Jersey Calf Management, Mortality, and Body Composition.

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(Abstract)

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In experiment one, week old Jersey bull calves (n=39) were assigned to one of four diets: 21/21 (n=8), 27/33 (n=8), 29/16 (n=9), MILK; or a baseline sacrifice group (n=6). Diets 21/21, 27/33, and 29/16 were milk replacers containing 21, 27, or 29% CP, and 21, 33, and 16% fat, respectively. Diet 21/21 was fed at 15% of BW. Diets 27/33, 29/16, and MILK supplied 180g CP/d. Calves were fed 4 wk. Weight, hip height, wither height, heart girth, and body length were measured weekly. Weekly plasma samples were analyzed for PUN, NEFA, and glucose. Calves were processed to estimate body composition. Feed efficiency and ADG were greatest for calves fed MILK**,** least for calves fed 21/21, and intermediate for calves fed 29/16 and 27/33. Calves fed 27/33 or MILK had the greatest gains of fat and percentage fat in the empty body. Body fat percentage of calves fed 29/16 or 21/21 was not changed by diet**.** Performance of calves fed 27/33 and 29/16 was similar except that calves fed 29/16 were leaner and calves fed 27/33 had a propensity for elevated NEFA. Feeding 180g of CP in the MR was beneficial to calf performance compared with diet 21/21.
In experiment two, tissues from a subset of calves [21/21 (n=4), 27/33 (n=5), 29/16 (n=5), MILK (n=3), baseline (n=2)] were scanned using dual energy x-ray absorptiometry to estimate mass, fat, CP, and ash. Liver, organ, and carcass mass by DXA were correlated to scale weights (R^2= 0.99, 0.62, and 0.79, respectively). DXA was a poor predictor of percentage fat, CP, and ash (adjusted R^2 <0.10).
Experiment three determined level of calf mortality in the United States; and identified opportunities to reduce mortality. Herds (n=88) were representative of the US Jersey population. Production averaged 7180 ±757 kg milk annually. Herds averaged 199 births annually. Mortality was 5.0% from birth to 24 h (M24) of life and 6.7% from 24 h to 3 mo of life (M3). Level of mortality (M24) was highest in herds that calved on pasture. Lower levels of mortality (M3) were associated with use or maternity pens and earlier weaning

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Chapter One

Introduction

Interest in Jerseys and Jersey calves appears to be increasing. The American Jersey Cattle Association (AJCA) has reported a record high number of registrations; more than 70,000/yr, over the last 2 yr indicating an increase in participation in Jersey breed programs. Participation in breed programs serves as an indirect indicator of a strong demand for Jersey cattle, which increases the market value of Jersey calves. Therefore, as demand for Jersey cattle increases more emphasis is placed on practices that enhance calf performance and/or reduce calf mortality.

In 1992 and 1996, the National Animal Health Monitoring Service (NAHMS) released the results of national surveys of calf management practices and mortality. The mean death loss of calves between birth and weaning was reported to be 8.4 and 11.4% in 1993 and 1996, respectively. These surveys were comprehensive and represented 78% of the dairy herds in the US but only 2.4% of the herds surveyed were Jersey herds. The Jersey calf is unique due to its smaller frame size, lighter birth weight, and genetics. Therefore, the NAHMS surveys do not necessarily represent reliable information on Jersey calves, and surveying management practice in Jersey herds is merited.

In addition to surveying management practices, intensive feeding trials designed to elucidate the specific nutrient requirements of Jersey calves might yield information that could be used to design feeding programs specifically for Jersey calves. Recently, intensified calf feeding programs have been developed for Holstein calves. These programs are designed to improve feed efficiency, ADG, and promote lean tissue growth. Calves fed intensive feeding programs are often encouraged to consume milk replacer at 15% of their body weight. Feeding calves aggressively may result in improvements in future milk yield. Researchers in Israel and Denmark reported

feeding black and white (Holstein or Holstein crosses) calves at or near ad lib intake during the first 6 wk of life increased first lactation milk yield, decreased age at first calving, and increased BW at calving. The mechanisms by which feeding calves more liberally improves their lactation potential are unclear but may be related to changes in mammary tissue development and lean frame size. The results of these studies have led researchers to reconsider conventional calf feeding programs that limit-feed milk to calves.

Special milk replacers formulations have been developed for use in intensified feeding programs. These milk replacers are typically 28 to 30% CP and 16 to 20% fat. Whole cows milk typically contains 25 to 30% CP on a DM basis. The nutrient composition of these diets is designed to promote efficient gains in lean body tissue. Therefore, the higher level of CP in milk replacers that are fed near ad lib intake would appear to have merit. However, these programs may not be applicable to Jersey calves due to breed differences in BW, frame size, and metabolic BW.

Objectives:

The objectives of the experiments described in this work were:

1) To examine the relationship between dietary protein and energy and growth, body composition, protein retention, energy utilization, and feed efficiency in Jersey bull calves.
2) To investigated the potential usefulness of dual energy X-ray absorptiometry to estimate body composition.
3) To characterize management practices associated with calf mortality.
4) To identify differences in heifer management practices by level of milk production.
5) To assess the relationship between region of the country, herd size, level of production, and other management practices with calf mortality.

6) To identify opportunities for improvements in Jersey calf and heifer management.

Organization

The first experiment was designed to address objectives that focused on the impact of nutrition on body composition and growth. The second experiment was designed to evaluate the effectiveness of DXA in evaluating body composition. The final study was designed to focus on objectives that dealt with Jersey calf management and mortality.

Chapter 2 is a discussion of the literature related to calf nutrition, body composition, the impact of nutrition on body composition, and methods of evaluating body composition in calves.

Chapter 3 contains a review of survey data that was collected to evaluate management, nutrition, mortality, and other calf management practices on dairy farms in the United States.

Chapter 4 is organized in two sections. The first section reviews the materials and methods utilized in experiments 1 and 2 to evaluate growth and body composition of calves fed differ levels of fat and protein. The second section details the materials and methods used in surveying Jersey herds in the US to collect data on calf management, nutrition, and mortality.

Chapter 5 discusses the influence of dietary fat and protein on body composition.

Chapter 6 examines the usefulness of DXA for evaluating composition in calves.

Chapter 7 describes the management of Jersey calves in the United States.

Chapter 8 summarizes the key findings in all experiments.

Chapter Two
Diets for Preweaned Calves

Growth and development

Growth and development are complex phenomena that begin at conception and continue until maturation and are unique but interrelated. Batt (1980) defined growth as quantitative changes in the body while development expresses qualitative changes. More specifically, growth involves an increase in body size including increases in BW, heart girth, volume, or stature. Development encompasses changes in shape, conformation, or function of tissues. In a review of growth and development of ruminants, Owens et al. (1993) explained the primary mechanisms of growth as 1) hyperplasia, the accumulation of new cells; and 2) hypertrophy, the enlargement of cells. Growth and development can be categorized into several unique periods including prenatal, neonatal, prepubertal, pubertal, and post pubertal. Each of these phases is distinct and involve metabolic processes that vary considerably as the animal moves through these stages.

During prenatal development, all of the organism's cells grow by hyperplasia, but post-natally, the majority of growth occurs by hypertrophy (Owens et al., 1993). In humans, cells divide 42 times before birth, but only five times from birth to maturity (Batt, 1980). A similar observation has been made in rats. In late gestation, the prenatal rat may increase the number of new cells produced by as much as 60% per day; just prior to birth, the rate of new cells produced drops to 20%, and at puberty the rate of new cell production is only 2% per day (Hafez and Dyer, 1969). The function of cell division in adults is considerably different from prenates; in the mature animal new cells are produced at a steady but slow rate to maintain cell numbers by replacing cells that are lost (Hafez and Dyer, 1969).

The literature is replete with information regarding growth in various stages of life of the bovine. However, the remainder of this treatise will focus primarily on nutritional and management factors, and their effect on growth and development in the calf. The definitions of growth provided previously explain this phenomenon in a broad sense, but the following explanation of growth is narrower and more directly applicable; "Growth and development occur in the neonate when the input of nutrients to the organism is more than enough to make good the losses incurred in the dissipation process. This excess fills out the organism through the building up of an elaborate internal organization composed of cellular subunits. Materials and energy made available for growth are used to produce new cells, to fill out old cells or to create extracellular material like fat." (Calow, 1978).

Milk composition as a means of estimating nutrient requirements of the neonate

All neonatal mammals depend on their dams to ingest and convert nutrients that are not readily digestible by the neonate to a highly digestible source of nutrients, i.e., milk. The degree of reliance on lactation to provide nutrients varies considerably from species to species. For example, the American Association of Pediatrics (1997) discouraged weaning breast-fed human infants before 12 mo of age; on the other hand, calves can be weaned successfully as early as 6 wk of age (Davis and Drackley,1998). The difference in weaning age between species is related to the species ability to consume nutrients from sources other than milk (Jenness, 1985). Studying the nutrient composition of milk can provide valuable insight into the nutrient requirements of the neonate during the period of its life when the dam's milk is the primary source of nutrition.

Jenness (1985) stated, "The biological function of milk is to supply nutrition and immunological protection to the young mammal." Therefore, understanding the composition of milk is a logical starting point to understanding the nutrient needs of the neonate. The composition of milk from several different species is shown in

Table 2.1. Species such as the dolphin, fur seal, and bear produce milk with a high caloric density, which is achieved by synthesizing milk that contains a high concentration of fat and a low concentration of lactose. These species live in habitats that require them to expend a great deal of energy for maintenance. Maintenance energy requirements are influenced by the physiological stage at birth, i.e., species where the neonate becomes ambulatory soon after birth are less dependent on their dams than species where the neonate does not become ambulatory soon after birth. In the case of the dolphin and the seal, a high proportion of the neonate's caloric intake is expended to maintain a constant body temperature. On the other hand, species such as the horse and the red kangaroo produce milk with relatively low caloric density, and their milk has a low concentration of fat but a high concentration of lactose. The foal is able to begin consuming roughages soon after birth and is less dependent on milk to provide its caloric needs. The red kangaroo lives in a warm habitat, resides in its dam's pouch, and requires less energy for thermoregulation. Milk composition also varies within a species (Table 2.2). Possibly, intra-species variation in milk indicates differences in neonatal nutrient requirements of for different breeds. For example, Jersey and Guernsey calves may have higher maintenance energy requirements and thus require a more energy-dense diet than calves of the Holstein or Ayrshire breed, as indicated by the breed differences in milk composition.

Table 2.1. Composition of milk of various species.

Species	Percentage by weight						Energy (kcal/100g)
	Water	Fat	Casein	Whey Protein	Lactose	Ash	
Red kangaroo	80.0	3.4	2.3	2.3	6.7	1.4	76
Human	87.1	4.5	0.4	0.5	7.1	0.2	72
Rabbit	67.2	15.3	9.3	4.6	2.1	1.8	202
Gray squirrel	60.4	24.7	5.0	2.4	3.7	1.0	267
Rat	79.0	10.3	6.4	2.0	2.6	1.3	137
Dolphin	58.3	33.0	3.9	2.9	1.1	0.7	329
Black bear	55.5	24.5	8.8	5.7	0.4	1.8	280
Fur seal	34.6	53.3	4.6	4.3	0.1	0.5	516
Indian elephant	78.1	11.6	1.9	3.0	4.7	0.7	143
Horse	88.8	1.9	1.3	1.2	6.2	0.5	52
Pig	81.2	6.8	2.8	2.0	5.5	1.0	102
Camel	86.5	4.0	2.7	0.9	5.0	0.8	70
Reindeer	66.7	18.0	8.6	1.5	2.8	1.5	214
Cow (*bos taurus*)	87.3	3.9	2.6	0.6	4.6	0.7	66
Cow (*bos indicus*)	86.5	4.7	2.6	0.6	4.7	0.7	74
Water buffalo	82.8	7.4	3.2	0.6	4.3	0.8	70
Goat	86.7	4.5	2.6	0.6	4.3	0.8	70
Sheep	82.0	7.2	3.9	0.7	4.8	0.9	102

Adapted from Jenness (1985).

While species and breeds vary in the concentration of many nutrients in their milk the osmolality of milk is almost always maintained at 0.3 *M*, regardless of species or breed (Jenness, 1985). The osmolality of blood is also 0.3 *M*. Similarities in the osmolality of blood and milk are not coincidental. If a difference existed between the osmolality of milk and blood, then an osmotic gradient would be created during digestion and fluid would tend to flow between blood and milk in an attempt to achieve equilibrium. If the osmolality of milk favored the flow of water from blood to milk, then the electrolyte balance might be upset, which could result in dehydration.

However, the similar osmolality of blood and milk prevents the flow of fluid from capillaries to the lumen of the intestine and thus prevents dehydration.

Table 2.2. Composition of milks of five breeds of dairy cattle.

	Mean percentage by weight					
Breed	Total solids	Fat	Casein	Whey protein	Lactose	Ash
Ayrshire	12.69	3.97	2.68	0.60	4.63	0.72
Brown Swiss	12.69	3.80	2.63	0.55	4.80	0.72
Guernsey	13.69	4.58	2.88	0.61	4.78	0.75
Holstein	11.91	3.56	2.49	0.53	4.61	0.73
Jersey	14.15	4.97	3.02	0.63	4.70	0.77

(Reinart and Nesbitt, 1956) as sited by Larson (1985).

Understanding the composition of milk allows one to make a qualitative assessment of the nutrient needs of the neonate. Based on the composition of cow's milk, we can infer that calves require a diet that has approximately 3.9 to 5.0% fat, 3.2% CP, 4.6% lactose, and less than 1% mineral on an as fed basis. However, one needs to consider both the qualitative and quantitative aspects of neonatal nutrition when determining the nutrient requirements of the neonatal calf. If a calf were nursing its dam, the composition and the quantity of milk produced would provide the essential nutrients that the calf requires to maintain its body and grow. Thus, examining the composition of milk without considering the quantity of milk that the suckling calf consumes has some shortcomings in defining the specific nutrient requirements of the calf.

Two factors determine the intake of milk in suckling animals: 1) level of milk production of their dam; and 2) the ability of the neonate to consume milk. Milk production of a cow is dictated by a wide variety of factors including her plane of nutrition, environmental conditions, and genetics. Advances in nutrition, management, and genetics allow most dairy cows to produce far more milk than their calves can consume. Therefore, the ability of the calf to consume milk would be the limiting factor if dairy calves were allowed to suckle their dams. Bar-Peled et al.

(1997) allowed Holstein calves to suckle their dams for 15 min twice per day until they were 6 wk old; these calves had an average intake of 17 L/calf per day. Lineweaver and Hafez (1969) fed Holstein and Hereford calves a milk replacer (MR) that was reconstituted to either 6.5 or 19.5% solids. Milk replacer was delivered using an automated nursing station, and calves were fed 4 times daily or allowed ad lib intake. Calves allowed ad lib intake of the MR reconstituted to 19.5% solids had the greatest DMI (3.25%) as a percentage of BW, greatest ADG, ADG as a percentage of initial BW, and the greatest feed efficiency (Table 2.3). There is considerable debate in the contemporary literature over the appropriate level of intake for dairy calves which are raised as replacement heifers. Traditionally, dairy calves have been limit fed the liquid portion of their diet to encourage the intake of dry calf starter. However, more recently it has been suggested that preweaned calves may benefit by consuming liquid at near ad lib intake (Drackley, 2001).

Table 2.3. Effect of DM composition and feeding method on milk replacer consumption and body weight gain in calves.

Breed	Hereford		Holstein				
Number of calves	6	7	6	6	4	4	
Dry matter, % of diet	6.5	19.5	6.5	6.5	19.5	19.5	
Feeding method	ad lib	ad lib	ad lib	4 times/day	ad lib	4 times/day	SEM
DMI, kg/day	0.83[d]	1.06[bcd]	1.27[abc]	0.86[cd]	1.45[a]	1.27[abc]	0.11
ADG, kg	0.49[c]	0.55[bc]	0.72[ab]	0.54[bc]	0.87[a]	0.87[a]	0.06
Efficiency, kg dm/kg gain	1.68[a]	1.90[a]	1.78[a]	1.58[a]	1.65[a]	1.47[a]	0.06
Daily consumption, % initial body weight	2.60[bc]	3.10[ab]	2.50[c]	2.04[d]	3.25[a]	3.03[abc]	0.34
Daily gain, % initial body weight	1.55[abc]	1.61[ab]	1.40[bc]	1.30[c]	1.96[a]	2.07[a]	0.40

[abcd]Means with similar superscripts are not statistically significant at $P<0.05$.

Adapted from Lineweaver and Hafez (1969).

Digestive anatomy and physiology of the preweaned calf

Understanding the basic digestive anatomy and physiology of the calf is indispensable to understanding the nutrient requirements of the calf. The anatomy and physiology of the digestive system of the newborn calf differs from mature ruminants.

Digestion in the young calf is more like that of a monogastric than a ruminant. The young calf requires more digestible diets than mature ruminants because the young calf lacks the digestive apparatus required for digestion of forages and roughages. The rumen is the dominant compartment of the stomach and the abomasum makes up less than 12% of the weight in the mature animal, but the abomasum accounts for 50% of the weight of the newborn calf's stomach tissue. Consumption of dry feed with a high potential for fermentation to volatile fatty acids (VFA) encourages an increase in volume of the forestomach of neonates with a corresponding increase in tissue weight, musculature, and absorptive capacity (Brownlee, 1956; Warner and Flat, 1965; Warner et al., 1956; Huber, 1969).

A calf experiences three distinct phases in digestive tract development (NRC, 1989). Phase one is the preruminant phase. During this phase, the calf's diet consists of highly digestible liquid feeds. The preruminant calf can digest energy in the form of fat and lactose but is not capable of digesting starch, cellulose, or hemicellulose, and the calf requires a high quality protein source. Milk protein sources are optimum. The second phase of rumen development is a transitional phase in which the calf is consuming both liquid and dry feeds and the beginning to digest plant proteins, starch, cellulose, hemicellulose, and to synthesize B-complex and K vitamins. However, in this phase the calf still requires a highly digestible liquid source of nutrients until its rumen becomes fully developed and efficient at digesting fiber, starch, cellulose, and hemicellulose. The final phase is the ruminant phase in which the rumen is fully developed and capable of digesting roughages.

Estimates of the nutrient requirements of calves

A combined understanding of the bovine digestive anatomy and physiology of the calf and the composition of milk are helpful in understanding the precepts of dairy calf nutrition. However, a much more detailed description of nutritional requirements of the calf can be found in the Nutrient Requirements of Dairy Cattle (NRC) (1989, 2001) recommendations for feeding dairy cattle as well as the NRC (2000) recommendations for feeding beef cattle. In the sections that follow, the NRC recommendations for feeding dairy calves and the foundations on which these recommendations are built will be discussed and evaluated.

Energy requirements and the role of dietary fat

Energy requirements of the calf are not easily established. The calf partitions energy in the diet into that used for maintenance and growth. Brody (1945) reported that fasting metabolism must be measured to determine energy required for maintenance. To measure fasting metabolism, the animal is fasted 15 h, housed in a thermoneutral environment, and physical activity is limited. When these conditions are met, then the heat production of the animal can be measured and quantity of heat produced by the animal is indicative of maintenance cost of the animal (Davis and Drackley, 1998). The heat produced by the fasting animal represents the energy expended for maintenance, which includes energy required to support circulation, respiration, excretion, and muscle tension (Brody, 1964). Dietary energy in excess of the calf's maintenance energy expenditure is available for growth. Energy used for growth is utilized in synthesis of protein, fat, or bone mineral tissue. Estimates of energy used for growth can be obtained by measuring growth in the animal and composition of tissue gained. Determining composition of gain requires accurate estimates of body composition of the animal.

Determining how the animal partitions energy can be difficult, but determining the quantity of energy available in a feedstuff can be equally difficult. The Dairy NRC (2001) and the Beef NRC (2000) express the energy requirements of the calf in terms of ME; however, net energy for gain (NE_g) and maintenance (NE_m) are given in the tables.

The equations used to calculate the daily energy requirements for calves fed milk or MR are shown below:

NE_m (Mcal)= $0.086\ LW^{0.75}$

where LW = live weight in kg. (1)

NE_g (Mcal) = $(0.84\ LW^{0.355} \times LWG^{1.2}) \times 0.69$

where LWG = live weight gain in kg. (2)

ME (Mcal) = $0.1\ LW^{0.75} + (0.84\ LW^{0.355} \times LWG^{1.2})$ (3)

DE (Mcal) = ME/0.96 (4).

Equation (1) assumes that the fasting calf produces heat that is equivalent to 86 kcal/kg of metabolic BW. This equation was adopted by the Dairy NRC (1989, 2001) and has validated by several researchers (Roy et al., 1957; Johnson and Elliot, 1972; Scharma, 1993; Holmes and Davey, 1976). Equation (2) contains the portion of the Toullec (1989) equation, i.e. equation (3), which accounts for growth and assumes an efficiency of metabolizable energy (ME) used for growth of 69%. Equation (3) accounts for both maintenance and gain. The efficiency of use of ME from milk or MR is 86%, therefore the portion of equation (3) that accounts for maintenance energy is equally to equation (1) divided by 0.86. The second portion of equation (3) determines the energy required for growth in terms of live weight (LW) and live weight gain (LWG). Equation (4) assumes the conversion of digestible energy (DE) to ME is 96% efficient.

