	6.93
28/25 MR	Mar - May	3	72.92	74.51	78.53	5.61
Mean SE			2.42	2.30	2.93	2.35
P			0.24	0.44	0.85	0.45

Table A.8 Heart girth measurements for Farm B with treatment by season interactions.

			Heart Girth (cm)			
Diet	Season	N	Birth	Week 4	Week 8	Total Gain
20/20 MR	Sept - Nov	6	71.69	74.93	77.00	5.31
20/20 MR	Dec - Feb	3	71.12	73.66	75.25	4.13
20/20 MR	Mar - May	3	70.46	75.46	82.13	11.67
28/20 MR	Mar - May	19	69.82	70.17	75.43	5.61
28/25 MR	Sept - Nov	5	74.74	77.79	79.93	5.19
28/25 MR	Dec - Feb	3	72.18	76.20	78.53	6.35
28/25 MR	Mar - May	3	73.59	76.80	85.23	11.64
Mean SE			2.25	2.86	3.03	2.79
P			0.43	0.88	0.72	0.64

Table A.9 Body length measurements for Farm B with treatment and season interactions.

			Body Length (cm)			
Diet	Season	N	Birth	Week 4	Week 8	Total Gain
20/20 MR	Sept - Nov	3	65.09	71.65	82.56	17.47
20/20 MR	Dec - Feb	6	65.03	81.44	83.35	18.32
20/20 MR	Mar - May	3	66.04	68.58	81.28	15.24
28/20 MR	Mar - May	19	63.98	70.78	81.36	17.38
28/25 MR	Sept - Nov	3	74.77	76.52	84.60	9.83
28/25 MR	Dec - Feb	5	66.68	72.39	77.95	11.27
28/25 MR	Mar - May	3	67.95	69.43	76.62	8.67
Mean SE			3.73	4.19	2.15	2.33
P			0.52	0.23	0.009	0.10

Table A.10 Hip width measurements for Farm B with treatment and season interactions.

			Hip Width (cm)			
Diet	Season	N	Birth	Week 4	Week 8	Total Gain
20/20 MR	Sept - Nov	3	14.87	19.42	19.37	4.50
20/20 MR	Dec - Feb	6	13.09	15.48	15.72	2.63
20/20 MR	Mar - May	3	13.34	13.34	14.61	1.27
28/20 MR	Mar - May	19	12.71	13.52	15.64	2.93
28/25 MR	Sept - Nov	3	16.27	18.74	19.05	2.78
28/25 MR	Dec - Feb	5	13.97	14.50	15.88	1.91
28/25 MR	Mar - May	3	12.01	13.23	13.76	1.75
Mean SE			0.86	0.83	1.08	0.89
P			0.34	0.74	0.83	0.38

Table A.11 Average daily gain for Farm C with treatment by week interactions.

Average Daily Gain (kg)									
Diet	N	1	2	3	4	5	6	7	8
20/20 MR	7	0.12	0.54	0.31	0.54	0.57	0.58	0.68	0.61
28/20 MR	5	0.06	0.31	0.23	0.39	0.71	0.61	0.79	0.64
Mean SE		0.52	0.01	0.05	0.19	0.18	0.16	0.25	0.29
P		0.86	0.13	0.58	0.24	0.26	0.81	0.46	0.86

Table A.12 Hip height measurements for Farm C with treatment by week interactions.

Hip Height (cm)					
Diet	N	Birth	Week 4	Week 8	Total Gain
20/20 MR	7	71.39	77.41	80.14	8.75
28/20 MR	5	69.41	78.04	81.14	11.73
Mean SE		1.52	1.04	1.07	1.59
P		0.38	0.68	0.91	0.31

Table A.13 Wither height measurements for Farm C with treatment by week interactions.

Wither Height (cm)					
Diet	N	Birth	Week 4	Week 8	Total Gain
20/20 MR	7	70.58	74.20	80.75	10.17
28/20 MR	5	62.64	73.61	79.44	16.80
Mean SE		4.64	1.18	1.03	1.13
P		0.26	0.73	0.41	0.51

Table A.14 Heart girth measurements for Farm C with treatment by week interactions.

Heart Girth (cm)					
Diet	N	Birth	Week 4	Week 8	Total Gain
20/20 MR	7	69.67	77.67	90.38	20.71
28/20 MR	5	68.20	76.52	87.76	19.56
Mean SE		1.42	2.21	1.17	2.79
P		0.48	0.72	0.17	0.91

Table A.15 Body length measurements for Farm C with treatment by week interactions.