These equations are the basis for establishing the required caloric intake of a calf at a given weight and a given target rate of gain when the calf is housed in a thermoneutral environment. The thermoneutral zone is the range of temperatures in which the heat production of the calf is relatively constant (Davis and Drackley, 1998). 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 to be 15-25°C for young calves, but older calves have a lower critical temperature between –5 to –10°C (NRC, 2001). However, the critical lower temperature can be more accurately calculated using the equation Gonzalez-Jimenez and Blaxter (1962) developed:

$$T\ (°C) = 13.7 - 0.315\ (\text{age in d})^2 \quad (5)$$

Equation (5) indicates that the calf's lower critical temperature is a function of age. When ambient temperature falls below this lower critical temperature then average daily gain (ADG) will decline unless the caloric intake is increased by increasing level of intake or supplementing the diet with additional fat.

The appropriate level of dietary fat for young calves is a subject of debate. Scibilia et al. (1986) assigned 36 Holstein bull calves to a 2 (-4°C or 10°C ambient temperature) x 3 (10, 17.5, 25% fat MR) factorial design experiment. Calves assigned to the -4°C treatments had significantly lower ADG than calves assigned to the 10°C treatments but calves fed higher fat MR increased ADG. However, at 10°C, ADG was not different for the calves fed 17.5% fat and 25% fat diets, indicating that there is little benefit in weight gain of feeding Holstein bull calves MR with more than 17.5% fat.

Jaster et al. (1990) fed calves liquid diets at 9% of BW. The diets were whole milk, whole milk plus 113g of fat supplement, MR, or MR plus 113g of fat supplement. Calves were born between December and April when average minimum daily temperature ranged from -8.6°C in January to 4.7°C in April. The milk was 25.2% CP and 27.6% fat on a DM basis. Milk replacers contained 21% CP and 20% fat on DM basis. The fat supplement contained 7% CP and 60% fat on a DM basis. Calves fed the diets containing supplemental fat had greater gains from d 3 to 28 and consumed more solids than calves that were not supplemented with fat, indicating that the increasing the fat content of the diet is beneficial in cold weather.

The increased nutrient requirements of calves in cold environments can also be met by increasing DMI. Schingoethe et al., (1986) fed Holstein calves born between October and March and housed in calf hutches 3.6 kg/d of whole milk (0.45 kg of solids), 3.6 kg/d of whole milk plus 113g of a whey-fat blend (0.56 kg of solids), or 4.5 kg/d of whole milk (0.56 kg of solids). Diets were fed in either one or two feedings daily. Average minimum temperature during the experiment was -18°C. Composition of milk fed was

26.3% CP and 32.5% fat on a DM basis. The whey-fat blend was 8.5% CP and 25% fat on a DM basis. Calves were weaned at 6 wk of age. Calves fed 0.56 kg of solids per d had greater weight gains than calves fed 0.46 kg of solids per d. Calves fed twice daily had superior weight gains to calves fed once daily. The researchers concluded that feeding higher levels of DM during cold weather was essential for optimum growth.

Feeding supplemental fat can also reduce the incidence of scours. Fowler (1993) reported increased feed efficiency and decreased incidence of scours when level of dietary fat increased in isonitrogenous diets. Numerically, optimum feed efficiency and fecal scores were obtained when calves were fed diets containing 20% or more fat, as shown in Table 2.4.

Table 2.4. Effect of fat level in a 22% protein milk replacer on growth, feed conversion and fecal score.

	Fat Level					
	0%	5%	10%	15%	20%	25%
ADG, lb.	1.07[a]	1.17[a]	1.17[a]	1.13[a]	1.25[a]	1.33[a]
Feed/lb gain	1.92[a]	1.56[ab]	1.56[ab]	1.58[ab]	1.43[b]	1.36[b]
Fecal score[A]	1.76[a]	1.54[ab]	1.45[bc]	1.39[bc]	1.23[c]	1.23[c]

[abc]Means with different superscripts differ (P<. 05).

[A]lower numbers indicate lower severity. As cited by Fowler (1993).

Calves fed milk replacers with higher levels of fat deposit more body fat (Gerrits et al., 1996; Donnelly and Hutton, 1976b) and increased body fat could be beneficial to the calf in periods of stress (Davis and Drackley, 1998). The most recent NRC (2001) report states, “Research data on optimal concentrations of fat in milk replacers are conflicting.” Due to their smaller size, it is feasible to assume that Jersey calves might 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 are likely to use more energy to maintain body temperature.

Protein requirements in the calf and the role of dietary protein

Protein is a critical component of the diet of the young calf. Amino acid requirements of the calf are not well defined and are expressed in terms of nitrogen (Davis and Drackley, 1998). Level of CP in milk or MR, containing proteins derived from milk can be calculated by multiplying the level of nitrogen (N) in the diet by 6.38 (NRC, 2001).

The Dairy NRC (2001) adopted the apparent digestible protein system (ADP) for estimating the calf's requirement for dietary protein developed by Roy (1970) and calculated using the factorial method of Blaxter and Mitchell (1948).

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

where BV = the biological value of the protein;

E = endogenous urinary N;

G= N in gain;

M = fecal N;

and D = DM intake. (6)

The Dairy NRC (2001) sets BV at 80% for milk derived proteins, E is set at 0.2 g/kg of metabolic BW, G is set at 30 g N/kg of LWG, M is set at 1.9 g/kg dm, and D is DM intake in kg. The estimate of BV is based on the assumption that efficiency of N use for growth above maintenance is 80% when the milk proteins are the source of N in the diet (Donnelly and Hutton, 1976b). Estimates of urinary nitrogen and nitrogen in gain are in agreement with values reported in the literature by (Blaxter and Wood, 1951; Roy, 1970). Estimates of metabolic fecal nitrogen are based on the work of Roy (1980).

While components of the ADP equation (6) seem complex, the equation effectively partitions dietary intake protein into maintenance or gain. This system of evaluating protein requirements for the calf is more useful than the CP requirements recommended

by the 1989 Dairy NRC, which expresses the calf's requirement for protein as CP but does not attempt to estimate the portion of dietary protein that is utilized for maintenance and gain. Developing a system for accurately estimating the requirement of amino acids for calves would be an improvement over the ADP system. However, it is likely that the calf's requirement for amino acids is very similar to the amino acid profile in milk proteins. Therefore, if the calf is fed a diet in which the protein sources are milk proteins, milk proteins derivatives, or from other protein sources that have an amino acid profile similar to milk then the ADP system is an adequate system for indirectly estimating the amino acid requirements of the calf.

Dietary protein is essential for growth and development of a wide variety of tissues. Several researchers (Diaz et al., 2001; Gerrits et al., 1996; Donnelly and Hutton, 1976b) have demonstrated that level of dietary protein significantly impacts body composition. Altering the ratio of protein to energy in the diet influences body composition of preweaned calves. Davis and Drackley (1998) recommend that MR powder contain between 18 and 24% CP. However, the appropriate level of CP in the diet depends on the level of intake and energy supplied (Davis and Drackley, 1998). 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. This concept is demonstrated in Table 2.5. At low levels of intake, a MR with 20% CP and 20% fat supplies enough energy and protein to support similar rates of daily gain. At higher levels of feeding, the energy supplied will support a greater rate of gain than the protein, indicating that higher levels of protein in the milk replacer would improve rates of gain. Therefore, it is important to balance or couple the calf's protein and energy requirements. 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 2.5. Energy and Protein allowable gains for a 22.7 kg calf fed a 20% fat, 20% protein milk replacer at ambient temperature of 20°C .

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

Values calculated using NRC (2001).

Development and history of milk replacers

Milk replacers were first manufactured in 1951. Development of MR occured primarily for economic reasons; prior to 1951 calves were fed whole milk but the increasing market value of milk created a market for lower cost 'milk substitutes,' i.e., milk replacers (Fowler, 1993). Considerable research has been devoted to determining the most nutritionally desirable and economical formulation for MR. Manufacturers of MR face the constant challenge of providing a product to promote growth indistinguishable from whole milk and yet be an economical alternative to whole milk.

Manufacturers of MR have considered digestibility of a wide variety of ingredients in MR formulations. Butterfat, casein, and whey protein are the sources of fat and protein in milk. These ingredients can be used in a MR formula; however, the cost of these ingredients is generally too high to make a MR that is an economical alternative to whole milk. Therefore, much research has been conducted on byproducts that can be used to replace some or all of the butterfat, casein, and whey protein in milk replacer formulas. Figure 2.1 outlines the process by which byproducts are derived from the processing of milk. Nutrient composition of these byproducts is outlined in Table 2.6. These products are often utilized in the formulation of MR because they are readily digestible and

economic alternatives to milk protein and yet have amino acid profiles that are similar to milk protein.

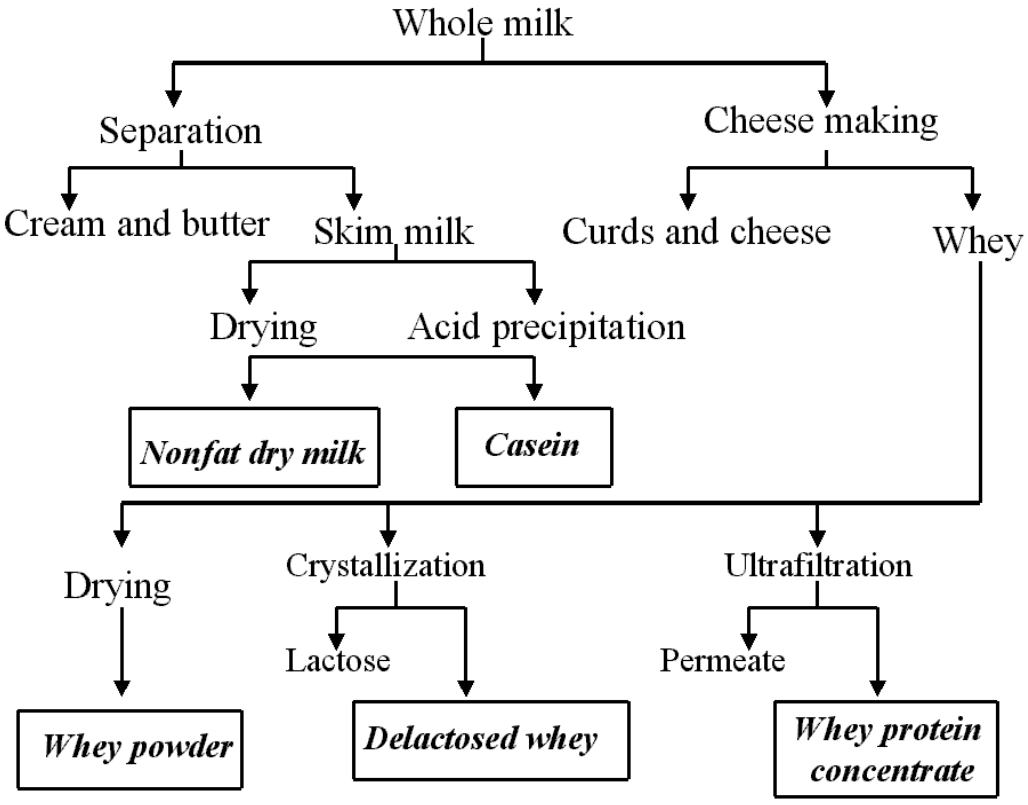


Figure 2.1 . Steps in processing the associated byproducts used in manufacture of milk replacers (Tomkins and Jaster, 1991) as cited by Davis and Drackely (1998).

Table 2.6. Chemical composition of milk byproducts (% of DM).

Ingredient	Dry Matter	Crude Protein	Crude Fat	Lactose	Ash
Dried skim milk	98	34	0.1	54	5.6
Whey protein concentrate	98	34	3.5	52	6.0
Dried whey	98	12	0.2	74	8.5
Delactosed whey	98	23	1.5	55	16.0
Sodium caseinate	96	85	0.5	-	2.5

Adapted from (Davis and Drackley, 1998)

Non-milk sources of protein considered in the formulation of milk replacers include wheat protein, potato protein concentrate, soy protein concentrate, soy flour, meat

solubles, fish protein concentrate, sprayed dried red blood cells, and animal plasma. However, digestibilities of these alternative protein sources are inferior to skim milk (Table 2.7). Reasons for inferior digestibility of non-milk protein sources are largely due to differences in the amino acid profile of these proteins. 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. In addition, soy proteins contain antigenic proteins that result in allergic reactions in young calves (Davis and Drackley, 1998). Other proteins, for example wheat proteins, have lower digestibilities in the young calf but improved digestibility in older calves (Davis and Drackley, 1998). More recently, proteins from blood sources, e.g. plasma and red blood cells, have been consider for use in MR. Quigley et al. (2000) evaluated red blood cell protein in MR and was able to replace up to 43% of the protein in the MR without affecting weight gain, feed efficiency, starter intake, fecal scores or d scouring, indicating that the red blood cell protein could be an alternative source of protein for use in MR.

Table 2.7. Crude protein digestibility of milk replacers containing various protein sources.

Protein source	Percent of milk protein replaced	CP digestibility %
Skim milk	-	97.0
Whey protein concentrate	100	90.2
Whey proteins	100	89.9
Soluble wheat protein	20	94.9
Modified soy flour	50	72.1
Heated soy flour	50	64.1
Soy protein concentrate	75	58.7
Soy flour	75	54.8
Meat solubles	33	54.8
Fish flour	67	83.7
Fish protein concentrate	100	53.8

Adapted from (Davis and Drackley, 1998).

Butterfat is highly digestible but is also very expensive. However, other saturated fats including tallow, choice white grease, and lard are very digestible and acceptable for use in MR formulation. Unsaturated fats such as, most vegetable oils, are generally 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).

Intensified rearing of calves

Liquid feeding schemes have been suggested to promote rapid growth of calves. Calves fed conventional liquid feeding schemes, i.e. 8 to 10% of BW, gain little during the first weeks of life, later increasing to rates rarely exceeding 250 to 400 g/d. Mowrey (2001) fed Jersey and Holstein calves MR (20% fat and 20% CP) reconstituted to 12.5% solids at a rate of 31% of metabolic BW. Sufficient energy was provided for 227 g ADG according to NRC (2001). Figure 2.2, demonstrates the lack of BW gain during the 1st two weeks of life and indicates that feeding calves a 20/20 MR at 31% of metabolic weight provides only enough energy to maintain 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. The diets were designed to support 227 g of ADG and calves should have gained more than 8 kg BW over the duration of the experiment but the Jersey calves gained less than 5 kg BW. This indicates maintenance energy requirement of Jersey calves may have been higher per unit of metabolic BW than Holstein calves and that NRC (2001) equations for maintenance energy may not be appropriate for Jersey calves. Increasing the feeding rate and/or increasing the caloric content of the liquid diet may improve the growth of young calves and this maybe particularly important in Jersey calves.

Feeding schemes designed to promote higher ADG and feed efficiency by allowing calves to consume more MR than 8 to 10% of BW are referred to as ‘intensified’ feeding schemes. Generally, these schemes are designed to provide enough nutrients in the liquid

diet to support ADG of 1000 g or more in Holstein calves (Drackley, 2001). Intensified feeding programs promote rapid growth and are associated with improvements in feed efficiency because as the level of DMI increases, a smaller fraction of the DM consumed is required for maintenance and more energy is available to support growth. The feed efficiency of lambs and piglets is generally much higher than that of calves because these animals consume more DM per unit of metabolic BW (Figure 2.3). A calf fed liquid feed at 8 to 10% BW consumes approximately 2.7 units of feed DM per unit of gain but lambs and piglets allowed ad lib intake of milk often achieve feed efficiencies of less than 1.5 units of feed per unit of gain. Theoretically, calves can gain at similar levels of feed efficiency when fed similar levels of DM per unit of metabolic BW.

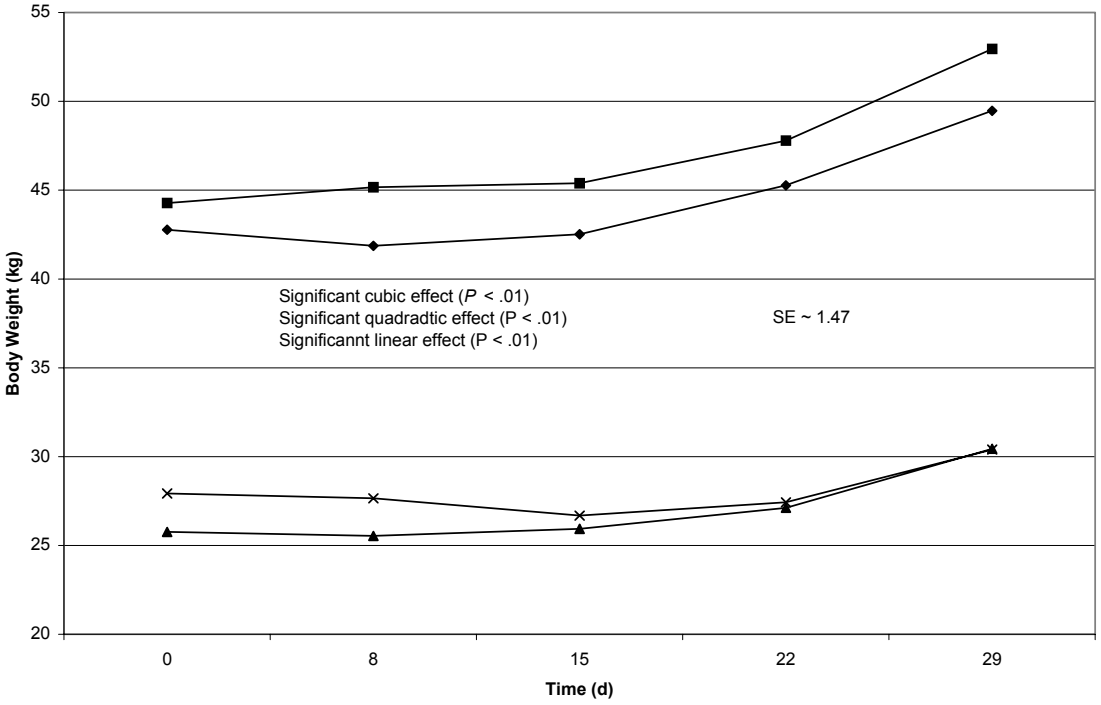
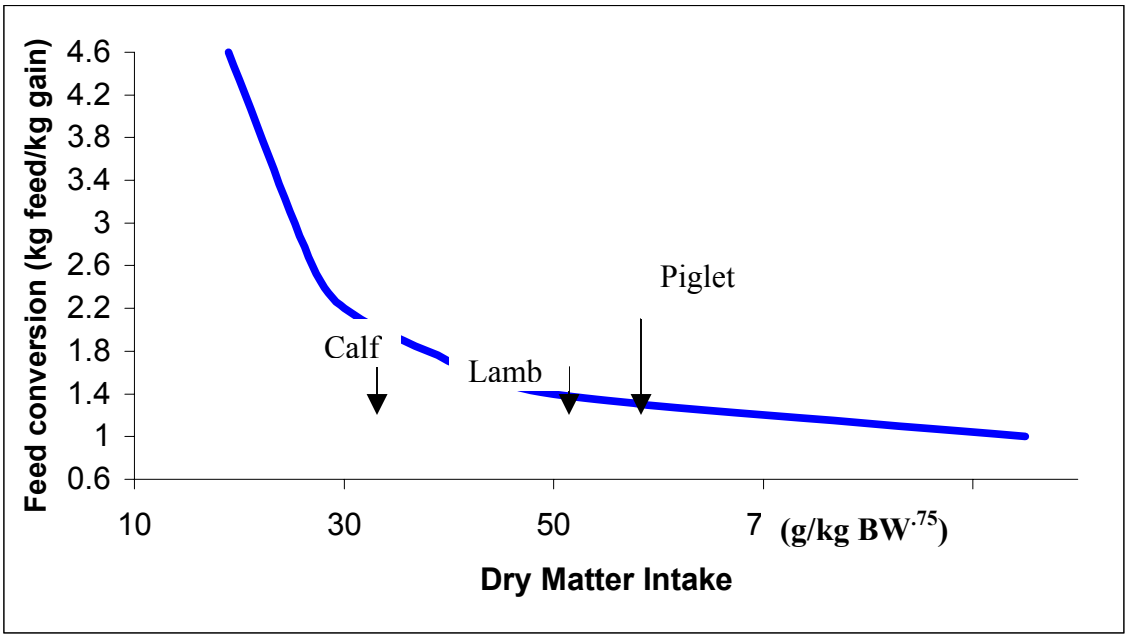


Figure 2.2. BW (kg) on d 1 to d 29 of Holstein females (♦), Holstein males (■), Jersey females (▲), and Jersey males (×). Significant breed by time interaction; differences detected on all d. (Mowrey, 2001).

Figure 2.3. Efficiency of feed conversion. Adapted from (Davis and Drackley, 1998).



Increased weight gain has resulted from feeding MR with increased nutrient density or increasing the amount of DM fed each d. Khouri and Pickering (1968) fed calves reconstituted whole milk at 11.3, 13.9, 15.9 and 19.4% of BW. Average BW gain increased from 410 to 940 g/d and feed efficiency increased, particularly between the two intermediate levels of intake.

Bartlett (2001) varied both rate of feeding and level of CP in diets fed to Holstein calves in a series of experiments. In one experiment, MR (reconstituted to 12.5% DM) was fed at 10% or 14% of BW and CP in the MR varied from 14% to 26%. In another 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. The results are reported in Table 2.8. Increasing rate of feeding resulted in increased feed efficiency and an increase in body fat %. Increasing 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 %.

There appears to be a significant role of dietary protein in the intensified calf feeding schemes. Tomkins and Sowinski (1995) fed calves isocaloric diets with varying levels of CP. Average daily gain increased as dietary protein increased with the highest ADG from birth to 42 d in calves fed a MR containing 24% CP and 18.5% fat (Table 2.9). The g of ADP required to support a target rate of gain for a calf of a given BW can be determined using equation (6), and then ADP can be converted to CP based on the digestibility of the protein source in the diet. Finally, the CP concentration required in the MR can be determined by dividing the g of CP required by the estimated DMI of the calf. Some examples of CP levels for a calf weighing 22.7 kg are shown in Table 2.5. (Davis and Drackley, 1998) calculated that a calf weighing 45.4 kg and gaining 1134 g/d requires a MR that contains 27.2% CP. Therefore, the theoretical level of CP in a MR designed for intensified feeding programs is somewhere between 27% and 30% CP.

Table 2.8. The effect of varying the level of intake and crude protein on feed efficiency and body fat deposition.

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

[m]Whole milk.

(Bartlett., 2001)

Table 2.9. The influence of protein levels in milk replacers on growth and performance. of Holstein male calves fed isocaloric diets to 42 days of age.

Treatment	1	2	3	4	5	6	MR fed g/d
Crude protein%	14	16	18	20	22	24	
Crude fat %	22.0	21.3	20.6	20.0	19.2	18.5	
	ADG g						
D 1-7	-45[a]	45[ab]	91[b]	64[b]	104[b]	18[ab]	454
D 8-14	32[a]	77[a]	109[ab]	86[ab]	91[ab]	163[b]	567
D 15-21	449[a]	485[a]	499[ab]	481[a]	567[bc]	603[bc]	680
D 1-42	322[a]	376[b]	386[b]	404[bc]	422[bc]	440[d]	737

[abcd]Means with different subscripts differ (P<0.05).

(Tomkins and Sowinski, 1995) as cited by Davis and Drackley (1998).

Gerrits et al. (1996) conducted two experiments using Holstein Friesian x Dutch Friesian calves by varying the ratio of protein to energy (g digestible protein/MJ protein free energy) from 8.5 to 20.0 and from 6.0 to 18.5 in experiments one and two, respectively.

Calves in experiment one were reared from 80 kg to 160 kg and were fed either 663 or 851 kJ of protein-free energy per kg of metabolic BW. In experiment two, calves were fed either 564 or 752 kJ of protein-free energy per kg of metabolic BW. Protein digestibility increased as intake of protein increased in both experiments. Increased protein intake resulted in an increased deposition of both protein and fat. Daily intakes of 244 g of protein resulted in maximum protein deposition. However, as the level of dietary protein increased, only 30% of the extra protein in the diet was deposited as tissue protein.

Donnelly and Hutton (1976a, 1976b) fed Friesian bull calves MR that ranged from 15.7 to 29.6% CP. Calves were fed for target ADG of 610 or 830 g. Body composition was altered as level of protein in the diet changed. Calves fed a MR containing 29.6% CP had the greatest digesta-free body protein % and the lowest proportion of energy gain as fat. Conversely, calves fed a MR containing 15.7% CP had the lowest digesta-free body protein % , highest % body fat, and the highest proportion of gain as fat (Table 2.10). Calves fed diets containing higher levels of protein had a reduction in body fat and an increase in digesta-free body protein.

In a similar experiment, Diaz et al. (1998) adjusted intake of a MR in an attempt to achieve target ADG of 500 g, 950 g, or 1400 g. A 30% CP MR was selected so that protein would not limit growth. Feed efficiency (gain/feed) increased from 0.64 to 0.74 between the extremes of 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.

Table 2.10. Content of the gross chemical components and energy in digesta free body weight gains.

Dietary crude protein (%)	15.7	18.1	21.8	25.4	29.6	31.5
Component						
Water (%)	58.9	59.9	61.7	62.3	62.8	64.5
Fat (%)	22.3	20.0	18.4	15.3	11.7	11.8
Protein (%)	16.6	17.2	17.3	19.0	21.5	19.6
Ash (%)	2.3	2.6	2.7	3.3	3.8	4.1
Energy (MJ/kg)	12.4	11.9	11.2	10.7	9.5	9.3
Proportion of energy gain as fat	0.70	0.66	0.64	0.58	0.47	0.51

From Donnelly and Hutton (1976b).

The research clearly demonstrated that calves fed intensified feeding programs require higher levels of CP for lean growth (Bartlett, 2001; Gerrits et al., 1996; Donnelly and Hutton, 1976a; Donnelly and Hutton, 1976b; Diaz et al., 2001). 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.

Rapid growth and heifer development

Few research trials have examined long-term effects of accelerated growth in the preweaned calf on mammary development and milk production. Previous work (Sejrsen et al., 1982; Swanson, 1954; Swanson, 1960; Capuco et al., 2000) demonstrated that rapid growth (ADG >1 kg) in heifers between 3 mo of age and puberty can be detrimental to mammary development and future milk production. At least three theories exist for the negative relationship between rapid growth and mammary development. The first theory involves growth and development of the mammary gland. The mammary gland grows more rapidly than the animal from approximately 3 mo of age to puberty. Heifers

that grow rapidly during this period of time deposit a disproportionately high amount of fat in the mammary gland. Swanson, (1960) proposed that deposition of fat in the mammary gland led to reduced milk production in the mature animal. The second theory is an endocrine theory; rapid weight gains in prepubertal heifers result in shifts in hormonal concentrations. Sejrsen et al., (1983) suggested that shifts in growth hormone or other hormones in heifers that were growing rapidly during the prepubertal period resulted in a reduction in parenchymal tissue development. More recently, a third theory has been proposed by VandeHaar and Silva, (2002). The new theory suggests that adipose tissue in the mammary gland may secrete compounds and/or hormones that interfere with the synthesis of parenchymal tissue. However, not all experiments have shown a negative relationship between rapid rates of growth during the prepubertal period and future milk yield (Sejrsen, 1997) indicating that the relationship between growth and mammary gland development is very complex.

Few studies have examined the influence of gains in the preweaned calf on body composition and mammary development. In one such study, Sejrsen et al. (1998) fed preweaned calves MR with 58 g or 73 g CP/Mcal ME from 5 to 42 d of age and demonstrated that rate of gain in the preweaned calf did not affect mammary tissue development. Diets resulted in ADG ranging from 632 to 895 g from d 5 to 42. Calves were sacrificed when their BW reached 250 kg. There was no difference in amount of parenchymal tissue between treatments indicating that rapid growth from 5 to 42 d of age was not detrimental to mammary development.

Rapid growth and future milk yield

Assessing, parenchymal tissue development provides an indirect estimate of future milk yield. However, conventional methods of measuring parenchymal tissue involves removal of the mammary gland thus preventing lactation. Few studies have examined the relationship between pre-weaning diet and future milk yield in young calves. Bar-Peled et al. (1997) fed Holstein calves either MR (control) or allowed calves to suckle their dams for 15 min twice per d. Control calves consumed 3.33 L of MR (3.0% fat and 4.6%

CP, as fed) per day, while intake of suckled calves averaged 16.9 kg/d of milk (3.12% fat and 3.28% CP). Calves that were suckled had gained nearly 300 g more per d from birth to 6 wk of age. They were 30 d younger when they conceived, 5.3 cm taller and 37 kg heavier at calving, and produced 453 kg ($P<0.08$) more milk in their first lactation. In a similar experiment, Danish researchers (Foldager et al., 1997) fed Danish Black and White calves from 5 to 42 d of age 4.6 kg/d of whole milk or allowed calves to consume milk ad libitum from their dams or from an open bucket. Ad libitum intake of milk increased ADG by approximately 200 g/d from birth to 42 d of age. Calves that consumed milk ad lib produced 1.6 kg more milk/d in their first lactation, gained 16.4 kg more BW in the first 250 d of lactation, and tended to consume more dm (0.6 kg/d) during their first lactation. No difference was detected in milk production between calves that suckled or consumed milk ad libitum, indicating that level of milk intake and not presence of the dam resulted in higher levels of production.

Body composition analysis

Growth can be measured as an increase in BW or an increase in frame size. However, these measures ignore composition of gain. It is likely that there is an optimum composition of gain in calves. Diet and rate of gain have an influence on composition of gain. Several researchers suggest that maximizing protein content of gain is optimum in the young calf (Diaz et al., 2001; Davis and Drackley, 1998; Gerrits et al., 1996; Donnelly and Hutton, 1976b). However, few if any long-term studies have been conducted relating composition of gain in young calves to future milk production and performance.

Whole body analysis of composition

Body composition of animals has been of interest to scientists for well over 100 years. (Reid et al., 1955) reviewed the history of body composition analysis in farm animals and noted that in the late 1800's, German researchers including von Berzold, (1881), von Hosslin (1881), and Pfeiffer, (1886) published results of studies that evaluated the composition of animals. German researchers developed a methodology for evaluating body composition and studied mammals, birds, amphibians, and fish. These researchers

found that morphologically similar animals had similar body compositions. Methodology of determining composition has been refined since these early experiments. Powell and Huffman (1968) reported that the most accurate method of assessing carcass composition required animal sacrifice and chemical analysis. Contemporary researchers (Diaz et al., 2001; Bartlett, 2001; Tikofsky et al., 2001; Donnelly and Hutton, 1976b; Gerrits et al., 1996) have analyzed body composition of calves by sacrificing the animal and conducting chemical analysis of the body. The methodology varies between researchers but the general principal involves sacrifice and dividing the animal into three or four components. These components are then homogenized in a grinder and sub-sampled to permit analysis to determine their composition and a weighted average is calculated to estimate empty body composition of the animal.

Multi-compartment models of analysis

Composition of an animal can be broken down into many different levels including the atomic, molecular, cellular, and tissue (Heymsfield and Wang, 1997). At the atomic level, the composition of the animal can be described in terms of the elements that make up the animal. At the molecular level, the body can be broken down into lipids, water, proteins, carbohydrates, and minerals (Wang et al., 2002). At the cellular level, body composition can be described in terms of cell mass, extracellular fluid, and extracellular solids. Theoretically, body composition could be measured on the sub-atomic level, however, the usefulness and practicality of measuring composition at the sub-atomic level is questionable. Measuring body composition at the tissue level is generally the most useful in humans and animals as body fat % and bone mineral density are frequently associated with performance, disease, and health. At the tissue level, the body can be described as adipose tissue, visceral tissues, skeletal muscle, bone, and brain (Heymsfield and Wang, 1997).

In cattle, the most common model of body composition is the molecular model of body composition because researchers are most interested in determining the level of fat, protein, and ash in the body. In beef cattle, deposition of body fat in the tissue is related to market value, and analyzing the body composition of the live animal provides an assessment of market value of the animal. The molecular model of body composition is a multi-component model of body composition with five to six components: fat, water, protein, glycogen, bone mineral, and non-bone mineral. This model is often modified into simpler models with fewer components (Figure 2.4). The five component (5-C) model of body composition is often reduced into two component (2-C) models of body composition such as fat and fat free components, or bone mineral and soft tissue (Buzzell and Pintauro, 2001). In many cases, only a few of the five components of body composition are of interest and the reduced models are more practical than the 5-C model.

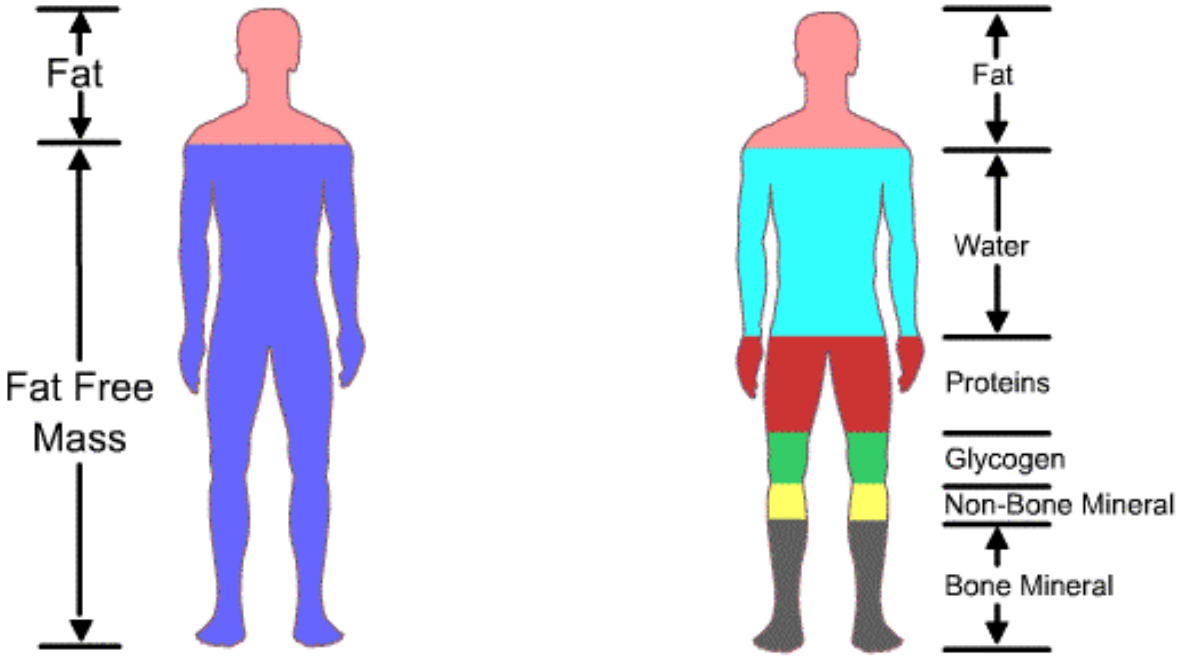


Figure 2.4. Models of body composition. On the left is a two component (2-C) model of body composition showing fat and fat free mass. On the right is a six component (6-C) model of body composition showing fat, water, protein, glycogen, non-bone mineral, and bone mineral. Courtesy of Buzzel and Pintauro (2001).

Common methods of analyzing body composition

Methods of analyzing body composition can be divided into two broad categories. Invasive methods of measuring body composition involve subjecting the animal to procedures that cause some degree of pain and/or discomfort for the animal, and in some cases may interfere with organ function. The most invasive methods of analysis require sacrificing the animal. Non-invasive methods of analysis cause little pain or discomfort to the animal, but in many cases, these methods provide estimates of composition that are less reliable than invasive measures of composition.

Dilution

Dilution techniques have been used to evaluate body composition of animals in vivo. Dilution techniques utilize the relationship between body water and other components. A reduction in water content accompanies an increase in body fat (Moulton, 1923; Powell and Huffman, 1968). As percentage fat in an animal increases, the concentration of water, protein, and ash in the empty body are diluted (Moulton, 1923). Body fat percentage can be estimated indirectly from measurements of body water in an animal. Urea space (US) is one such technique. Bartle et al. (1987) used the following technique to determine US in Hereford x Angus and Chiania steers. Blood samples were drawn before and 12 min following infusion of a saline solution (0.66 ml/kg live weight) containing 20% urea. Then US was estimated using the following equation

US = mg urea-infused/(change in PUN x Live weight x 10)

where PUN was expressed as mg urea-N/100ml (7)

Steers were then slaughtered and the right half of the carcass and all of the internal components were analyzed to determine fat, nitrogen, and water content of the empty body (EB). The cattle ranged between 6.5 and 38% body fat. Equations were developed to predict water %, fat %, and nitrogen % in EB based on US and live weight. These equations were correlated to chemical composition (r^2 =0.67). Hammond et al. (1990)

evaluated US with Holstein steers and developed equations to predict empty body fat, protein, and water that were correlated to chemical analysis (r^2 = 0.95, 0.95, 0.83, respectively). Hammond et al., (1988) suggested that repeated measurements of US throughout a feeding trial provided a better estimate of body composition than a single measurement due to inconsistency in estimates of US. Dilution techniques provide reasonable estimates of EB composition in animals that are chemically mature. In cattle, body water content decreases in fat-free mass from conception until chemical maturity at 5-10 months of age. Chemically maturity can by defined as the point in time when the animal's body water remains relatively constant; cattle remain 'immature' to approximately 200 d of age and from 200 to 500 d of age, they are in a transition until chemical maturity is reached at approximately 500 d of age (Reid et al., 1955). Estimates of body composition based on US in young animals that are not yet chemically mature may be inaccurate.

Bioelectrical impedance

Bioelectrical impedance analysis (BIA) is frequently used to evaluate body composition in human subjects. This technique is based on the ability of tissues to conduct an electrical current. Aqueous tissues conduct electricity due to dissolved electrolytes. Impedance is the resistance of a biological conductor to the flow of alternating current (Brodie et al., 1998). Impedance of tissue is affected by the volume of the conductor (i.e., the volume of the subject), length of the conductor (i.e., the height of the subject), and presence of dissolved electrolytes. Adipose tissue and bone mineral are poor conductors i.e., have a high degree of impedance. On the other hand, soft lean tissues are good conductors of electricity due to the presence of dissolved electrolytes. Differences in electrical conductivity in bone mineral, adipose tissue, and lean soft tissue can be used to estimate body composition (Ellis, 2000). Zack (2002) evaluated body composition of human subjects (average age 22.7 yr) with both BIA and dual energy x-ray absorptiometry (DXA) and reported a high correlation between BIA and DXA (r= 0.998) for estimates of body fat %, lean body mass, and fat mass, indicating that BIA is an appropriate method of evaluating the body composition of human subjects.

Human subjects are frequently evaluated with BIA because it is safe, measures body composition rapidly, noninvasive, inexpensive, portable. However, the theory behind BIA assumes an object is a perfect cylinder with uniform cross-sectional area. Humans and animals do not fit this description, and inaccuracy in estimation of body composition is likely to result (Zack, 2002). Factors other than body composition can affect conductivity of a human subject including differences in gender, age, ingestion of a meal prior to measurement, muscle mass, physical activity, menstrual cycle, degree of hydration, and position of electrodes (Brodie et al., 1998). It is unlikely that BIA is appropriate for assessing body composition in calves because of these variables. In particular, the level of hydration or dehydration in a calf is an area of concern. Diarrhea is common in calves and results in varying degrees of dehydration and electrolyte balance.

Another method that is frequently used to evaluate body composition in humans is underwater weighing (UWW). This is a 2-C model of body composition (fat and lean tissue) and is often considered the gold standard for evaluating body composition in humans. Lean tissue is denser than fat, thus the density of a human can be used to estimate their body composition (Ellis, 2000). Archimedes principle states that an object will displace a volume of water equal to its volume when submersed in water; UWW utilizes this principal to determine the density of the body (Buzzell and Pintauro, 2001). Body composition is determined by comparing the volume of water displaced and/or the subject's weight, when they are submersed in a tank of water, to their BW. A few technical adjustments must be made to account for the air volume of the lungs because the presence of air in the lungs will alter the volume of water displaced by an individual. Ellis (2000) reported that every 100-ml error in estimation of lung volume results in an increased uncertainty of measurement of body fat of ~1%. In humans, lung volume is determined and accounted for in the equations used to estimate body fat. Determining lung volume in animals is difficult. However, this method has been used to evaluate the body fat in animal carcasses. In one such study, (Elowsson et al., 1998) reported a

correlation of (r = 0.77) between UWW and chemical analysis in estimation of body fat mass in pig carcasses.

Dual x-ray absorptiometry analysis of body composition

Dual-Energy X-ray absorptiometry (DXA) was first introduced in 1987 for use in evaluating bone mineral density in human subjects (Zack, 2002). Recent estimates by the National Osteoporosis Foundation indicate that 89% of bone mineral density tests performed in the United States utilize DXA (Smith and Shoukri, 2000). This technology has gained widespread acceptance because of its accuracy, precision, fast scanning time, and non-invasive nature (Heymsfield et al., 1989; Ellis, 2000; Hansen et al., 1990; Zack, 2002). There are three manufacturers of DXA equipment: Hologic, Lunar, and Nordland. The basic components of the DXA instrument manufactured by Hologic are an X-ray generator and tube that produces a fan shaped beam at 2 energies, 100 kVp and 140 kVp, and a cadmium tungstate detector (Zack, 2002). A computer and software package also are required for interpreting the readings detected by the DXA instrument. Available software packages available allow the estimation of bone mineral density and body composition.

Body composition is estimated by DXA utilizing a three-component model of body composition (i.e., fat, lean, and bone mineral mass). Ellis (2000) explained the principle of DXA in the following way, "When an x-ray or photon source is placed on one side of an object, the intensity of the beam on the opposite side of the object is related to its thickness, density, and chemical composition." The difference between the initial intensity and the final intensity of the x-ray that was passed through an absorber (e.g., tissue) is called attenuation. The ratio of attenuation in the high energy and low energy beam are referred to as an attenuation ratio (Rst) in soft tissue. Svendsen et al. (1993) reported that Rst and fat % are inversely and linearly related, which allows fat % in soft tissue to be calculated based on its Rst. Using the Rst, DXA can distinguish between

adipose tissue and lean tissue; this is a 2-C model of body composition. In a similar manner, DXA is also capable of distinguishing between bone mineral tissue and soft tissue, which is another 2-C model of body composition. Therefore, DXA simultaneously measures two 2-C models of body composition. Bone mineral does not contain any fat; therefore, when DXA has distinguished between the bone mineral and the soft tissue, then the estimates of fat and lean tissue can be applied to the soft tissue. The result is a 3-C model of body composition that yields bone mineral mass, fat mass, and lean tissue (excluding bone mineral) mass.