Body Length (cm)					
Diet	N	Birth	Week 4	Week 8	Total Gain
20/20 MR	7	69.00	74.92	80.14	11.14
28/20 MR	5	69.60	79.76	81.28	11.68
Mean SE		2.07	2.25	3.01	2.92
P		0.84	0.17	0.81	0.51

Table A.16 Hip width measurements for Farm C with treatment by week interactions.

Hip Width (cm)					
Diet	N	Birth	Week 4	Week 8	Total Gain
20/20 MR	7	12.25	13.06	14.18	1.93
28/20 MR	5	12.07	13.21	15.5	3.43
Mean SE		0.22	0.36	0.82	0.65
P		0.56	0.78	0.30	0.07

Appendix B

Table B.1 Average daily gain for Holsteins with week by treatment interaction .

H X H Average Daily Gain (kg)								
Diet	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
20/20	0.07	0.07	-0.07	0.32	0.26	0.31	0.35	0.28
28/20	0.24	0.10	0.18	0.34	0.34	0.23	0.40	0.26
Mean SE	0.09	0.24	0.24	0.24	0.20	0.07	0.09	0.10
P	0.32	0.24	0.62	0.22	0.56	0.52	0.32	0.42

Table B.2 Average daily gain for Jerseys with week by treatment interactions.

J X J Average Daily Gain (kg)								
Diet	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
20/20	0.02	0.10	-0.10	0.15	0.52	0.21	0.22	0.14
28/20	0.14	0.22	-0.16	0.18	0.20	0.19	0.28	0.15
Mean SE	0.18	0.50	0.50	0.49	0.24	0.14	0.18	0.21
P	0.32	0.24	0.62	0.22	0.56	0.52	0.32	0.33

Table B.3 Average daily gain for crossbreds with week by treatment interactions.

Crossbred Average Daily Gain (kg)								
Diet	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
20/20	0.09	0.01	0.24	-0.06	0.21	0.23	0.23	0.40
28/20	0.13	0.26	0.16	0.24	0.25	0.28	0.26	0.12
Mean SE	0.21	0.56	0.56	0.55	0.28	0.16	0.20	0.23
P	0.42	0.24	0.62	0.22	0.56	0.54	0.32	0.41

Table B.4 Weekly calf starter intake by treatment, breed, and gender with treatment by week interactions.

Weekly Grain Intake (kg)								
Breed	20/20 Heifer	N	28/20 Heifer	N	20/20 Bull	N	28/20 Bull	N
HXH	4.79	13	4.88	9	2.68	9	2.64	8
JXJ	2.16	3	2.98	4	2.69	1	3.33	2
Crossbred	3.86	3	4.68	3	2.49	3	4.50	3
Mean SE	3.04		5.27		5.27		3.72	
P (effect of diet)	0.60							

Table B.5 Body length total gain by treatment and breed.

Total Gain of Body Length				
Breed	N	20/20 MR	N	28/20 MR
HXH	21	15.17	17	20.88
JXJ	4	14.61	6	15.03
Crossbred	11	13.97	10	14.89
Mean SE		2.60		2.70
P (effect of diet)		0.15		

Table B.6 Hip height total gain by breed and treatment

	Hip Height Total Gain (kg)			
	N	20/20	N	28/20
HXH	21	8.23	17	11.45
JXJ	4	13.13	6	10.80
Crossbred	11	8.44	10	10.16
Mean SE		1.61		2.28
P (diet)		0.003		

Table B.7 Wither height total gain by breed and treatment.

	Wither Height Total Gain (kg)			
	N	20/20	N	28/20
HXH	21	8.10	17	11.13
JXJ	4	10.43	6	10.29
Crossbred	11	8.20	10	9.41
Mean SE		1.37		1.95
P (diet)		0.02		

Table B.8 Heart girth total gain by breed and treatment.

	Heart Girth Total Gain (cm)			
	N	20/20	N	28/20
HXH	21	16.35	17	19.09
JXJ	4	13.17	6	18.54
Crossbred	11	15.35	10	19.14
Mean SE		1.93		2.73
P(diet)		0.01		

Table B.9 Weekly Hip width measurements by treatment.

		Weekly Hip Width (cm)								
Diet	N	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Total Gain
20/20 MR	37	12.71	13.11	13.35	13.82	14.30	14.78	15.10	15.69	2.93
28/20 MR	33	12.55	13.16	13.62	13.91	14.49	15.13	15.98	16.66	5.48
Mean SE		0.25	0.27	0.28	0.28	0.28	0.28	0.25	0.26	0.96
P (effect of diet)		0.67	0.90	0.48	0.83	0.63	0.36	0.01	0.01	0.11

Table B.10 Hip width gain by treatment.

		Hip Width Total Gain (cm)		
	N	20/20	N	28/20
HXH	21	4.16	17	4.54
JXJ	4	1.80	6	3.03
JXH	11	2.91	10	7.89
HXJ		2.85		6.45
Mean SE		0.79		1.13
P (diet)		0.11		

Table B.11 Average plasma urea nitrogen by treatment, breed, and gender.

PUN (mg/dl)								
Breed	20/20 Heifer	N	28/20 Heifer	N	20/20 Bull	N	28/20 Bull	N
HXH	11.73	13	12.53	9	10.27	9	13.18	8
JXJ	11.61	3	13.39	4	10.40	1	13.22	2
Crossbred	12.07	7	11.03	7	10.93	4	12.84	3
Mean SE	4.45		4.68		5.94		4.68	
P (effect of diet)	0.47							

Table B.12 Average plasma glucose by treatment, breed, and gender.

Plasma Glucose (mg/dl)								
Breed	20/20 Heifer	N	28/20 Heifer	N	20/20 Bull	N	28/20 Bull	N
HXH	91.44	13	101.86	9	82.41	9	100.04	8
JXJ	90.63	3	113.91	4	80.17	1	92.02	2
Crossbred	96.61	7	77.13	7	87.89	4	115.38	3
Mean SE	20.17		24.70		34.93		24.70	
P (effect of diet)	0.40							

Table B.13 Week 1 total plasma proteins by treatment, breed, gender.

Week 1 Total Proteins (mg/dl)								
Breed	20/20 Heifer	N	28/20 Heifer	N	20/20 Bull	N	28/20 Bull	N
HXH	28.19	13	26.04	9	33.2	9	30.11	8
JXJ	20.88	3	22.22	4	28.27	1	41.55	2
Crossbred	29.65	7	46.40	7	37.64	4	19.98	3
Mean SE	6.95		6.95		12.04		8.51	
P (effect of diet)	0.66							

Table B.14 Full stomach weights by breed and treatment.

Full Stomach (kg)				
Breed	20/20 MR	N	28/20 MR	N
H X H	8.37	9	8.48	8
J X J	7.41	1	7.56	2
Crossbred	6.45	4	6.77	5
Mean SE	2.47			
P	0.63			

Table B.15 Empty stomach weights by breed and treatment.

Empty Stomach (kg)				
Breed	20/20 MR	N	28/20 MR	N
H X H	2.84	9	2.60	8
J X J	2.50	1	2.67	2
Crossbred	1.84	4	2.02	5
Mean SE	1.21			
P	0.93			

Appendix C

Crossbred Study

Hip Width

Source	DF	Mean Square	F Value	Pr>F	
Trt	1	9.15	1.38	0.2454	
Breed	2	135.59	20.43	<.0001	
Trt X Breed	2	4.70	0.71	0.4969	
Gender	1	12.79	1.93	0.1707	
Trt X Gender	1	3.07	0.46	0.4992	
Breed X Gender	2	3.20	0.48	0.6198	
Trt X Gender X Breed	2	1.97	0.30	0.7449	
Calf (TBG)	55	6.64			
Week (HW)	7	437.31	62.47	84.99	<.0001
HW X Trt	7	11.58	1.65	2.25	0.0297
HW X Breed	14	21.85	1.56	2.12	0.0102
HW X Trt X Breed	14	5.89	0.42	0.57	0.8860
HW X Gender	7	9.50	1.36	1.85	0.0772
HW X Trt X Gender	7	3.40	0.49	0.66	0.7051
HW X Breed X Gender	14	6.90	0.49	0.67	0.8036
HW X Trt X Breed X Gender	14	16.85	1.20	1.64	0.0668
Error	385	282.98	0.74		

Grain Intake

Source	DF	Mean Square	F Value	Pr>F
Trt	1	371.61	10.60	0.0020
Breed	3	52.92	1.51	0.2226
Trt X Breed	3	182.71	5.21	0.0031
Gender	1	93.17	2.66	0.1090
Trt X Gender	1	18.58	0.53	0.4698
Breed X Gender	3	87.80	2.36	0.0816
Trt X Gender X Breed	1	28.45	0.81	0.3717
Calf (TBG)	53	35.05		
Week (GI)	7	1460.85	177.78	<.0001
GI X Trt	7	19.49	2.37	0.0221
GI X Breed	21	7.03	0.86	0.6500
GI X Trt X Breed	21	14.83	1.80	0.0169
GI X Gender	7	1.63	0.20	0.9856
GI X Trt X Gender	7	12.31	1.50	0.1666
GI X Breed X Gender	21	4.51	0.55	0.9489
GI X Trt X Breed X Gender	7	4.96	0.60	0.7530
Error	371	8.22		