In addition, DXA has also been utilized to evaluate body composition of pigs (Elowsson et al., 1998; Mitchell et al., 1998a; Mitchell et al., 1998b; Mitchell et al., 1996) and chickens (Mitchell et al., 1997). In early studies, pigs were used to evaluate and calibrate DXA for measuring body composition in human infants and small children (Ellis, 2000). More recently, DXA has been evaluated as a method of measuring body composition in live pigs to provide information on body composition that could be useful in determining market value of the carcass in the live animal.

In a study with eight,12-wk old Swedish Landrace x Yorkshire piglets (15-22 kg), Elowsson et al. (1998) compared DXA, underwater weighing (UWW), and chemical analysis as measures of body composition. Pigs were euthanized, and head, thoracic organs, abdominal organs were removed. Each carcass was scanned three times with DXA (DPX-L, Lunar, Madison, WI) and body composition was estimated using a pediatric software package (Pediatric, 1.5b, DPX-L, Lunar). Following DXA analysis carcasses were analyzed using UWW. The carcasses were weighed first in air and then in water. Carcass density was calculated as:

CD = [(weight in air)/(weight in air – weight water)]/density of water (7)

Fat free mass was calculated as:

% fat = (a/CD – b) x 100; where a and b are constants for density of fat and fat free mass, respectively. (8)

Finally, the carcasses were divided along the midline and the right half was dissected into forelimb, hind limb, and remainder of the carcass was separated into muscle, fat, and bone. These components were homogenized and analyzed for fat and bone mineral. Chemical analysis of body composition was taken as the most accurate measure of composition and DXA estimates and UWW were compared with values derived using chemical analysis. Correlations between DXA and chemical analysis for body composition were highly correlated (r = 0.90 – 1.0). However, DXA overestimated bone mineral mass, lean mass, total weight, and underestimated fat mass. Even so, DXA was a better predictor of fat mass than UWW (r = 0.77), which also overestimated fat mass.

In studies using similar methodology as Elowsson et al. (1998), Mitchell et al (1998b) examined composition of pigs. They reported a high correlation ($R^2 = 0.97$) between DXA measurement of lean tissue mass (total mass – fat and bone mass) and carcass protein in pigs weighing 10 to 61 kg (Mitchell et al., 1998b). In a study with small pigs (5-27 kg), Mitchell et al. (1998a) developed an equation that regresses DXA on carcass protein. The resulting equation accurately predicted carcass protein ($R^2 = 0.92$). In the same study, DXA estimated bone mineral content within 2% of estimates of BMC from total body ash.

The usefulness of DXA has been evaluated in estimating whole body composition of pigs and DXA may be useful for evaluating body composition of calves. Generally, invasive methods of body composition analysis are applied to calves requiring sacrifice of the animal. These methods do not allow body composition in individual animals to be measured at different points in growth and development. Nor do current methods of body composition analysis in calves allow for body composition of individual animals to be related to future performance. Researchers have reported a relationship between the rate of growth in young calves and future milk performance including milk yield (Bar-Peled et al., 1997; Foldager et al., 1997). Changes in body composition of young calves due to diet may explain the differences in future performance, but the invasive measure of body composition that are commonly used to evaluate calves make it difficult to test

this hypothesis. Non-invasive measures of body composition like DXA would be useful in testing this hypothesis.

What is the ideal body composition?

Considerable time and effort have been devoted in this treatise and others to consider alterations in body composition and methods of determining body composition of calves. However, a question that begs to be asked is, "What is the ideal body composition of a dairy replacement heifer?" As stated previously, the literature indicates that in the prepubertal heifer (>3 mo. of age to puberty), growth rates in excess of 1 kg/d result in reduced first lactation milk yield (Swanson, 1960). However, few if any studies relating growth rate of prepubertal dairy heifers and future milk yield have evaluated body composition of these animals. Therefore, the relationship between body composition and future milk yield in prepubertal heifers is difficult to elucidate. Limited research has been conducted that assesses the relationship between growth and body composition of young calves and future milk yield. As stated previously, (Sejrsen et al., 1998) reported a positive relationship between growth and mammary and parenchymal development when calves were fed for rapid gains from birth to 6 wk of age but a negative relationship after six weeks of age. In a similar study, Foldager et al. (1997) reported ad lib feeding from birth to 6 wk of age improved first lactation milk yield by 1.6 kg/d compared to conventional feeding (MR fed at 10% of BW). Ad lib feeding from birth to 12 wk of age resulted in a 3.6 kg/d reduction in milk yield compared with conventional feeding. Theoretically, calves fed ad lib deposit more adipose tissue and have a higher percentage body fat than calves that are limit-fed. Even though body composition was not measured by Foldager et al. (1997), or Bar-Peled et al. (1997), it is reasonable to conclude that the calves fed ad lib diets had higher levels of body fat than calves fed the control diets. If this is true, then it would appear to be advantageous to feed calves from birth to 6 wk for rapid growth and deposition of fat. Results of Sejrsen et al. (1998) and Foldager et al. (1997), would indicate that deposition of body fat from 6 to12 wk of age is detrimental to future milk production. These hypotheses should be tested directly.

The relationship between body composition and future performance has been measured in other species. Several such studies have been conducted with poultry. Yannakopoulos et al., (1995) reported that increased carcass fat in Japanese quail resulted in an earlier age at first lay and determined age at onset of sexual maturity. Similar results have been reported with broilers (Robbins et al., 1988) dwarf and normal chickens (Brody et al., 1984), and white turkey hens (Renema et al., 1994). Zelenka et al., (1984) found that body composition affected early maturing and late maturing quail differently. In the early maturing quail the first lay was a function of chronological age and % body lipid, but in late maturing quail a critical lean weight and/or skeletal development determine sexual maturity. Renema et al., (1994) fed male line large white turkey hens from wk 4 to 28 either full feed or diets that were restricted so that BW was either 10 or 20% less than full fed controls. The birds fed for a 20% reduction in weight had less breast muscle and abdominal fat early in lay, and sexual maturity was delayed, but the birds fed restricted diets had an increase in settable egg production. Therefore, diet restriction is desirable in breeder hens even though sexual maturity is delayed. Moran et al., (1983) also found that decreased fat accretion early in sexual maturity improved reproductive capacity apart from an alteration of BW in small white breeder toms. In poultry nutrition, restricting the diet and reducing fat accretion may improve reproductive performance in breeders. However, age at sexual maturity and/or age at first lay is reduced by increasing body fat deposition. It is important to note that poultry differ from other species of production. Poultry have been genetically selected for very rapid rates of gain and rapid deposition of body fat. Broilers are capable of reaching market weight by 7 wk of age (Cheeke, 1999). However, rapid rate of gain does not favor reproduction and the ability of broilers to gain weight and deposit fat can result in leg problems and reduced egg production. Thus, broiler breeders are typically fed diets that restrict levels of energy to slow rate of growth and improve reproduction. Poultry are very different than cattle and other mammals physiologically, and chicks have a very different diet than neonatal mammals.

In mammals, sexual maturity and body composition do not appear to be as closely related as in poultry. Rozeboom et al. (1995) reported that age at puberty is not related to body composition in gilts. The relationship between body composition and sexual maturity has been considered in cattle. The plane of nutrition, particularly level of energy in the diet, is inversely related to age at puberty in cattle (Greer et al., 1983; Buskirk et al., 1995; (Maas, 1987). Simpson et al. (1998) tested the hypothesis that a critical body fat % must be reached in cattle to initiate puberty; they reported body fat % didn't significantly affect variation in age at first conception in beef heifers but a combination of BW, body condition score, BW gain, and age may initiate the onset of puberty in heifers. The results of Simpson et al. (1998) led to the conclusion that body composition alone doesn't determine the onset of puberty.

The 'ideal' body composition of a dairy replacement heifer in terms of future composition is not known. Some researchers (Van Amburgh, 2002; Drackley, 2001) suggest that the goal of calf rearing is to maximize the rate of lean tissue growth. On the other hand the work of Swanson (1954, 1960, 1967), Serjsen et al. (1982), Sejrsen et al., (1983) Sejrsen et al., (1998), Sejrsen et al., (2000), Sejrsen, (1997), and several others using older prepubertal heifers would lead us to believe that slower rates of gains might favor lifetime performance.

Objectives

Recent studies have indicated a possible relationship between calf feeding programs and growth and development of the heifer after weaning. Ratios of energy to protein in MR influence composition of BW gain

Therefore, the objectives of this study are to examine the relationship between dietary protein and energy on ADG, empty body weight gain, wither height, heart girth, body length, hip height, body composition, protein retention, efficiency of energy utilization, feed efficiency, and health in Jersey bull calves. We will also compare dual energy X-ray absorptiometry estimates of body composition to chemical measures.

Chapter Three
Calf Mortality Surveys

Introduction

Calf mortality has a significant economic impact on the dairy industry. In recent years, the price of replacement dairy heifers has increased, indicating that heifers are in short supply. The USDA sponsored the National Dairy Heifer Evaluation Project (NDHEP) as a part of the National Animal Health Monitoring System (NAHMS). The NAHMS reported a mean death loss between birth and weaning of 8.4 and 11.4% in 1993 and 1996, respectively. The increase in calf mortality between 1993 and 1996 indicates that supply of dairy heifers may be declining due to an increase in calf mortality.

The purpose of NDHEP was to collect information on health and management characteristics that could be related to the long-term health and economic performance of heifers (Losinger and Heinrichs, 1997). Data were collected from 1685 dairy operations during 1991 and 1992. Participating herds were representative of 78% of the dairy herds in the United States (Heinrichs et al., 1994). These herds reported 47,057 births and 4427 deaths (9.4%) in preweaned calves (Losinger and Heinrichs, 1997). Average herd size was 86 mature cows and 66 heifers (Losinger and Heinrichs, 1997). However, the majority of herds, 94.9%, were Holstein herds, and only 2.4% of herds surveyed were Jersey herds (Heinrichs et al., 1994).

Calf mortality as reported by NDHEP (NAHMS, 1993) is broken down by cause in Table 3.1. Several studies have shown that calf mortality is related to a variety of management factors and/or factors that are indicative of the level of herd management. Table 3.2 lists major risk factors associated with calf mortality. Health, management, and feeding practices associated with calf mortality will be discussed in detail in the following sections of this treatise.

Table 3.1. Causes of death in preweaned calves

Cause of death	% Death loss	SE
Scours, diarrhea	4.4	±0.4
Respiratory problems	1.8	±0.1
Joint or navel problems	0.2	±0.1
Trauma	0.2	±0.1
Other	1.0	±0.2
Unknown	0.8	±0.1

(Heinrichs et al., 1994; NAHMS, 1993)

Table 3.2. Factors associated with mortality in preweaned calves as determined by several regional and national surveys.

Risk Factor	Relationship
Region of the country	Higher mortality in western herds
Rolling herd average for milk	Lower mortality in high producing herds
Grouping calves prior to weaning	Higher mortality when calves are grouped
Primary calf feeder	Lower mortality with female calf feeder
First roughage before 20 d of age	Lower mortality when roughage fed
Calves fed mastitic milk	Higher mortality
Calves fed whole milk or colostrum	Lower mortality
Herd size	Lower mortality in smaller herds
Housing	Lower mortality with easy observation of calves

Adapted from,(Heinrichs et al., 1994; James et al., 1984; Losinger and A.J.Heinrichs, 1997; Winston, 1998)

Management factors

It is logical to assume that well managed herds have lower levels of calf mortality. However, defining 'superior' management is more difficult and is somewhat subjective. Jordan and Fourdraine (1993) utilized the dairy records processing centers to identify 128 herds with the highest rolling herd average for milk production in the United States. A survey was mailed to these herds, and 61 herds responded. The objective was to characterize management practices in high producing herds. High producing herds had a low incidence of metabolic disorders, made aggressive use of AI to breed cows and heifers, aggressively managed udder health, and vaccinated both the milking herd and replacement herd to prevent disease. While these are indirect measures of management, they can be useful in establishing benchmarks for superior herd management.

Level of milk production may be an indicator of level of management. Herds with higher levels of milk production are likely to implement aggressive management practices with the milking herd probably also manage the heifers and calves aggressively. Several researchers report lower levels of calf mortality in herds with high levels of milk production, which indicates that high producing herds also have superior calf management (James et al., 1984; Losinger and Heinrichs, 1997). These researchers also identified lower levels of calf mortality in small herds, implying that smaller herds manage calves intensively. However, Jenny et al. (1981) reported higher levels of calf mortality in smaller herds. In this data set, larger herds also were higher producing herds, indicating that herd size and level of production could be confounded.

Management factors may be confounded by multiple factors. For example, Losinger and Heinrichs (1997) determined that calf mortality was higher in the Western region of the United States than in other regions of the country. They suggest that location and herd size may be confounded because herds located in the Western region of the United States tend to be larger than herds located in other regions. Large herds are more likely to utilize hired help to feed and manage calves. Hartman et al. (1974) reported lower calf

mortality when calves were fed by the herd owner than when calves were fed by hired help. Hired help may manage calves less intensively because they have less stake in the performance of calves. Another possibility is that hired help used on the farms surveyed by Hartman et al (1974) had very diverse responsibilities and did not have as much skill in feeding calves as the herd owner.

Level of management is related to calf performance and mortality but it can be difficult to categorize herds by level of management. Therefore, indirect measures of management such as milk production, herd size, and other measurements of herd performance are utilized to categorize herd management. These categories can then be used to assess the relationship between overall herd management and calf mortality.

Colostrum and management of the newborn

The newborn calf is faced with a dramatic transition as it adjusts to living outside of the uterus. The neonatal calf must initiate breathing and respiration, maintain and regulate its acid/base balance, engage its metabolic machinery to accommodate digestion of milk, and develop the ability to regulate its body temperature (Davis and Drackley, 1998). The newborn calf is born with a naive immune system that has limited function. For these reasons, the calving environment may play a critical role in calf health and performance. A clean, dry, well-ventilated calving environment may benefit calves as they make the dramatic transition to extrauterine life without encountering major environmental stress. However, calves born in dirty, wet, and poorly ventilated environments may face considerable added stress due to their environment. Therefore, calving environment can dramatically affect calf mortality and morbidity.

In addition to providing a good environment for calving, the survival and performance of the newborn calf is affected by colostrum intake. Colostrum is rich in large molecules such as IgG, proteins, and a wide variety of other compounds that can pass the small intestine of the newborn calf and provide passive transfer of immunity to the newborn calf (Davis and Drackley, 1998). Heinrichs and Swartz, (1990) recommended newborn

calves receive a minimum of 3.8 L of colostrum per d during the first 3 d of life. Stott et al. (1979) demonstrated that colostrum should be fed within a few h after birth because the efficiency of Ig absorption declines rapidly during the first 12 h of life. Therefore, feeding calves an adequate quantity (2 L) of high quality colostrum, i.e., >50 g IgG/ml, soon after birth is essential to developing passive immunity in the calf and increases the calf's likelihood of survival. Overall, producers are doing a reasonably good job of colostrum management. Recent estimates show that 69% of producers feed colostrum within 6 h after birth and 43% feed between 2 and 4 L of colostrum at the first feeding (NAHMS, 1996b).

Calf mortality and disease

The 1996 NDHEP survey indicated that 60.5% of deaths in preweaned calves were due to scours and diarrhea. Scours and diarrhea result when the calf is subjected to nutritional stress that upset the delicate balance between the animal, its environment, and etiological agents (McGuirk, 1992). Davis and Drackley (1998) list 5 major stressors that may result in scours: 1) birthing in an unsanitary environment; 2) inadequate colostrum intake; 3) poor colostrum quality; 4) overfeeding or feeding a poor quality MR; and 5) housing in unsanitary, overcrowded, and poorly ventilated conditions. Reducing these stresses may reduce the risk of calf mortality considerably.

The NAHMS (1996b) reported that 24.5% of deaths were the result of respiratory disease. One of the greatest risk factors associated with respiratory disease is housing (Davis and Drackley, 1998). In particular, proper ventilation that allows adequate airflow through calf housing is critical in preventing respiratory disease. Otterby and Lin (1981) demonstrated that calves need four complete air changes per hour to remove humidity and stale air from the environment. Therefore, proper calf housing is a critical component in reducing the risk of mortality.

Feeds and feeding

Herds that feed calves whole milk after their initial feedings of colostrum reported a lower level of calf mortality (Losinger and Heinrichs, 1997). Intake of the newborn calf is limited, and young calves require a nutrient dense diet to meet their requirements for maintenance and growth. Whole milk has a greater nutrient density than MR, which may explain the improved survival ability of calves that are fed whole milk after their initial feeding of colostrum. However, there is considerable variation between farms in liquid diets offered to preweaned calves. The NAHMS (1993) study revealed that 32.7% of farms fed whole milk, 52% fed transition milk, i.e., 2nd and 3rd milking colostrum, 38% fed unsalable milk from treated cows, and about 60% fed MR.

Colostrum and transition milk are non-saleable and often fed to calves. These feeds are economical alternatives to saleable milk and milk replacers. A mixture of colostrum and transition milk contains between 16 and 18% total solids, but first milking colostrum can be as high as 24% and transition milk can be as low as 13.6% solids (Foley and Otterby, 1978). According to the NAHMS survey (1993), feeding transition milk and colostrum has fallen out of favor with producers. There are several challenges associated with feeding calves these feeds, which may discourage their use. Considerable variation in the composition of colostrum and transition milk can present some challenges because it is difficult to maintain consistency in the diet when fed to calves. Another challenge in using colostrum and transition milk as a feed is storage and preservation. Foley and Otterby (1978) summarized several different methods of preservation including cold storage, freezing, bacterial inoculation, and fermentation at ambient temperature. All of these methods of storage can be effective, but the practicality of many of these methods is questionable.

In the United States, whole milk, on average, contains about 12.5% solids and on a DM basis, 25.6% CP, 29% fat, 40% lactose and 5.6% ash (Brown, 2001). The typical composition of Jersey milk (14.5 % solids) is 26% protein, 34.5% fat, 34.5% lactose and 4.8% ash. In contrast, a standard 20:20 MR is about 95% DM and contains about 22.2%

protein and a similar amount of fat. Given the difference in nutrient density between whole milk and MR, it is reasonable to expect calves fed whole milk to grow better than those fed an equivalent amount of DM from MR; this may be particularly true with the young Jersey calves.

One of the concerns with feeding waste milk to calves is transmission of disease. Whole milk may contain pathogenic organisms including Salmonella spp., Staphlococcus aureus, Streptococcus spp., Klebsiella spp., Mycoplasma spp., Listeria monoctyogenes, Aeromonas spp., Pseudomonas spp., and Escheria coli (Cullor, 2000). The use of on-farm pastuerizers may reduce risk of transmission of disease to calves fed waste milk. However, to date, few research trials have been conducted to determine the effectiveness of these systems. There are conflicting reports on effectiveness of pasteurization in killing *Mycobacterium paratuberculosis.* Stabel (2000) reported that pasteurization effectively killed the *M. paratuberculosis* organism. However, Millar et al. (1996) reported finding *M. paratuberculosis* DNA in pasteurized milk available for retail purchase in the United Kingdom. Differences in methods of pasteurization utilized in Europe and the high temperature short time method used by Stabel (2000) may account for differing results.

Another concern with feeding waste milk is the likelihood that antibiotics are present. Selim and Cullor (1997) tested 189 samples of milk offered to calves on 12 different dairy farms for presence of ß-lactams and tetracycline. Sixty-three percent of these samples were positive for antibiotics. Antibiotic contaminated milk may alter gut microflora of calves and result in digestive upsets. Selim and Cullor (1997) reported that Escheria coli cultured from waste milk samples was resistant to antibiotics with less than one third of the samples being sensitive to tetracycline or ampicillin. Wray (1990) reported that milk containing antibiotics was less palatable, and that calves fed antibiotic milk had reduced rates of gain. Possible reasons for reduced rates of gain include interference with rumen microflora, presence of pathogens, and decreased intake of milk DM. However, in a short-term study, Wray (1990) found no evidence of increased

antibiotic resistance of the gut micro flora in calves fed milk containing antibiotics. Even so, producers should use waste milk as a calf feed with caution given the possible risk of digestive upsets due to presence of pathogens and antibiotics.

Concerns with safety of feeding waste milk and economics of feeding saleable milk are likely reasons why MR is fed. Over 60% of the herds in the NAHMS (1996a) surveys reported using MR as a feed for calves. Earlier in this treatise, an extensive discussion has been presented on the formulation, protein source, energy source, and feeding of milk replacers as it relates to calf performance and health; these topics will not be discussed here. However, data presented by NAHMS (1996a) indicate that MR is a very effective feed for young calves.

Although, feeding roughages in the first 20 d of a calf's life reduces risk of disease (Losinger and Heinrichs, 1997). It is unclear why calves fed roughages in early life were at a decreased risk of mortality in the NDHEP. From a physiological standpoint, feeding roughages to young calves is detrimental because these feeds have a lower energy density than liquid feed or calf starter. There is a positive correlation between intake of calf starter and rumen development (Warner et al., 1956). One would expect consumption of hay in young calves to be detrimental to their health and result in increased mortality and morbidity, but results of the NDHEP indicate that the opposite is true. Therefore, the relationship between calf mortality and early intake of roughage should be examined in more depth.