Total Weight Gain

Source	DF	Mean Square	F Value	Pr > F
Trt	1	3984.82	34.18	<.0001
Breed	3	1250.72	10.73	<.0001
Gender	1	610.14	5.23	0.0263
Trt*Breed	3	478.29	4.10	0.0109
Trt*Gender	1	1.46	0.01	0.9112
Breed*Gender	3	188.62	1.62	0.1965
Trt*Breed*Gender	1	65.17	0.56	0.5752

Average Daily Gain

Source	DF	Mean Square	F Value	Pr > F
Trt	1	1.27	34.18	<.0001
Breed	3	0.40	10.73	<.0001
Gender	1	0.19	5.23	0.0263
Trt*Breed	3	0.15	4.10	0.0109
Trt*Gender	1	0.0005	0.01	0.9112
Breed*Gender	3	0.06	1.62	0.1965
Trt*Breed*Gender	1	0.21	0.56	0.5752

Body Weight

Source	DF	Mean Square	F Value	Pr>F
Trt	1	6999.66	29.27	<.0001
Breed	2	17907.64	74.88	<.0001
Trt X Breed	2	334.96	1.40	0.2556
Gender	1	378.28	1.58	0.2141
Trt X Gender	1	133.61	0.56	0.4582
Breed X Gender	2	172.21	0.72	0.4915
Trt X Gender X Breed	2	272.22	0.89	0.4179
Calf (TBG)	52	239.15		
Week (BW)	7	3153.76	550.36	<.0001
BW X Trt	7	104.98	18.32	<.0001
BW X Breed	14	53.13	9.27	<.0001
BW X Trt X Breed	14	10.58	1.85	0.1036
BW X Gender	7	15.53	2.71	0.0544
BW X Trt X Gender	7	3.60	0.63	0.5792
BW X Breed X Gender	14	3.82	0.67	0.6581
BW X Trt X Breed X Gender	14	2.60	0.45	0.8206
Error	364	5.73		

Body Length

Source	DF	Mean Square	F Value	Pr>F
Trt	1	647.70	5.04	0.0289
Breed	2	5058.91	39.40	<.0001
Trt X Breed	2	39.39	0.31	0.7371
Gender	1	204.60	1.59	0.2124
Trt X Gender	1	40.20	0.31	0.5782
Breed X Gender	2	14.72	0.11	0.8919
Trt X Gender X Breed	2	8.55	0.07	0.9357
Calf (TBG)	53	128.41		
Week (BL)	7	1272.21	163.18	<.0001
BL X Trt	7	11.39	1.46	0.1798
BL X Breed	14	18.40	2.36	0.0038
BL X Trt X Breed	14	10.07	1.29	0.2097
BL X Gender	7	8.40	1.08	0.3773
BL X Trt X Gender	7	5.43	0.70	0.6752
BL X Breed X Gender	14	12.91	1.66	0.0627
BL X Trt X Breed X Gender	14	17.69	2.27	0.0056
Error	371	7.80		

Plasma Urea Nitrogen

Source	DF	Mean Square	F Value	Pr>F
Trt	1	7.73	0.27	0.6135
Breed	2	18.48	0.64	0.6032
Trt X Breed	2	4.29	0.15	0.8639
Gender	1	98.84	3.40	0.0849
Trt X Gender	1	0.02	0	0.9790
Breed X Gender	2	0.80	0.03	0.9730
Trt X Breed X Gender				
Calf (TBG)	15			
Week PUN	7	50.81	2.83	0.0093
PUN X Trt	7	16.86	0.94	0.4788
PUN X Breed	14	5.45	0.30	0.9926
PUN X Trt X Breed	14	21.11	1.18	0.3028
PUN X Gender	7	60.52	3.37	0.0026
PUN X Trt X Gender	7	16.51	0.92	0.4936
PUN X Breed X Gender	14	13.79	0.77	0.7005
Error	112	17.94		

Hip Height

Source	DF	Mean Square	F Value	Pr>F
Trt	1	696.21	12.52	0.0008
Breed	2	3636.03	65.40	<.0001
Trt X Breed	2	124.12	2.23	0.1169
Gender	1	59.75	1.07	0.3045
Trt X Gender	1	207.26	3.73	0.0587
Breed X Gender	2	21.75	0.39	0.6781
Trt X Gender X Breed	2	225.17	4.05	0.0229
Calf (TBG)	55	55.60		
Week (HH)	7	546.82	204.24	<.0001
HH X Trt	7	7.86	2.94	0.0053
HH X Breed	14	2.18	0.82	0.6518
HH X Trt X Breed	14	3.19	1.19	0.2790
HH X Gender	7	1.45	0.54	0.8041
HH X Trt X Gender	7	4.80	1.79	0.0872
HH X Breed X Gender	14	1.59	0.59	0.8707
HH X Trt X Breed X Gender	14	3.79	1.42	0.1419
Errror	385	2.68		

Heart Girth

Source	DF	Mean Square	F Value	Pr>F
Trt	1	2913.16	30.47	<.0001
Breed	2	6445.18	67.41	<.0001
Trt X Breed	2	204.15	2.14	0.1281
Gender	1	108.74	1.14	0.2910
Trt X Gender	1	55.50	0.58	0.4494
Breed X Gender	2	103.17	1.08	0.3471
Trt X Gender X Breed	2	83.15	0.87	0.4249
Calf (TBG)	54	95.62		
Week (HG)	7	1517.76	300.25	<.0001
HG X Trt	7	27.53	5.45	<.0001
HG X Breed	14	3.50	0.69	0.7821
HG X Trt X Breed	14	1.52	0.30	0.9938
HG X Gender	7	10.42	2.06	0.0468
HG X Trt X Gender	7	4.70	0.93	0.4834
HG X Breed X Gender	14	12.46	2.46	0.0024
HG X Trt X Breed X Gender	14	7.80	1.54	0.0935
Error	378	5.05		

Plasma Glucose

Source	DF	Mean Square	F Value	Pr>F
Trt	1	14097.77	31.76	<.0001
Breed	2	2167.51	4.88	0.0233
Trt X Breed	2	500.23	1.13	0.3500
Gender	1	602.56	1.36	0.2622
Trt X Gender	1	16.84	0.04	0.8482
Calf (TBG)	15	443.87		
Week (PG)	7	1875.55	7.59	<.0001
PG X Trt	7	2957.95	11.97	<.0001
PG X Breed	14	1270.32	5.14	<.0001
PG X Trt X Breed	14	2398.65	9.71	<.0001
PG X Gender	7	130.53	0.53	0.8144
PG X Trt X Gender	7	367.39	1.49	0.1799
Error	105	247.11		

Wither Height

Source	DF	Mean Square	F Value	Pr>F
Trt	1	665.82	15.90	0.0002
Breed	2	3237.56	77.31	<.0001
Trt X Breed	2	71.06	1.70	0.1929
Gender	1	8.21	0.20	0.6598
Trt X Gender	1	182.25	4.35	0.0417
Breed X Gender	2	37.57	0.90	0.4137
Trt X Gender X Breed	2	169.63	4.05	0.0230
Calf (TBG)	54	41.88		
Week (WH)	7	419.30	248.25	<.0001
WH X Trt	7	8.70	5.15	<.0001
WH X Breed	14	3.52	2.08	0.0121
WH X Trt X Breed	14	1.35	0.80	0.6702
WH X Gender	7	2.45	1.45	0.1838
WH X Trt X Gender	7	1.29	0.76	0.6188
WH X Breed X Gender	14	2.17	1.29	0.2130
WH X Trt X Breed X Gender	14	1.79	1.06	0.3927
Errror	378	1.69		

Total Plasma Proteins

Source	DF	Mean Square	F Value	Pr>F
Model	13	357.22	2.46	0.0118
Error	48	144.98		
Corrected Total	61			
Week Trt	1	216.61	1.49	0.228
Breed	3	135.51	0.93	0.431
Gender	1	0.660	0.00	0.947
Trt*Breed	3	358.42	2.47	0.073
Trt*Gender	1	560.82	3.87	0.055
Breed*Gender	3	270.93	1.87	0.148
Trt*Breed*Gender	1	494.99	3.41	0.071

Carcass

Source	DF	Mean Square	F Value	Pr>F
Model	5	2.13.42	11.57	<.0001
Error	20	18.44		
Corrected Total	25			
Week Trt	1	820.31	9.34	0.0062
Breed	3	1562.66	17.80	<.0001
Trt*Breed	1	18.10	0..21	0.6548

Full Stomach

Source	DF	Mean Square	F Value	Pr>F
Model	5	3.24	3.19	0.0281
Error	20	1.02		
Corrected Total	25			
Week Trt	1	4.50	4.42	0.0484
Breed	2	5.04	4.95	0.0179
Trt*Breed	2	2.25	2.21	0.1357

Empty Stomach

Source	DF	Mean Square	F Value	Pr>F
Model	5	0.52	1.93	0.1333
Error	20	0.27		
Corrected Total	25			
Week Trt	1	0.55	2.04	0.1684
Breed	2	0.53	1.94	0.1694
Trt*Breed	2	0.66	2.44	0.1123