Housing

Hartman (1974) found a relationship between calf housing and mortality. Calves that were housed in elevated pens had lower mortality than calves raised in pens. They concluded that facilities that allow closer observation of calves allow early detection and treatment of disease. However, James et al. (1984) found no relationship between calf housing and mortality in Virginia herds. Between 1974 and 1984, the use of calf hutches for calf housing increased. Calf hutches provide an environment that is more conducive to respiratory health, and may explain the different conclusions that James et al. (1984)

and Hartman (1974) found regarding the relationship between housing and mortality. Heinrichs (1993) reported that stress factors related to calf housing environment have an impact on incidence of disease. This hypothesis was supported by the increased level of mortality that was observed in calves housed in groups before weaning (NAHMS, 1996a). Calves fed in groups before weaning are more likely to transmit disease by calf-to-calf contact. Miller (1980) reported that respiratory disease was clustered within calf crops, indicating that calf-to-calf contact may play a role in spreading respiratory infections. If one calf in the group develops an infectious disease, then the other calves in the group are at an increased risk of infection, morbidity, and mortality.

Other considerations

Inbreeding is also becoming a concern in Jerseys. The average degree of inbreeding for Jersey calves registered in 1999 approached 6% (Wolfe, 2001a). Inbreeding has a negative impact on milk production (Miglior et al., 1992) and on reproductive performance (Hermas et al., 1987). However, few researchers have attempted to determine the impact of inbreeding on calf survival rates in Jersey herds. Young et al. (1969) summarized research from several university herds with lines of inbred and outbred cattle. Calves produced by mating parents from related genetic lines had lower birth weights and a lower survival rate than calves produced by mating parents from unrelated genetic lines. It is logical to assume that inbreeding would have a similar effect in Jersey calves.

Justification

The NAHMS (1993) and (1996a) collected data on management characteristics associated with the long-term performance of dairy calves. The objective of this NAHMS survey was to establish benchmarks for health and management of the United States dairy calf and heifer population. The NDHEP survey on calf mortality represented 78% of the national dairy cow population. However, only 2.4% of the herds surveyed were Jersey herds (Heinrichs et al., 1994). Table 3.1 summarizes management practices associated with calf mortality. It is likely that similar factors and management practices

(i.e., herd size, rolling herd average, feeding practices, calf housing, and the gender of the primary calf feeder) influence mortality in Jersey calves. Jersey calves are unique due to their lighter BW and smaller frame-size. Therefore, the risk factors associated with mortality in Jersey calves may differ from those associated with mortality in Holstein calves. Very few researchers have attempted to characterize the relationship between management practices and Jersey calf mortality. A better understanding of the relationship between calf mortality and management practices in Jersey herds will lead to a reduction in calf mortality.

Objectives

Our objectives were to determine the level of Jersey calf mortality in the United States; characterize management practices associated with calf mortality; identify differences in heifer management practices by level of milk production; assess the relationship between region of the country, herd size, level of production, and other management practices with calf mortality; and to identify opportunities for improvements in Jersey calf and heifer management.

Chapter Four
Materials and Methods

Calf Feeding Trial

Experimental procedure:

Thirty-three Jersey bull calves were assigned to four diets in a randomized complete block design. An additional 6 calves were assigned sacrificed at seven d of age to establish baseline composition. Calves were blocked by farm of origin. Calves were fed for four wk. In the 4th wk of treatment, calves were placed in metabolism crates for total collection of urine and feces. At the end of the 4th week, calves were sacrificed to enable body composition analysis.

Animals:

The experimental protocol was approved by the Virginia Tech Animal Care and Use Committee. Male Jersey calves were acquired from one of two sources: the Virginia Tech Dairy herd (n=10) or a Jersey breeder (n=32) located 100 km from the University. At birth, all calves were each fed 1 L pooled colostrum obtained from cows in the Virginia Tech Dairy herd and 1 L of high quality colostrum from the farm of origin. Colostrum from cows in the Virginia Tech dairy herd was collected and frozen (-20°C). Prior to the study the colostrum was thawed and warmed to 20°C. A colostrometer was used to determine specific gravity of colostrum and make an indirect assessment of immunoglobulin concentration as described by Fleenor and Stott (1980). Colostrum with a high immunoglobulin concentration (>50 mg/ml) was mixed in a clean, sanitized 189 L container and then transferred to 1 L bags and frozen (-20°C). Calves were fed an

additional 2 L of colostrum from the farm of origin at 12 h of age. From d 2 to 4, calves were fed a 21/21 MR at 10% of birthweight as fed. Three of the purchased calves died after being transported but before being assigned to treatment and were not replaced due to limited supply of Jersey bull calves.

At birth, vaccinations were administered for bovine rhinotracheitis and parainfluenza 3 (TSV-2, Pfizer Animal Health, Exton, PA), and rota- and corona virus (Calf Guard, Pfizer Animal Health), and five clostridial diseases with a toxoid (Vision Seven, Bayer Corp.). Calves received 1 ml of BoSe s.c. (.5 mg of selenium, 34 IU of vitamin E; Schering-Plough Animal Health Corp., Union, NJ), and Vitamin A and D (250,000 IU vitamin A, 37,500 IU vitamin D; Phoenix Pharmaceutical, Inc., St. Joseph, MO).

Calves were housed in separate location from the Virginia Tech dairy herd in an attempt to maintain biosecurity. All calves were fed a 20% CP, 20% fat, milk replacer (MR) (Dairy Partners, Winchester, TN) reconstituted to 12.5% DM from arrival until assignment to treatment. This adjustment period allowed the calves to be trained to drink from an open bucket. The first 15 calves received were fed 454g of MR (Dairy Partners, Winchester, TN) reconstituted to 12.5% powder at 06:00 and 16:00 h. Calves with a fecal score >2 were administered 1 L/d electrolytes (Entrolyte H.E, Pfizer Animal Health, Exton, PA). Calves were assigned to their treatment diets 5 d after arrival. The protocol for handling calves from arrival until assignment to treatment was later modified due to higher than acceptable death loss (3 out of 15) in calves between arrival and assignment to treatment. In the modified policy, calves were fed 1 L of oral electrolytes (Blue Ribbon Electrolyte^{TM}, Merricks, Middletown, WI) prior to being transported. Calves were fed MR twice daily for 5 d after arrival, 1 tablet of Sulfa-Max III (Agri-Labs) was dissolved in their MR. All calves were offered 1 L of oral electrolytes (Blue Ribbon Electrolyte^{TM}, Merricks, Middletown, WI) at 22:00 h until assignment to treatment.

Calf health was monitored daily. Fecal scores (1 to 4; 1=firm and 4= watery) were scored using the method of Diaz et al. (2001) and recorded daily. Body temperature was

recorded daily for the first 7 d after arrival and thereafter on Fridays. Respiratory scores were recorded daily (1 to 3; 1=health, 2=abnormal breathing but no fever, and 3 = fever, temp >39.8°C).

The following scour treatment protocol was used. When fecal score exceeded 2, or calves were off feed 50cc, of Gastrocote™ (Butler, Dublin, OH) was added to milk or MR for five consecutive feedings and calves received 1 L oral electrolytes (Blue Ribbon Electrolyte™, Merricks, Middletown, WI) in an open bucket at 22:00 h. If calves had a fecal score greater than 3 they recieved an additional 1 L of electrolytes at 13:00 h. Calves that had 2 consecutive d of fecal scores >3 were fed 20 g Gammulin™ (American Proteins Corporation, Ames IA) for 6 consecutive feedings. Regardless of fecal score the amount of MR and milk offered was not reduced. One calf (calf #18, diet 21/21) became weak and could not stand without assistance. He was treated with 1 L of warm (39°C) lactate ringers solution administered in 4 locations s.c., within 12 h he appeared to be thrifty.

Diets:

Thirty-nine calves were assigned randomly among four treatments at 4 to 7 d of age. Six calves were sacrificed 4 d after arrival to establish baseline body composition. Eight calves were assigned to milk; these calves were fed whole milk. Milk from two Jersey cows and bulk tank milk were blended to make a blend of milk that contained approximately 4.7% fat and 3.2% true protein. Nine calves were assigned to diet 29/16; these calves were fed a 28.5%, CP 16.4% fat MR. Eight calves were assigned to diet 27/33 and were fed a 27.3% CP 33.4% fat MR. Eight calves were fed a 20.6% CP, 20.6% fat MR (diet 21/21). Table 4.1 shows nutrient content of diets fed.

Table 4.1. Diet specifications on a powder basis.

	21/21	**27/33**	**29/16**	**Milk**	**Milk[C]**
DM, %	97.3	97.3	97.3	14.0[A]	97.3
Crude protein, %	20.6	27.3	28.5	3.5	24.3
Crude fat, %	20.6	33.4	16.4	4.8	33.4
Lactose+ash, %	58.8[B]	39.3[B]	55.1[B]	5.7[B]	39.6
Gross Energy, kcal/g	5427	6228	5357	848	5815
Crude fiber, %	0.15	0.15	0.15		
Calcium, %	0.90	0.90	0.90		1.00
Phosphorus, %	0.70	0.70	0.70		0.75
Iron, ppm	100	100	100		3.00
Copper, ppm	10	10	10		1.10
Cobalt, ppm	0.1	0.1	0.1		0.01
Zinc, ppm	40	40	40		38.00
Manganese, ppm	40	40	40		0.40
Iodine, ppm	1.02	1.02	1.02		0.20
Selenium, ppm	0.30	0.30	0.30		0.15
Vitamin A, IU/kg	9091	9091	9091		11500
Vitamin D_3, IU/kg	2273	2273	2273		307
Vitamin E, IU/kg	45	45	45		
Thiamine, mg/kg	6.61	6.61	6.61		3.30
Riboflavin, mg/kg	6.61	6.61	6.61		12.20
Niacin, mg/kg	2.64	2.64	2.64		9.50
d-Pantothenic Acid, mg/kg	13.22	13.22	13.22		25.90
Biotin, mg/kg	0.11	0.11	0.11		0.03
Ascorbic Acid, mg/kg	110	110	110		120
Pyridoxine Hydrochloride, mg/kg	6.61	6.61	6.61		4.40
Folic Acid, mg/kg	0.55	0.55	0.55		0.60
Vitamin B_{12}, mg/kg	0.07	0.07	0.07		0.05
Choline Chloride, mg/kg	1322	1322	1322		1080

[A]Estimated.

[B]Lactose+Ash determined by difference.

[C]Minerals and vitamin values adapted from (Toullec, 1989) values expressed on a 97.3% DM basis.

Target daily level of intakes for milk, 29/16, and 27/33, provided sufficient CP to support maintenance, plus 650g ADG. The level of intake was adjusted weekly based on change in BW from the previous wk for each calf. Diets were adjusted using the method suggested by (Blaxter and Mitchell, 1948) as adapted by NRC (2001), e.g., a 30-kg calf gaining 650g/d requires 181g of crude protein. Calves fed 21/21 served as a control and were fed MR at 15% of BW, readjusted weekly.

After the initial pretreatment adjustment period, calves were fed 3 times per d (0600, 1200, and 1800 h). Milk or MR was offered in an individual open bucket and calves. Refusals were recorded 30 min after the meal was offered. Fresh water was available ad lib and intake was recorded once daily. No dry feed was offered. Calves were housed in calf hutches located on a bed of coarse gravel.

Digestibility study:

During the 4th week of treatment, calves were housed in metabolism crates (75 cm by 150 cm) for 5 d [**29/16** (n=6), **27/33** (n=6), **21/21** (n=5), and **milk** (n=5)]. The first 2 d of the collection period allowed the calves to adapt to the crate. Diets were fed at 06:00, 12:00, and 16:00 h. Fresh water was available at all times. Calves were monitored frequently, and total collection of feces and urine was conducted on d 4 and 5 of the collection period. Urine was weighed at 6-h intervals, acidified (22 ml of 6N HCl/kg of urine), pooled, subsampled after 24 h, and stored frozen for later analysis. Feces were collected in palpation sleeves attached to the calves using velcro^{TM}. Feces were weighed once daily and frozen for later analysis. Milk and MR were sampled once during each collection week. Calves consumed all of the milk or MR offered with no refusal. Fecal samples were composited and a subsample was air dried at 80°C in a Wisconsin drying oven for 7 d to >90% DM and ground for later analysis. Fecal Samples were ashed at 600°C for 14 h. Dry matter, kjeldahl, and ether extract analysis on fecal samples and kjeldahl analysis on urine were conducted by the Virginia Tech Forage testing lab.

Weekly measurements:

Calves were weighed, and measured for hip height, wither height, heart girth, and body length, and blood samples were obtained, at 14:00 h Friday following arrival and then weekly each Friday thereafter.

Blood samples:

Two blood samples were taken by jugular venipuncture. One sample was collected in a vacutainer (Becton Dickinson, Franklin Lakes, MN) treated with Potassium EDTA and the second sample was collected in a heparinized vacutainer (Becton Dickinson, Franklin Lakes, MN). Whole blood was centrifuged for 5 min at 13,700 x *g* (Autocrit Ultra3, Clay Adams) to determine packed cell volume. Calves with packed cell volumes >30 were considered dehydrated and were monitored closely for changes in fecal scores. Plasma was isolated by centrifugation at 3200 x *g* for 20 min, and stored frozen for later analysis. Samples were analyzed for plasma glucose (Glucose kit procedure No. 510, Sigma Diagnostics, St Louis, MO) and NEFA (NEFA C kit, Wako Chemicals GmbH, Neuss, Germany). Samples were analyzed for PUN using the urease and indophenol reaction (Chaney and Marbach, 1962; Weatherburn, 1967). Absorbance of samples was read on a Microplate Autoreader (Bio-tek instruments, Fredrick, MD) at dual wavelengths of 405 nm and 625 nm.

Environmental conditions:

Daily temperatures averaged 20°C in August, 17°C in September, and 11°C in October at the Blacksburg, VA (Latitude 37 11N Longitude 080 25W) National Weather Station. Average precipitation was 8 to 9 cm/mo from August to October. Therefore, we concluded that environmental conditions did not increase maintenance energy requirements due to cold stress.

Sacrifice procedure and body composition:

Baseline calves (n=6) were sacrificed at 5 to 7 d of age. Six of the 9 calves assigned to each of the other diets 29/16 (n=7), 27/33 (n=6), 21/21 (n=6), and milk (n=5) were sacrificed at the end of the 4th week of treatment. By design, 2 of the calves sacrificed per diet were to be from the Virginia Tech herd, inadvertently, all of the calves sacrificed on 21/21 were purchased calves. Two or three of the calves sacrificed from each diet, **29/16** (n=2), **27/33** (n=2), **21/21** (n=3), and **Milk** (n=3), were placed in metabolism crates for 5 d prior to slaughter and the remaining calves were housed in hutches until sacrifice. Body composition of calves housed in hutches or metabolism crates for 5 d prior to slaughter was evaluated. Calves were slaughtered by captive bolt and exsanguination in the necropsy room of the Virginia-Maryland Regional College of Veterinary Medicine. Blood was collected into a tared plastic bag. The gastrointestinal tract was removed, weighed, stripped of its contents, and reweighed. The calf was separated into the following components: 1) head, hide, feet, and tail (HHFT); 2) internal organs and blood (BO); and 3) carcass (CAR). The carcass fraction was divided and the left half was discarded. Each component was weighed, bagged, frozen (-20°C) and later transported to Cornell University for further processing. Each component was ground seven times in a grinder (Model 8016, Autio Co., Astoria, OR, 10 mm screen). Grab samples of each component from each animal slaughtered were collected, bulked, subsampled, weighed, and refrozen at (-20°C) for later analysis of DM, CP, fat, ash, and gross energy (GE).

Analysis of tissue samples:

Samples were freeze dried for 72 h with shelf temperature set at 24°C (VirTus 20 SRC-X; The VirTus Co., Inc., Gardiner, NY). Samples were turned after 24 h to ensure drying in 72 h. This procedure dried samples to >90% DM.

Crude protein (N), ash, and ether extract were analyzed by Cumberland Valley Analytical Services, Hagerstown, MD. To determine N, 0.08g of pelleted tissue was analyzed (Nitrogen Combustion Analyzer, Leco FP-528. Leco, 3000 Lakeview Avenue, St. Joseph, MI) according to AOAC, (1990) standards. Ash was determined by placing 0.5 g of material in a furnace at 550°C for 2 h according AOAC, (1990). Ether extract analysis

was conducted by extracting 1g of material with anhydrous ether in Soxtet unit for 45 min according to AOAC, (1990) standards. Moisture was analyzed according to AOAC, (1990), approximately 1g of sample was dried at 135°C for 2 h. Gross Energy (GE) was determined by bomb calorimetry (Parr Model 1281, Parr Inc, Moline, IL).

Calculations

Empty body composition (EBW) was calculated for each individual as:

$$EBW_i = CAR_i + HHFT_i + BO_i \quad (1)$$

Empty BW gain (EBG) was calculated for each individual as:

$EBG_i = EBW_i -$ [initial live BW_i * RLBW]

where RLBW is the ratio of live EBW to BW in baseline calves.

(2)

Empty body composition in terms of quantity of fat, CP, ash, and water was calculated for each individual as:

grams of $component_i$= [(grams of CAR_i)* (% component in CAR_i)] + [(grams of $HHFT_i$) * (% component in $HHFT_i$)] + [(grams of BO_i) * (% component in BO_i)]. (3)

Body composition as a % was calculated for individual animals as:

% component in EBW(i) = component(x)/EBW(i) (4)

Digestibility of nutrients (fat, CP, and GE) was calculated for individual animals as:

digestibility of $nutrient_i$= (intake of $nutrient_i$ – fecal output of $nutrient_i$)/intake of $nutrient_i$ (5)

Apparent partial efficiency (APE) of use of nutrients (fat, CP, and GE) was calculated for each individual as:

APE of $nutrient_i$= EBG of $nutrient_i$/[total intake of $nutrient_i$* digestibility of nutrient] (6)

Retention of N was calculated for individual animals as:

digestibility of nutrient$_i$ = [intake of nutrient$_i$– fecal output of nutrient$_i$ - urinary output of nutrient$_i$]/intake of nutrient$_i$ (7)

Statistical design and analysis:

Calves were assigned to treatment in a randomized complete block design where farms were blocks. Calves were also blocked by whether or not they were placed in a metabolism crate. However, no differences were detected due to this blocking factor so it was not included in the model. Initial measurements, i.e. BW, girth, wither height, hip height, PUN, NEFA, or glucose, were used as a covariate.

For weekly measurements the following model statement was:

$$Y_{ijkl} = \upsilon + D_i + F_j + DF_{ij} + C_{(ij)k} + B_1 (\bar{A}_k - \bar{A}_.) + W_l + WD_{il} + WDF_{ijl} + E_{ijkl}$$

Where:

$B_1 (\bar{A}_k - \bar{A}_.)$ = the covariate term for measurement at time 0

D = diet (i =1…4); fixed effect

F = farm (j = 1, 2); random effect

W = week (l=1…4); fixed effect

C = calf (k=1…8); (total of 33 calves); random effect

E = residual.

The main effect was tested using the diet by farm interaction (DF_{ij}) as the error term. Significance was declared at $P < 0.05$. Means were separated using a Tukey test.

For variables that were only measured once during the experiment:

$$Y_{ijk} = \upsilon + D_i + F_j + DF_{ij} + E_{ijk}$$

Where:

D = diet (i = 1…4); fixed effect

F = farm (j = 1, 2); random effect

E = residual; (k = 1…33, 1…10)

The interaction between diet and farm (DF_{ij}) was not included for analysis of body composition because all of the calves fed diet 21/21 were purchased.

Data measured daily or weekly was analyzed using Proc GLM with repeated measures (SAS, 2002). Data measured only one time during the experiment was analyzed using Proc GLM (SAS, 2002). Health and fecal scores were analyzed using the Proc Freq (SAS, 2002).

Calf management survey

Jersey herds were selected from 622 herds participating in the American Jersey Cattle Associations (AJCA) performance programs in 1999. These herds ranged from 1 to 1267 completed lactations for a total of 43,271 lactations.

Herd selection

From the list of 622 herds provided by the AJCA, 181 herds with fewer than 20 completed lactations were deleted from the list. They represented 1626 completed lactations, or 3.8% of the total. Herds with more than 20 completed lactations (n=442) located in AZ, CA, ID, IN, PA, OH, OR, NC, NH, NY, KY, SC, TN, VA, VT, WA, and WI were used as the pool from which survey participants were selected. These states were selected because they represented 30,798 completed lactations (71.2%) of the Jerseys enrolled in performance programs. These states also were selected due to proximity of herds to each other in regions. They were grouped into the five regions: **SEAST** (KY, TN, VA, NC, and SC); **PAOHIN:** (PA, OH, and IN); **NEAST:** (NH, VT, and NY); **WIS:** (WI); and **WEST:** (AZ, CA, OR, WA, and ID).

Within each of these regions, herds were stratified by rolling herd average milk production, and herd size. Herds invited to participate were randomly selected by region, with-in each herd size and milk production stratification. Eighty-eight herds participated in the survey divided across regions, **SEAST** (n=16), **PAOHIN** (n=25), **NEAST** (n=17), **WIS** (n=8), and **WEST** (n=22).

Herds selected to participate were mailed a copy of the survey (see Appendix C) and asked if they would participate. If a herd refused to participate then an alternate herd was selected. Reasons for refusal included: no response to initial mailing and follow-up phone calls, herd dispersal, or lack of interest.

Each survey was conducted by face-to-face interview by one of two persons. Data was collected from December 2000 to June 2001.

Survey design and implementation

The survey was modeled after a survey conducted by Winston in1998 as part of a NC-119 project (Appendix C). Questions in the survey covered nutrition and care of the dam prior to calving, calving location and facilities, colostrum feeding, nutrition of preweaned calves, management of preweaned calves, housing of preweaned calves, replacement herd health, and records.