Liver

Source	DF	Mean Square	F Value	Pr>F
Model	5	0.19	2.44	0.07
Error	20	1.54	0.08	
Corrected Total	25	2.47		
Week Trt	1	0.30	3.90	0.0621
Breed	2	0.26	3.45	0.0517
Trt*Breed	2	0.005	0.06	0.9407

Full Intestines

Source	DF	Mean Square	F Value	Pr>F
Model	5	4.52	4.46	0.0068
Error	20	1.01		
Corrected Total	25			
Week Trt	1	55.26	10.58	0.0040
Breed	2	16.23	3.11	0.0496
Trt*Breed	2	0.53	0.10	0.7528

Empty Intestines

Source	DF	Mean Square	F Value	Pr>F
Model	5	1.26	4.65	0.0056
Error	20	0.27		
Corrected Total	25			
Week Trt	1	10.83	6.17	0.0219
Breed	2	4.58	2.61	0.0795
Trt*Breed	2	0.007	0.00	0.9514

Field Study

Farm A

Average Daily Gain

Source	DF	Mean Square	F Value	Pr > F
Trt	1	0.0009	0.06	0.8006
Season	2	0.01	0.73	0.4862
Trt*Season	1	0.01	0.78	0.3811
Gender	1	0.05	3.65	0.0625
Trt*Gender	1	0.002	0.11	0.7465
Season*Gender	1	0.00009	0.01	0.9380

Lbs of Gain

Source	DF	Mean Square	F Value	Pr > F
Trt	1	0.64	0.02	0.9003
Season	2	55.57	1.37	0.2645
Trt*Season	1	40.69	1.01	0.3218
Gender	1	139.69	3.45	0.0702
Trt*Gender	1	19.21	0.47	0.4947
Season*Gender	1	0.47	0.01	0.9148

Body Wt (BW)

Source	DF	Mean Square	F Value	Pr > F
Trt	1	42.75	0.33	0.5702
Season	1	164.49	1.27	0.2689
Trt X Season	1	193.56	1.49	0.2312
Gender	1	383.58	2.96	0.0956
Trt X Gender	1	0.28	0.00	0.9631
Gender X Season	1	31.27	0.24	0.6270
Calf (TSG)	31	129.81		
Week BW	7	716.96	153.98	<.0001
BW X Trt	7	4.85	1.04	0.4028
BW X Gender	7	5.75	1.24	0.2840
BW X Trt X Gender	7	0.57	0.12	0.9967
Error	238	4.66		

Body Length (BL)

Source	DF	Mean Square	F Value	Pr > F
Trt	1	22.74	0.60	0.4436
Season	1	50.80	1.35	0.2550
Trt X Season	1	107.12	2.84	0.1022
Gender	1	7.26	0.19	0.6640
Trt X Gender	1	57.21	1.51	0.2776
Gender X Season	1	0.02	0.00	0.9830
Calf (TSG)		31 37.77		
Week BL	2	725.40	96.29	<.0001
BL X Trt	2	22.98	3.05	0.0545
BL X Gender	2	33.50	4.45	0.0157
BL X Trt X Gender	2	49.18	6.53	0.0027
BL X Season	2	52.03	6.91	0.0020
BL X Trt X Season	2	1.07	0.14	0.8674
BL X Gender X Season	2	10.61	1.41	0.2523
BL X Trt X Gender X Season	0			
Error	62	7.53		

Hip Height (HH)

Source	DF	Mean Square	F Value	Pr > F
Trt	1	7.62	0.31	0.5812
Season	1	0.28	0.01	0.9158
Trt X Season	1	58.35	2.37	0.1317
Gender	1	81.92	3.33	0.0757
Trt X Gender	1	18.43	0.75	0.3922
Gender X Season	1	57.36	2.33	0.1349
Calf (TSG)	40	24.64		
Week HH	2	349.36	70.89	<.0001
HH X Trt	2	1.03	0.21	0.8122
HH X Gender	2	4.12	0.84	0.4375
HH X Trt X Gender	2	1.50	0.30	0.7381
HH X Season	2	1.06	0.22	0.8063
HH X Trt X Season	2	2.34	0.47	0.6241
HH X Gender X Season	2	1.01	0.20	0.8153
Error	80	4.93		

Wither Height (WH)

Source	DF	Mean Square	F Value	Pr > F
Trt	1	1.32	0.06	0.8099
Season	1	4.14	0.18	0.6701
Trt X Season	1	87.66	3.90	0.0554
Gender	1	63.88	2.85	0.0998
Trt X Gender	1	4.56	0.20	0.6548
Gender X Season	1	38.03	1.69	0.2009
Calf (TSG)	38	22.45		
Week WH	2	294.13	61.93	<.0001
WH X Trt	2	1.03	0.22	0.8047
WH X Gender	2	3.25	0.69	0.5071
WH X Trt X Gender	2	1.69	0.36	0.7023
WH X Season	2	2.29	0.48	0.6189
WH X Trt X Season	2	0.28	0.06	0.9437
WH X Gender X Season	2	0.42	0.09	0.9152
Error	76	4.75		