Statistical analysis

The Proc Corr procedure in SAS (2002) was used to detect significant ($P<0.10$) correlations between mortality and management factors. The Proc Univariate procedure in SAS (2002) was used to test the distribution of mortality from 1 day of life to 3 mo (M3) and mortality in the first 24 h, including stillbirths (M24) for normality. The Cramer-Von Misses statistic (SAS, 2002) indicated that neither M3 nor M24 were normally distributed. Therefore, the data were transformed as follows: NlogM3= nlog(M3+1) and NlogM24 = nlog(M24+1). The transformed data had a more normal distribution according to the Cramer-Von Misses statistic and the transformed data were analyzed with Proc Reg. Variables that were correlated to mortality with a $p<0.30$ (NlogM3 and NlogM24) were analyzed with Proc Reg in SAS using the stepwise elimination so that variables entered the model if $P<0.50$ and stayed if $P<0.05$. Outliers were identified by regressing M3 and M24 and selecting residuals (observed mortality minus predicted) that exceeded 3.5 times root MSE (Gill, 1978). After the outliers were removed, the stepwise regression procedure on the transformed data was repeated to identify prediction equations for Nlog(M3+1) and Nlog(M24=1). The predictor variables identified were analyzed using Proc Reg to determine appropriate coefficients for both M3 and M24.

Chapter Five

Influence of Dietary Fat and Protein Ratios on Body Composition of Jersey Bull calves.

Results and Discussion

Diets

The nutrient content of diets fed is detailed in Table 5.1. The experiment was designed to deliver equivalent amounts of protein to calves fed MILK, 27/33, or 29/16 and to deliver equivalent amounts of fat to calves fed MILK or 27/33. However, calves fed MILK consumed approximately 10% more fat than calves fed 27/33 (Table 5.2).

Growth

Calves fed MILK had higher ADG, BW gain, and feed efficiency than calves fed other diets (Figures 5.1 and 5.2, and Table 5.2, respectively). Calves fed 21/21 had the lowest ADG, weight gain, and feed efficiency, whereas calves fed 29/16 and 27/33 were intermediate. Calves fed 27/33 consumed more energy than calves fed 29/16, but ADG, total weight gained, and feed efficiency were not different. Calves fed MILK consumed similar grams of protein to calves fed 27/33 or 29/16 and consumed more fat, had greater ADG, greater total weight gains, and more efficiently converted feed to gain than calves on other treatments. Given that calves fed MILK and 27/33 consumed similar grams of protein, and that calves on both diets consumed more grams of fat than calves fed 29/16**,** it seems reasonable to expect growth of calves fed 27/33 would exceed calves fed 29/16 and be similar to the patterns of growth of calves fed MILK. The MR formulations were similar to whole MILK in nutrient content (Table 5.1) and the MR met or exceeded NRC (2001) requirements. Perhaps MILK contains unidentified growth factors not present in the MR fed or perhaps the metabolism of fat in the 27/33 is different than in MILK.

In wk 3 and 4, calves fed 21/21 were lighter than the calves fed the other diets (Figure 5.3 and Table 5.3). Over time, the difference in weight between calves fed 21/21 and other diets increased. These calves gained 110 g per day, indicating that feeding Jersey bull calves a 21/21 MR at 15% of BW is adequate to maintain BW but supports only a modest rate of gain. Feeding MR at 8 to 10% of BW is a common recommendation (Davis and Drackley J.K., 1998). Calves were not offered starter, which could account at least partially for the low rates of gain of calves fed 21/21. Mowrey (2001) fed Jersey calves MR (20% CP, 20% fat) at 31% of metabolic weight (about 10% of BW as fed). By design, the Jersey calves should have gained >7 kg from birth to 30 d of age but these calves only gained 3 kg. Results reported by Mowery indicate that feeding Jersey calves a 20% CP, 20% fat MR at 8 to 10% of BW supports only modest rates of ADG. Therefore, the current recommendation for feeding Jersey calves 8-10% of BW should be reconsidered and/or nutrient concentration of feeds offered should be increased.

No significant differences in hip height were detected between diets (Figure 5.4 and Table 5.3). However, calves fed MILK or 29/16 were taller than calves fed other diets. 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.

Calves had similar body lengths, wither heights, and heart girths across diets (Figures 5.5 to 5.7 and Table 5.3 and 5.4). A significant week by diet interaction was detected in wither height (Figure 5.6). Calves fed 21/21 appear to have had a slower rate of gain in wither height between wk 2 and 3 and then gain at a faster rate after wk 3. Body length, wither height, and heart girth are not particularly useful indicators of growth in calves due to the lack of precision in measuring these parameters, which leads to large standard errors.

Plasma indications of protein and energy metabolism

Feeding a MR that supplies more protein than the calf can utilize could result in elevated PUN. Calves fed 29/16 had PUN similar to other diets in wk 1 to 4 (Figure 5.8), indicating that feeding 180 g CP/day did not greatly exceed the calve's ability to utilize protein. Calves fed 21/21 showed a propensity toward lower PUN in wk 1 to 3, which would be expected since these calves were only fed 90 g CP/day. Few differences in blood glucose were detected, but calves fed 21/21 had lower levels of blood glucose at wk 4 than calves fed other diets (Figure 5.9). Diets varied in the amount of lactose fed (Table 5.1) but the similar level of blood glucose among diets indicates that blood glucose is tightly regulated in individual calves even though there is considerable variation between calves.

Calves fed 27/33 showed a propensity toward elevated NEFA (Figure 5.10). The increased NEFA in calves fed **27/33** is perplexing and indicates calves were mobilizing stores of body fat. However, these calves were gaining BW and depositing body fat similarly to calves fed MILK (Figure 5.11 and Figure 5.13). The source of fat in the MR was edible lard. Butterfat has a slightly higher digestibility than edible lard (Toullec et al., 1980), which may be due to the greater percentage of medium and short chained fatty acids in butter fat (Raven, 1970). Short and medium chain fatty acids (<C16:0) make up approximately 35% of the fatty acids in butterfat (Jenness, 1985), whereas less than 2% of the fatty acids in the edible lard in the MR fed were shorter than C16:0 (Fowler, 2002). However, digestibility of 27/33 and MILK were not different (Table 5.5) in this experiment. Tikofsky (2001) and Bartlett (2001) also reported elevated NEFA when Holstein bull calves were fed high fat MR. Similar observations have been made in lactating cows fed diets containing supplemental fat (Palmquist and Conrad, 1978). Elevation in NEFA accompanied with deposition of fat associated with feeding high fat MR to calves indicated that adipose tissue was turned over. However, when calves were fed a high fat diet in the form of whole milk (MILK), NEFA was not elevated. More research needs to be conducted to elucidate the mechanisms that elevate NEFA in calves fed high fat MR.

Health and water intake

Water intake varied considerably but few significant differences among diets were detected (Table 5.2 and Table 5.6). However, in wk 4 calves fed 29/16 consumed more water than calves fed 27/33 or MILK, and calves fed 27/33 tended to consume more water than calves fed 21/21 ($p=0.10$) (Table 5.6). It is unclear why calves fed 29/16 had greater water intake than the other diets in wk 4. Perhaps the higher level of lactose and ash in the diet resulted in an increase in osmolality thus promoting water intake but if this were the case one would expect the greater water intake in wk 1 to 3 (Table 5.6).

Average days scouring (days when calves had a fecal score that exceeded 2) were highest for calves fed 29/16 (6.1 d) and 27/33 (5.8 d) and were lowest for 21/21 (4.1 d). However, when fecal scores were averaged by week, the interaction between diet and week was significant ($p<0.01$) indicating that in wk 3 and 4, calves fed MILK had an increase in fecal score, while calves fed the other diets had a slightly decreased fecal score (Figure 5.14). Calves fed MILK tended to have a higher average fecal score in wk 4 than calves fed 21/21, 27/33, or 29/16 ($P<0.10$) but no other differences were detected. However, the average fecal score for calves fed MILK was less than 2 in wk 4, indicating that the calves had looser feces but were not scouring. A medication day was defined as any day that a calf received electrolytes or antibiotics. No differences were detected between treatments in days medicated as shown in Figure 5.15. Overall, health of the calves was similar among diets.

Digestibility and apparent efficiency of gain

Differences in digestion of N or fat were not observed among diets. Retention of N was similar among treatments with no differences observed in grams of dietary N/kg of gain (Table 5.5). These data indicate that digestibly of fat and N were similar among diets, and that digestibilities of fat and N in MILK were similar to the digestibility of these nutrients in other diets. Diaz et al. (2001) reported digestibilities of 93% for protein and 94% for fat in Holstein calves gaining 1100 g/day. Digestibilities for N were similar in

the current study but the total tract digestibility of fat was higher than reported by Diaz et al. (2001).

Apparent partial efficiency (APE) of use of fat, protein, and energy was calculated for each of the diets fed. Total amount of fat, protein, or energy in empty body weight gain (EBG) was divided by the total dietary intake of apparently digestible fat, protein, or energy, respectively. No differences were observed in APE of protein or energy among diets. However, the APE for fat was lower for calves fed 21/21 (Table 5.5). Tikofsky et al. (2001) fed Holstein calves isocaloric and isonitrogenous diets of MR containing 14.8, 21.6, or 30.6% fat on a DM basis. The APE for protein and energy were similar to the current study, but the APE of fat was 45 to 51% in Holstein calves, whereas the APE for fat was less than 40%. The lower APE for fat in Jersey calves may indicate that Jersey calves have a higher maintenance energy requirement than Holstein calves per unit of metabolic weight.

Body Composition

Composition of carcass (CAR); head, hide, feet and tail (HHFT); blood and organs (BO); and empty body (EB) are shown in Table 5.7. The CAR as a percentage of EBW was similar for calves on all diets and baseline calves, but calves fed MILK had more gross energy (GE) per gram of carcass than baseline calves and calves fed 21/21. Energy density of BO did not differ among diets or baseline calves but the BO as % of EBW was greater for calves fed 27/33 than for baseline calves. The difference in metabolic BW between calves fed 29/16, 27/33, or MILK and baseline calves or calves fed 21/21 indicate that baseline calves and calves fed 21/21 had a greater surface area than calves fed the other diets. A greater surface area per unit of BW would also explain the difference in HHFT as percentage of the EBW between baseline calves and calves fed 27/33, 29/16, or MILK (Table 5.7). Calves fed MILK had a greater energy density in the HHFT than baseline calves or calves fed 21/21. Calves fed MILK or 27/33 had more GE in the EB after 4 wk of treatment than calves fed other diets (Table 5.8). Calves fed 21/21 gained less GE in their EB than calves fed other diets. Calves fed 27/33 and MILK

had the greatest caloric content and greatest GE gains (numerically). Tikofsky et al., (2001) observed similar results in Holstein calves fed isocaloric diets; these calves gained more GE as the proportion of energy in the diet from fat increased.

While energy gains were not significantly different in calves fed 29/16, MILK or 27/33, fat % in EB was higher in calves fed high fat diets (Table 5.8, Figure 5.11 and 5.12). No other differences were detected in composition of gain. However, the higher percentage body fat in calves fed MILK or 27/33 indicates that increasing the fat percentage in the diet of Jersey bull calves resulted in an increased deposition of body fat. It is important to note that calves fed 29/16 or 21/21 had similar body fat percentage as baseline calves, indicating that these calves did not have any more body fat reserves after 4 wk of treatment than they did on the first d of treatment. Scibilia et al. (1986) reported that calves housed in environments below -4°C had lower ADG and required higher fat diets to maintain the same rates of gain as calves housed in warmer environments. Calves on this trial were not subjected to temperatures below -4°C, but if they had been, then the performance of the calves fed 29/16 or 21/21 may have been affected negatively. Quigley (1991 and 1996) reported that calves have elevated NEFA at weaning due to stress of weaning, which results in mobilization of body fat. Therefore, the low body fat percentage of calves fed 29/16 or 21/21 is a concern. More research needs to be conducted to determine the optimum body fat percentage of the preweaned calf.

Composition of EBG is shown in Figure 5.12 and Table 5.9. Differences in the composition of EBG, as a percentage of EBG, were not detected, but calves fed higher fat diets gained more fat (Table 5.9). Calves fed 21/21 had modest gains in BW (3.4 kg) and it is possible that our test lacked the necessary power to detect differences in composition of gain when EBG is modest.

Conclusions

Calves fed MILK showed superior performance (i.e. feed efficiency, ADG, and total weight gain) compared to other diets. Calves fed 29/16 and 27/33 showed similar

performance but calves fed 29/16 did not increase body fat percentage. Optimum percentage fat in a MR for Jersey calves fed 660 g of powder per day is greater than 16% but less than 33%. Feeding Jersey bull calves a 21/21 MR at 15% of BW is not advisable given that these calves were inferior to the other diets in feed efficiency, ADG, and total weight gain.

Table 5.1. Diet specifications on an as fed (powder) basis.

Variable	21/21	27/33	29/16	MILK	Milk[C]
DM, %	97.3	97.3	97.3	14.0[A]	97.3
Crude protein, %	20.6	27.3	28.5	3.5	24.3
Crude fat, %	20.6	33.4	16.4	4.8	33.4
Lactose+ash, %	58.8[B]	39.3[B]	55.1[B]	5.7[B]	39.6
Gross Energy, kcal/g	5427	6228	5357	848	5815
Crude fiber, %	0.15	0.15	0.15		
Calcium, %	0.90	0.90	0.90		1.00
Phosphorus, %	0.70	0.70	0.70		0.75
Iron, ppm	100	100	100		3.00
Copper, ppm	10	10	10		1.10
Cobalt, ppm	0.1	0.1	0.1		0.01
Zinc, ppm	40	40	40		38.00
Manganese, ppm	40	40	40		0.40
Iodine, ppm	1.02	1.02	1.02		0.20
Selenium, ppm	0.30	0.30	0.30		0.15
Vitamin A, IU/kg	9091	9091	9091		11500
Vitamin D_3, IU/kg	2273	2273	2273		307.00
Vitamin E, IU/kg	45	45	45		
Thiamine, mg/kg	6.61	6.61	6.61		3.30
Riboflavin, mg/kg	6.61	6.61	6.61		12.20
Niacin, mg/kg	2.64	2.64	2.64		9.50
d-Pantothenic acid, mg/kg	13.22	13.22	13.22		25.90
Biotin, mg/kg	0.11	0.11	0.11		0.03
Ascorbic acid, mg/kg	110	110	110		120
Pyridoxine hydrochloride, mg/kg	6.61	6.61	6.61		4.40
Folic acid, mg/kg	0.55	0.55	0.55		0.60
Vitamin B_{12}, mg/kg	0.07	0.07	0.07		0.05
Choline chloride, mg/kg	1322	1322	1322		1080

[A]Estimated.

[B]Lactose+Ash determined by difference.

[C]Minerals and vitamin values adapted from (Toullec, 1989) values expressed on a 97.3% DM basis.

Table 5.2. Total nutrient intake and performance of calves to day 26.

Variable	**21/21**	**27/33**	**29/16**	**MILK**	**SE**
Number of calves	8	8	9	8	
Liquid fed, kg	88.1[a]	145.8[b]	144[b]	138.6[c]	1.9
DM fed, kg	11.0[a]	18.2[b]	18.0[b]	19.4[c]	0.3
Average daily DM intake, kg[A]	0.42[a]	0.70[b]	0.69[b]	0.75[c]	
Protein fed, kg	2.26[a]	4.97[b]	5.13[bc]	4.90[b]	0.10
Fat fed, kg	2.27[a]	6.09[b]	2.95[b]	6.68[c]	0.10
Water intake, L	7.1[a]	13.4[ab]	16.4[b]	11.3[ab]	3.0
Average daily gain, g	110[a]	357[b]	368[b]	496[c]	26.0
Weight gained, kg	3.1[a]	10[b]	10.3[b]	13.9[c]	0.7
Feed efficiency (kg feed dm/kg gain)	0.282[a]	0.549[b]	0.567[b]	0.721[c]	0.041

[a, b, c] Values in a row with similar superscripts do not differ ($P<0.05$).
[A]Calculated as DM fed/26.

Table 5.3. Weekly heart girth, hip height, and weight.

		Heart Girth (cm)				Hip Height (cm)				Weekly Weight (kg)			
Diet	**N**	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 1**	**Week 2**	**Week 3**	**Week 4**
21/21	8	65.9	67.6	66.5	68.4	71.4	71.3	71.4	70.7	28.3	28.6	30.4[a]	31.2[a]
27/33	8	71.6	71.1	72.2	74.9	71.0	71.9	71.3	72.0	31.0	33.5	35.7[b]	38.7[b]
29/16	9	69.1	71.4	72.0	75.0	71.4	73.1	74.0	74.6	31.6	33.8	36.1[b]	38.8[b]
MILK	8	68.2	70.0	72.8	75.8	71.2	72.4	72.8	74.1	31.0	34.3	38.5[b]	42.0[b]
	Largest SE (of week)	1.6	1.5	1.4	1.5	1.1	1.1	1.0	1.1	0.1	0.1	0.01	0.01
	P (effect of diet)	0.37	0.74	0.14	0.17	0.97	0.38	0.57	0.19	0.1	0.1	0.01	0.01

[a.b.c] Values in the same column with the same superscripts do not differ (P<0.05).

Table 5.4. Weekly body length and wither height.

		Body Length (cm)				Wither Height (cm)			
Diet	**N**	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 1**	**Week 2**	**Week 3**	**Week 4**
21/21	8	65.8	65.0	68.1	67.7	70.0	70.2	68.7	71.2
27/33	8	65.9	68.7	71.4	70.6	70.0	70.9	72.1	72.9
29/16	9	67.6	69.4	70.6	72.5	70.0	70.0	72.5	74.4
MILK	8	66.9	67.7	71.4	71.0	69.3	71.4	72.4	75.2
	Largest SE (of Week)	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
	P (effect of diet)	0.48	0.22	0.42	0.34	0.68	0.64	0.41	0.23

Table 5.5. Nutrient retention and digestion.

Variable	21/21	27/33	29/16	MILK	SE	P
Nitrogen retention, g/kg gained	33.4	43.8	47.9	46.2	6.4	0.36
Nitrogen retained, %[A]	39.1	56.1	40.4	56.9	5.3	0.12
Nitrogen digested, %	83.2	90.0	89.6	92.6	1.3	0.12
Fat digested, %	97.3	96.9	98.8	97.8	0.6	0.20
APE fat, %[B]	10.8[a]	27.1[b]	30.3[b]	37.0[b]	5.7	0.02
APE protein, %[B]	79.6	48.5	59.1	71.7	27.3	0.80
APE GE, %[B,C]	22.7	32.2	37.3	30.3	8.5	0.56

[a,b]Values in the same row with the same superscripts are not different (P<0.05).
[A]Calculated from balance trial.
[B]Apparent partial efficiency (APE) calculated as (intake-gain)/(intake x digestibility).
[C]GE in MR by bomb calorimeter, GE in MILK calculated using formula: (9.21 x g fat) + (5.86 x g protein) + (3.95 x g lactose and ash) (Brisson et al., 1957; Lister, 1971).

Table 5.6. Weekly water intake (ml).

	21/21	27/33	29/16	MILK	SE	P
Week 1	310	573	380	234	170	0.60
Week 2	218	835	567	414	274	0.53
Week 3	313	539	733	603	138	0.35
Week 4	256[a]	492[b]	610[b]	274[ab]	46	0.03

[ab]Values in the same row with the superscripts are not different (P<0.10).

Table 5.7. Gross energy content of body components.

Variable	Baseline	21/21	27/33	29/16	MILK	SE	P
CAR, %EBW	30.0	31.1	31.4	31.3	31.9	1.5	0.89
GE CAR, kcal/g	4.3[a]	4.5[a]	4.8[ac]	4.7[ac]	5.1[bc]	0.2	0.01
BO, %EBW	16.6[a]	18.6[ab]	20.8[b]	19.3[ab]	20.4[ab]	1.1	0.07
GE BO, kcal/g	5.3	5.2	6.0	5.3	5.2	0.3	0.07
HHFT, %EBW	53.4[a]	50.2[ab]	47.8[b]	49.4[b]	47.7[b]	1.0	<0.01
GE HHFT, kcal/g	4.0[a]	4.0[a]	4.5[ab]	4.4[ab]	4.9[b]	0.1	<0.01

[a,b,c]Values in the same row with the same superscripts are not different (P<0.05).
Carcass (CAR), Blood and organs (BO), Head, hide, feet, and tail (HHFT).

Table 5.8. Composition of the empty body.

Variable	Baseline	21/21	27/33	29/16	MILK[A]	SE	P
Water, %EBW	65.4	58.4	58.8	58.7	57.6	3.6	0.44
Crude protein, %EBW	24.5	27.5	24.2	25.8	24.2	2.7	0.85
Ether extract, %EBW	2.8[a]	3.6[a]	6.8[b]	4.7[a]	8.2[b]	0.6	<0.01
Crude ash, % EBW	6.0	7.0	6.3	6.1	5.4	0.6	0.45
EBW, kg	24.9[a]	29.3[b]	37.1[c]	35.8[c]	35.5[c]	1.2	<0.01
GE EB initial, Mcal	37.5	40.2	41.9	40.5	36.0	2.0	0.19
GE EB final, Mcal		45.8[a]	66.6[b]	59.6[a]	69. 0[b]	5.9	0.02
GE gained, Mcal		6.9[a]	25.6[b]	20.1[b]	33.3[b]	5.9	0.02

[a,b]Values in the same row with the same superscripts are not different (P<0.05).
[A] for MILK GE calculated; GE = (9.21 x g fat) + (5.86 x g protein) + (3.95 x g lactose and ash) (Brisson et al., 1957; Lister, 1971).

Table 5.9. Changes in body composition.

Variable	21/21	27/33	29/16	MILK	SEM	P
Water gained, kg	1.32	4.37	4.75	5.48	1.53	0.16
Protein gained, kg	1.43	1.98	2.54	2.93	1.06	0.69
Fat gained, kg	0.16[a]	1.69[b]	0.83[a]	2.38[b]	0.24	<0.01
Ash gained, kg	0.46	0.62	0.57	0.54	0.23	0.95

[a,b]Values in the same row with the same superscripts are not different (P<0.05).

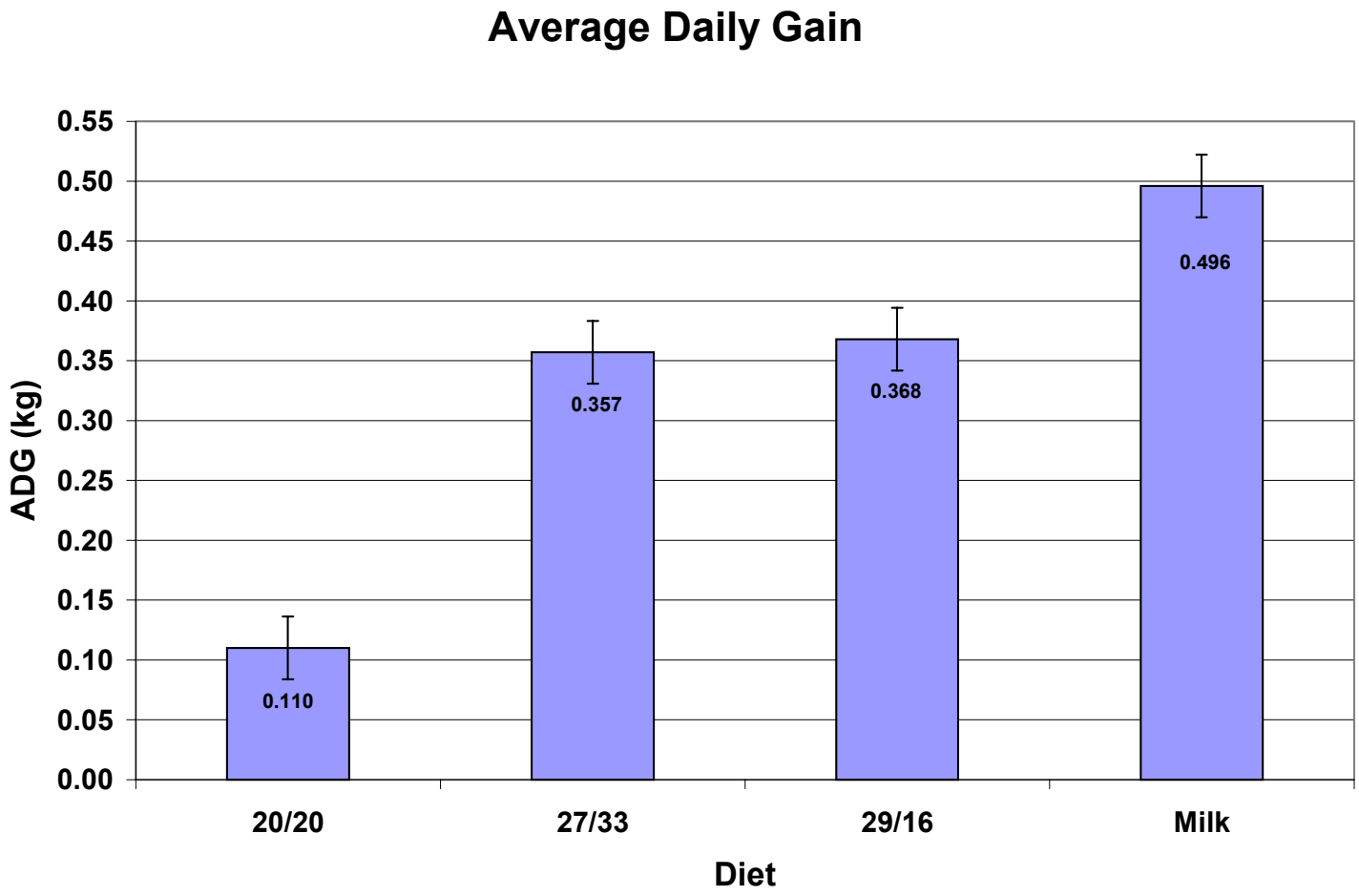


Figure 5.1. Average daily gains.

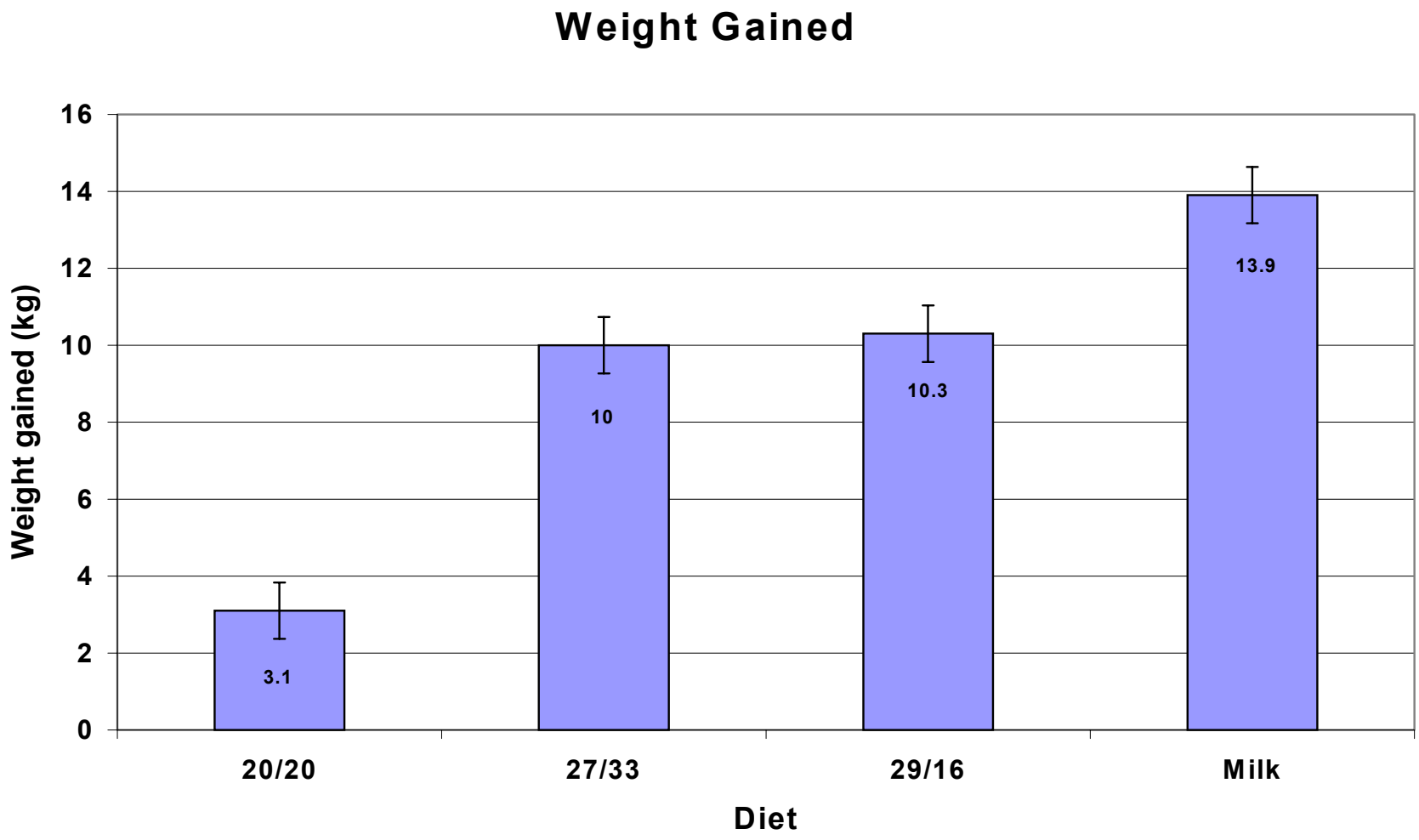


Figure 5.2. Total weight gained by diet.

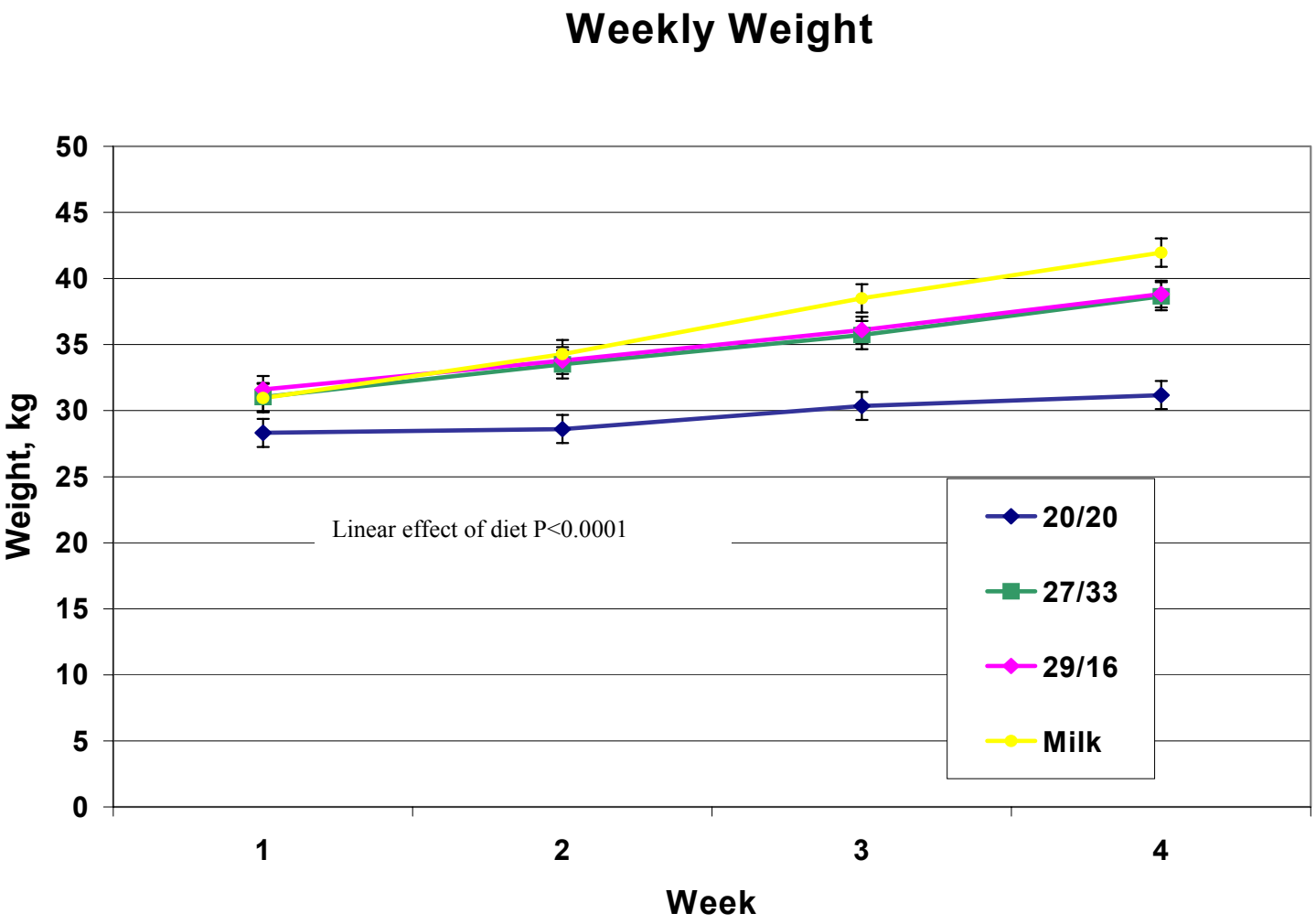


Figure 5.3. Weekly weight.

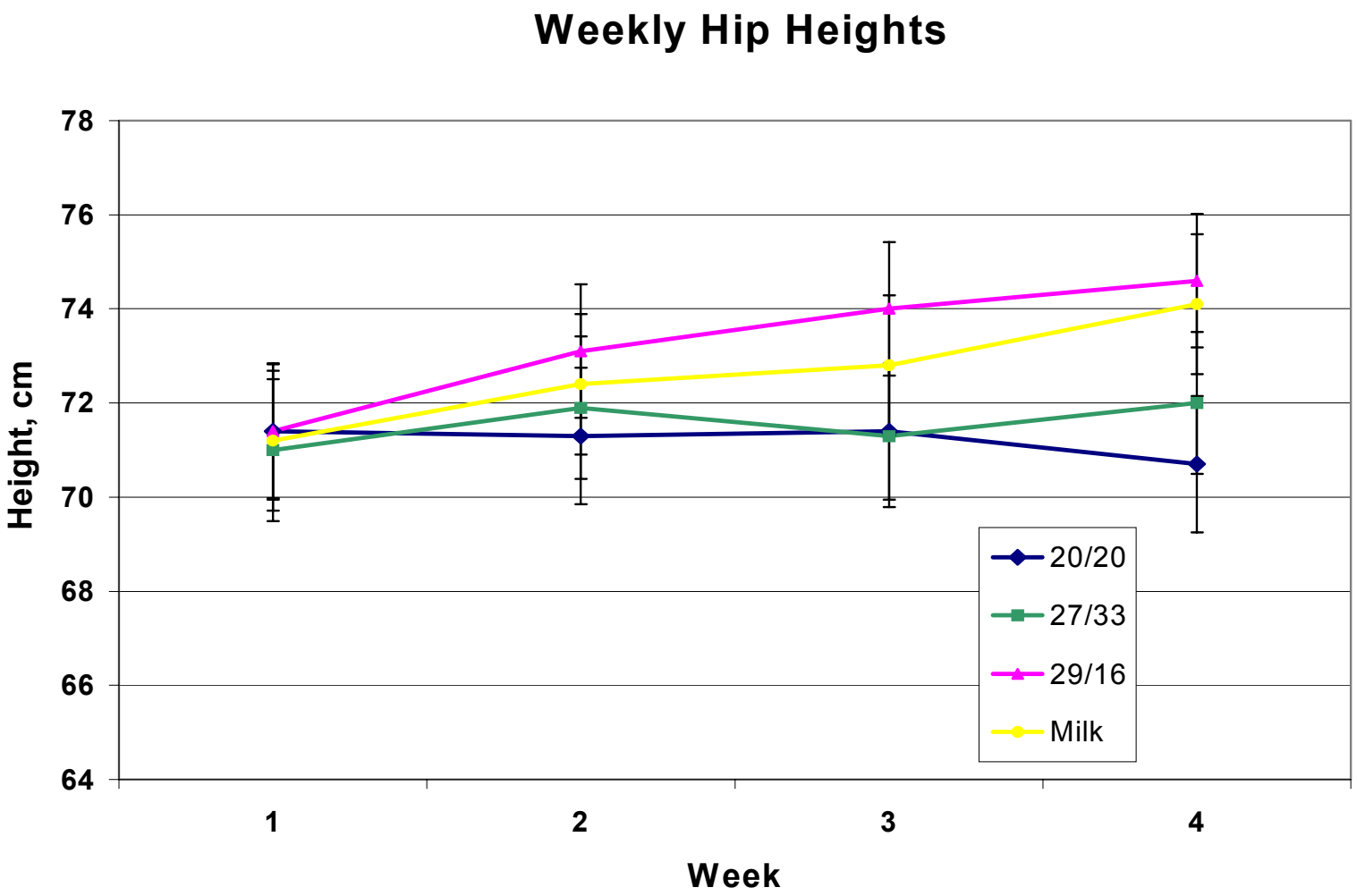


Figure 5.4. Weekly hip height.

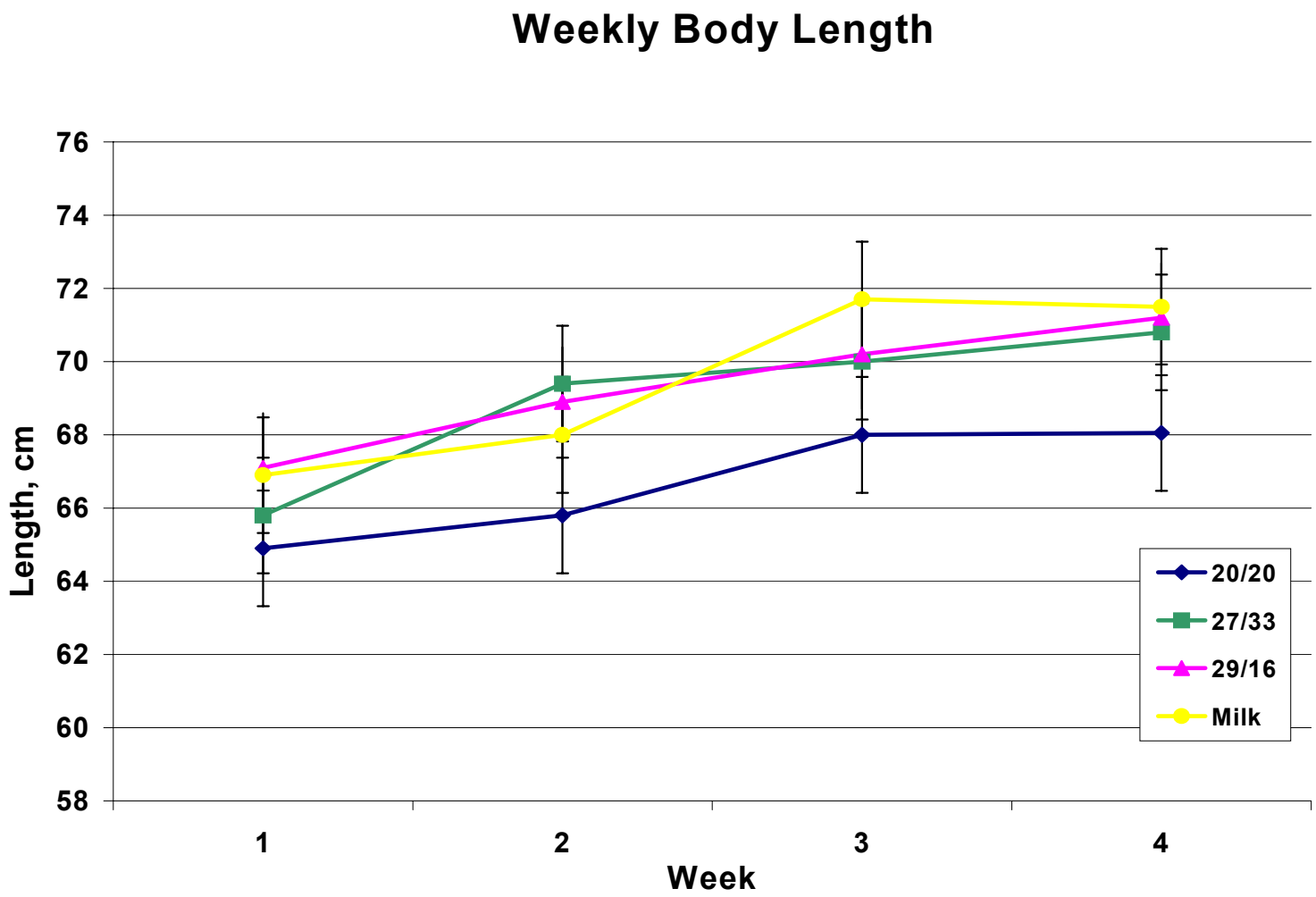


Figure 5.5. Weekly body length.