Heart Girth (HG)

Source	DF	Mean Square	F Value	Pr > F
Trt	1	9.37	0.27	0.6089
Season	1	26.38	0.75	0.3919
Trt X Season	1	201.79	5.73	0.0215
Gender	1	187.00	5.31	0.0265
Trt X Gender	1	50.95	1.45	0.2361
Gender X Season	1	59.24	1.68	0.2021
Calf (TSG)	40	35.21		
Week HG	2	1273.91	159.88	<.0001
HG X Trt	2	5.11	0.64	0.5294
HG X Gender	2	28.21	3.54	0.0336
HG X Trt X Gender	2	11.52	1.45	0.2415
HG X Season	2	6.61	0.83	0.4398
HG X Trt X Season	2	8.31	1.04	0.3572
HG X Gender X Season	2	1.01	0.13	0.8813
Error	80	7.97		

Hip Width (HW)

Source	DF	Mean Square	F Value	Pr > F
Trt	1	1.22	0.36	0.5567
Season	1	4.96	1.46	0.2441
Gender	1	0.95	0.28	0.6046
Calf (TSG)	17	3.41		
Week HW	2	2.64	2.92	0.0674
HW X Trt	2	0.49	0.54	0.5889
HW X Gender	2	0.92	1.02	0.3714
HW X Trt X Gender	2			
HW X Season	2	0.41	0.45	0.6414
HW X Trt X Season	2			
HW X Gender X Season	2			
HW X Trt X Gender X Season	0			
Error	34	0.90		

Farm B

Average Daily Gain

Source	DF	Mean Square	F Value	Pr > F
Trt	1	0.009	0.34	0.5805
Season	1	0.14	5.03	0.0660
Trt*Season	1	0.10	3.74	0.1012
Gender	1	0.004	0.16	0.7018
Trt*Gender	1	0.02	0.79	0.4095
Season*Gender	1	0.003	0.11	0.7497

Total lbs of Gain

Source	DF	Mean Square	F Value	Pr > F
Trt	1	37.34	0.34	0.5805
Season	1	551.34	5.03	0.0660
Trt*Season	1	409.84	3.74	0.1012
Gender	1	17.68	0.16	0.7018
Trt*Gender	1	86.05	0.79	0.4095
Season*Gender	1	12.22	0.11	0.7497

Body Wt (BW)

Source	DF	Mean Square	F Value	Pr > F
Trt	1	137.18	0.83	0.4037
Gender	1	2.73	0.02	0.9027
Trt X Gender	1	2.16	0.01	0.9137
Calf (TSG)	5	165.00		
Week BW	7	1035.91	94.20	<.0001
BW X Trt	7	9.77	0.89	0.5262
BW X Gender	7	4.16	0.38	0.9086
BW X Trt X Gender	7	15.54	1.41	0.2312
Error	35	11.00		

Body Length (BL)

Source	DF	Mean Square	F Value	Pr > F
Trt	2	20.90	0.63	0.5439
Season	2	54.27	1.64	0.2233
Trt X Season	2	70.10	2.12	0.1509
Gender	1	3.90	0.12	0.7355
Trt X Gender	1	0.19	0.01	0.9400
Gender X Season	1	6.55	0.20	0.6620
Calf (TSG)	17	33.10		
Week BL	2	670.00	39.31	<.0001
BL X Trt	4	53.44	3.14	0.0268
BL X Gender	2	6.63	0.39	0.6809
BL X Trt X Gender	2	28.36	1.66	0.2045
BL X Season	4	35.94	2.11	0.1013
BL X Trt X Season	4	17.68	1.04	0.4024
BL X Gender X Season	2	6.77	0.40	0.6753
BL X Trt X Gender X Season	0			
Error	34	17.05		

Hip Height (HH)

Source	DF	Mean Square	F Value	Pr > F
Trt	2	7.73	0.20	0.8189
Season	2	63.43	1.66	0.2197
Trt X Season	2	10.26	0.27	0.7679
Gender	1	13.98	0.39	0.5533
Trt X Gender	1	6.08	0.16	0.6950
Gender X Season	1	4.24	0.11	0.7431
Calf (TSG)	17	38.23		
Week HH	2	211.44	47.84	<.0001
HH X Trt	4	11.14	2.52	0.0592
HH X Gender	2	0.21	0.05	0.9532
HH X Trt X Gender	2	7.23	1.64	0.2097
HH X Season	4	7.38	1.67	0.1798
HH X Trt X Season	4	9.32	2.11	0.1010
HH X Gender X Season	2	4.20	0.95	0.3964
HH X Trt X Gender X Season	0			
Error	34	4.42		

Wither Height (WH)

Source	DF	Mean Square	F Value	Pr > F
Trt	2	27.81	0.97	0.3976
Season	2	30.86	1.08	0.3615
Trt X Season	2	6.62	0.23	0.7955
Gender	1	2.97	0.10	0.7511
Trt X Gender	1	2.55	0.09	0.7687
Gender X Season	1	0.05	0.00	0.9680
Calf (TSG)	11	28.55		
Week WH	2	195.92	51.30	<.0001
WH X Trt	4	11.39	2.98	0.0326
WH X Gender	2	0.59	0.16	0.8567
WH X Trt X Gender	2	8.01	2.10	0.1385
WH X Season	4	2.50	0.66	0.6273
WH X Trt X Season	4	17.27	4.52	0.0049
WH X Gender X Season	2	1.32	0.34	0.7109
Error	34	3.82		

Heart Girth (HG)

Source	DF	Mean Square	F Value	Pr > F
Trt	1	60.14	1.86	0.1994
Season	1	5.02	0.16	0.7008
Trt X Season	1	5.69	0.18	0.6826
Gender	1	6.05	0.19	0.6732
Trt X Gender	1	12.99	0.40	0.5387
Calf (TSG)	11	3.2.26		
Week HG	2	244.23	40.15	<.0001
HG X Trt	2	4.34	0.71	0.5011
HG X Gender	2	0.19	0.03	0.9699
HG X Trt X Gender	2	19.28	3.17	0.0617
HG X Season	2	10.73	1.76	0.1949
HG X Trt X Season	2	8.72	1.43	0.2598
HG X Gender X Season	2			
Error	22	6.08		

Hip Width (HW)

Source	DF	Mean Square	F Value	Pr > F
Trt	2	5.06	1.45	0.2755
Season	2	33.27	9.56	0.0039
Trt X Season	2	0.69	0.20	0.8229
Gender	1	1.27	0.36	0.5581
Trt X Gender	1	0.12	0.03	0.8575
Calf (TSG)	11	3.48		
Week HW	2	37.30	54.25	<.0001
HW X Trt	4	0.13	0.19	0.9411
HW X Gender	2	1.34	1.95	0.1659
HW X Trt X Gender	0			
HW X Season	4	4.54	6.61	0.0012
HW X Trt X Season	4	1.34	1.95	.01375
HW X Gender X Season	2	2.55	3.71	0.0408
Error	22	0.69		

Farm C

Average Daily Gain

Source	DF	Mean Square	F Value	Pr > F
Trt	1	0.15	3.38	0.0957

Lbs of Gain

Source	DF	Mean Square	F Value	Pr > F
Trt	1	610.92	3.38	0.0957

Body Weight

Source	DF	Mean Square	F Value	Pr > F
Trt	1	12.56	0.12	0.7508
Calf (Trt)	4	108.44		
Week (BW)	7	429.10	309.21	<.0001
BW X Trt	7	0.43	0.31	0.9439
Error 28	1.39			

Body Length

Source	DF	Mean Square	F Value	Pr > F
Trt	1	15.60	0.63	0.4846
Calf (TRT)	3	24.67		
Week (BL)	2	252.01	5.88	0.0385
BL X Trt	2	2.76	0.06	0.9383
Error	6	42.85		

Hip Height

Source	DF	Mean Square	F Value	Pr > F
Trt	1	1.03	0.05	0.8328
Calf (trt)	6	21.09		
Week (HH)	2	260.82	50.72	<.0001
HH X Trt	2	0.11	0.02	0.9785
Error	12	5.14		

Wither Height

Source	DF	Mean Square	F Value	Pr > F
Trt	1	28.67	0.28	0.6136
Calf (trt)	6	101.15		
Week (WH)	2	370.73	6.17	0.0144
WH X Trt	2	32.09	0.53	0.53
Error	12	560.09		

Heart Girth

Source	DF	Mean Square	F Value	Pr > F
Trt	1	28.67	0.28	0.6136
Calf (trt)	6	101.15		
Week (HG)	2	878.05	118.65	<.0001
HG X Trt	2	13.76	1.86	0.1979
Error	12	7.40		

Hip Width

Source	DF	Mean Square	F Value	Pr > F
Trt	1	0.59	0.77	0.6248
Calf (trt)	6	2.21		
Week (HW)	2	14.42	16.61	0.0003
HW X Trt	2	1.43	1.65	0.2331
Error	12	0.87		

Vita

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