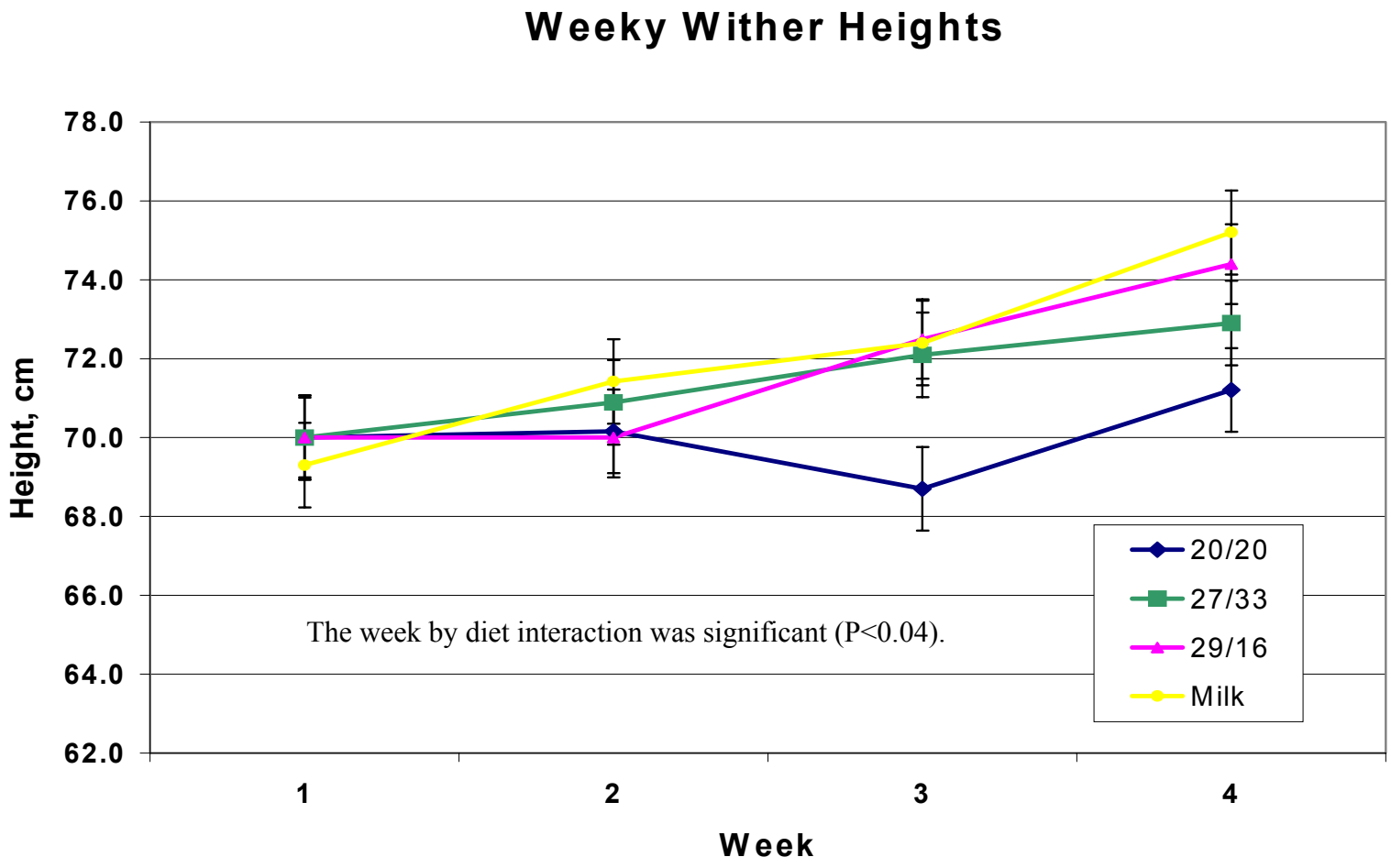


Figure 5.6. Weekly wither height.

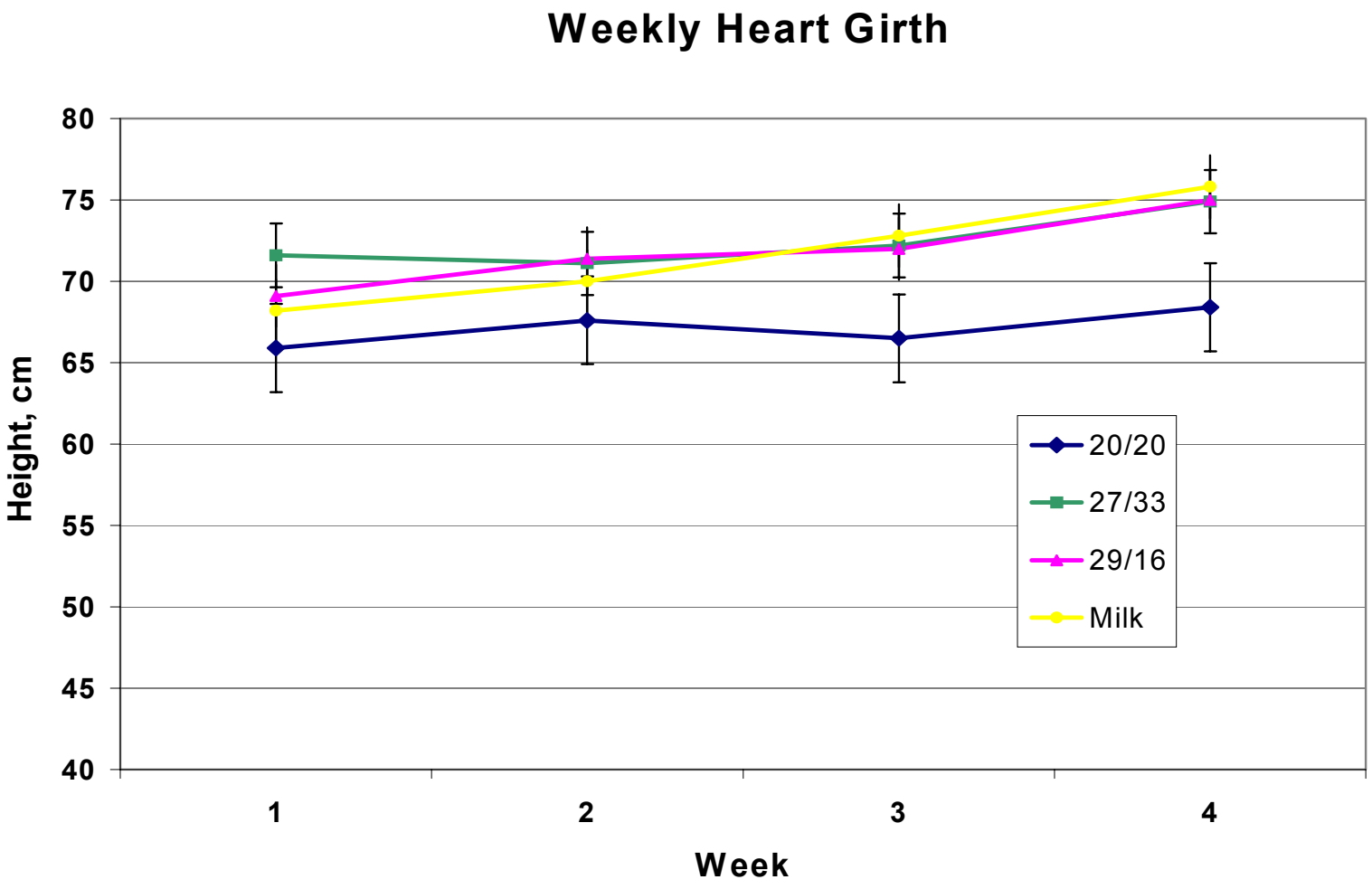


Figure 5.7. Weekly hearth girth.

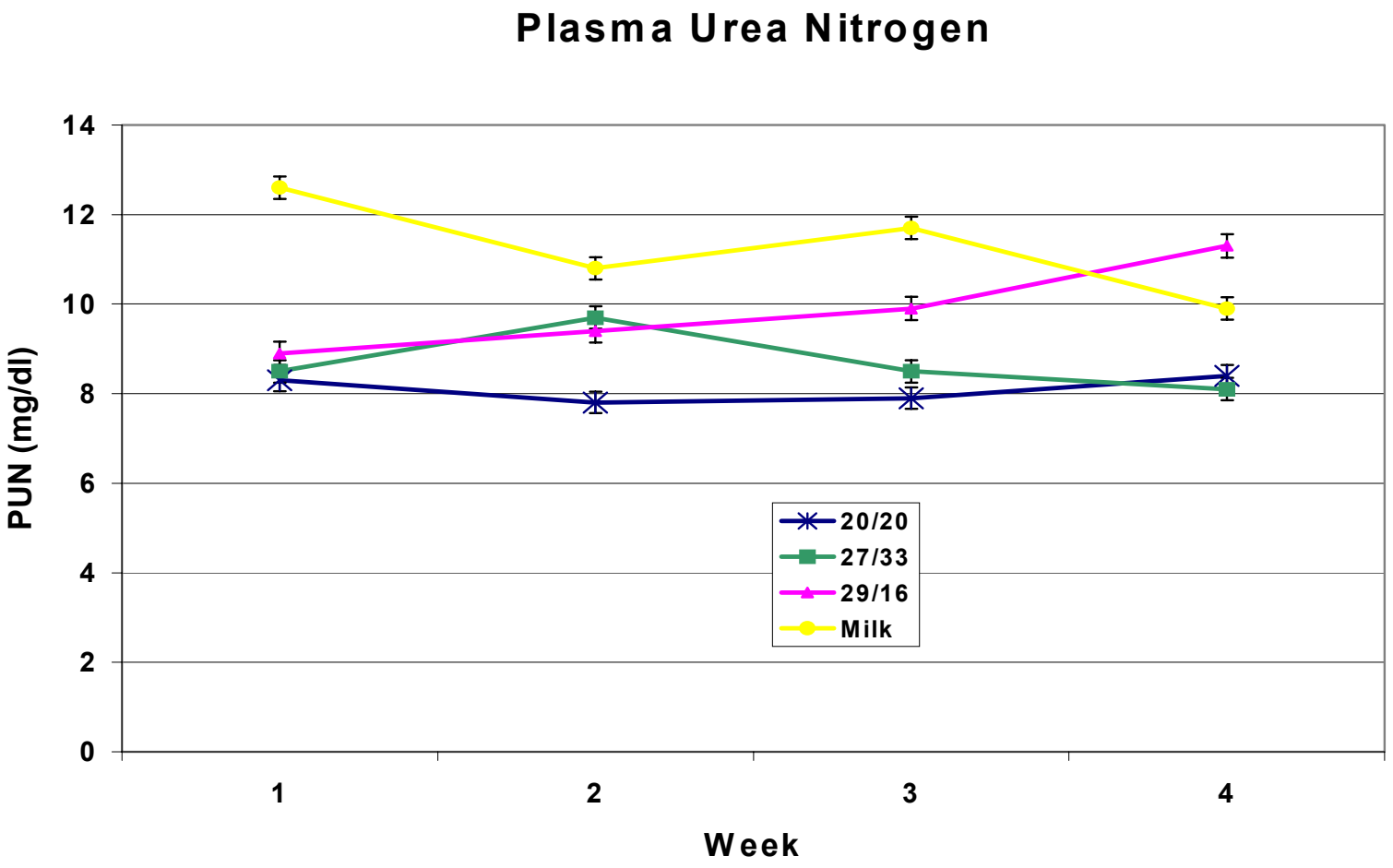

Plasma Urea Nitrogen
PUN (mg/dl)
14
12
10
8
6
4
2
0
1
2
3
4
Week
20/20
27/33
29/16
Milk

Figure 5.8. Weekly plasma urea nitrogen.

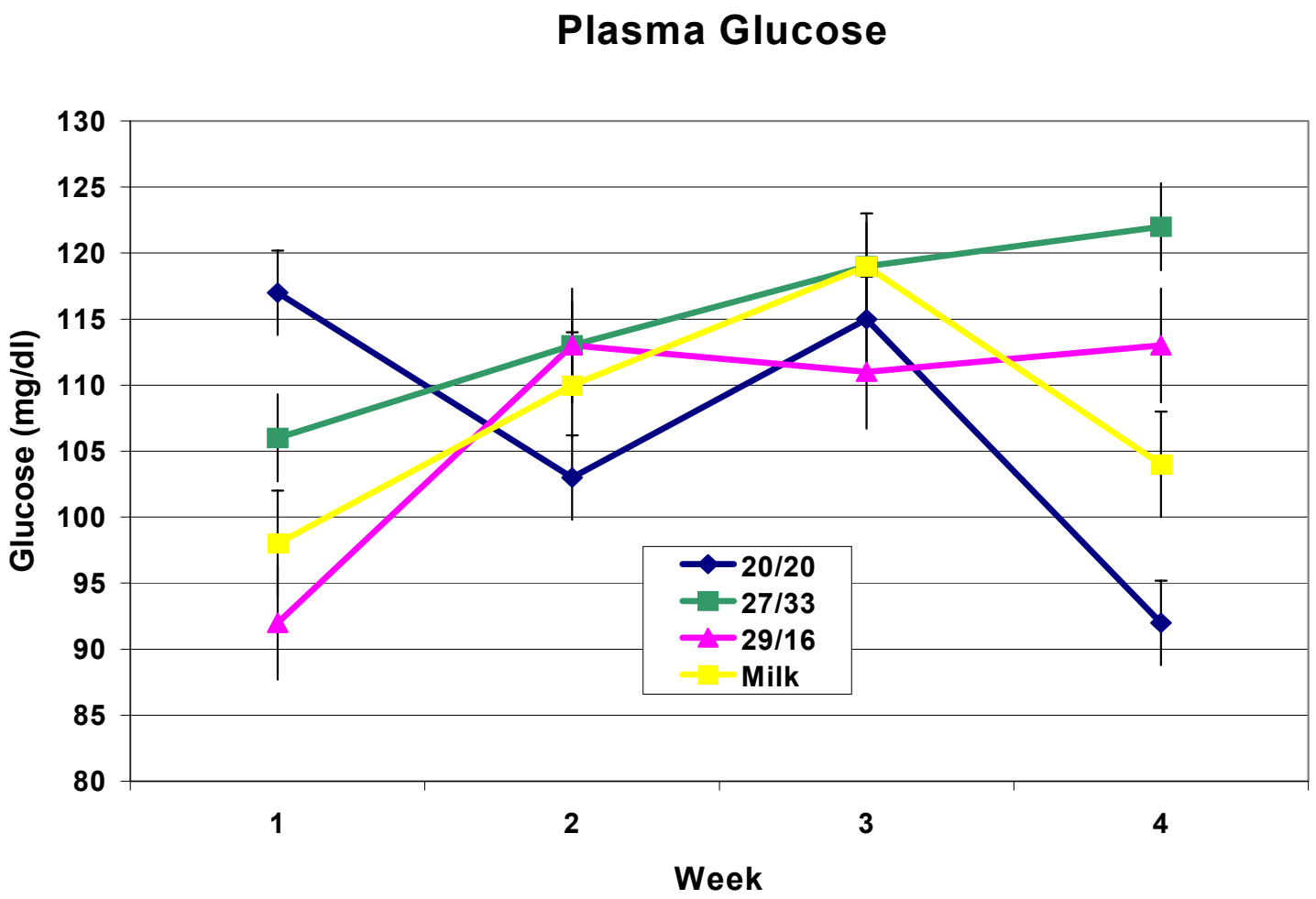


Figure 5.9. Weekly plasma glucose.

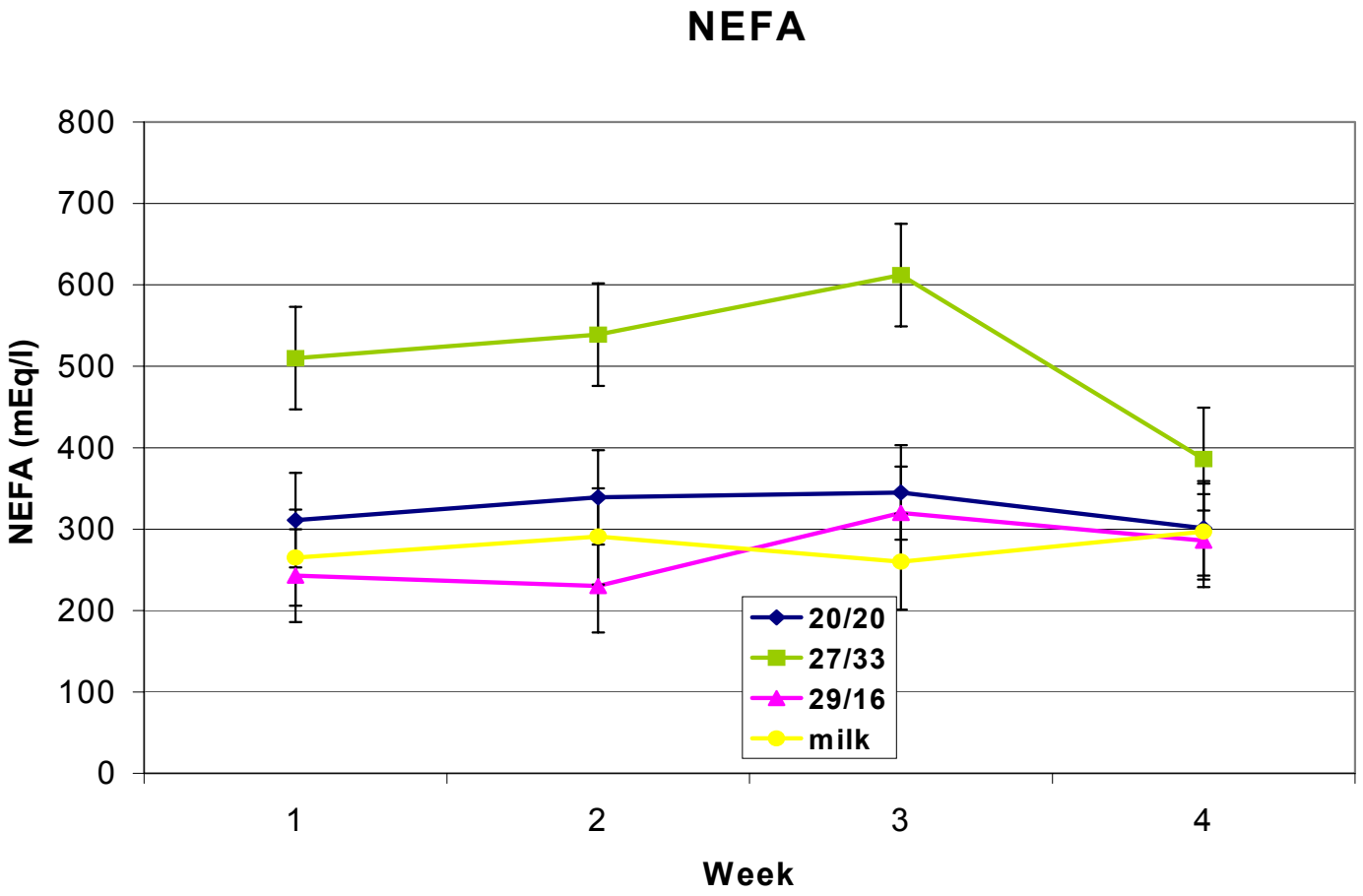


Figure 5.10. Weekly NEFA.

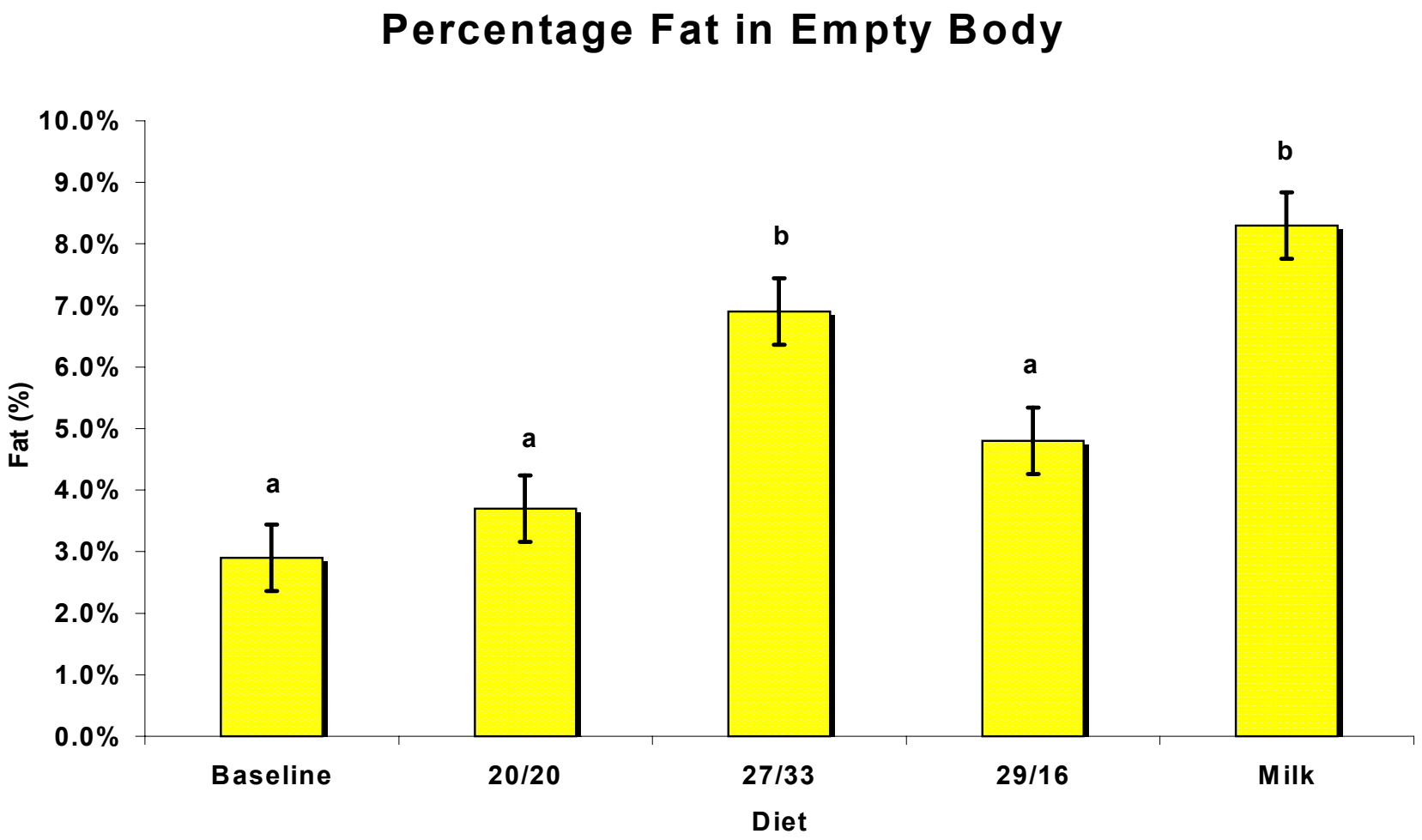


Figure 5.11. Percentage fat in empty body.

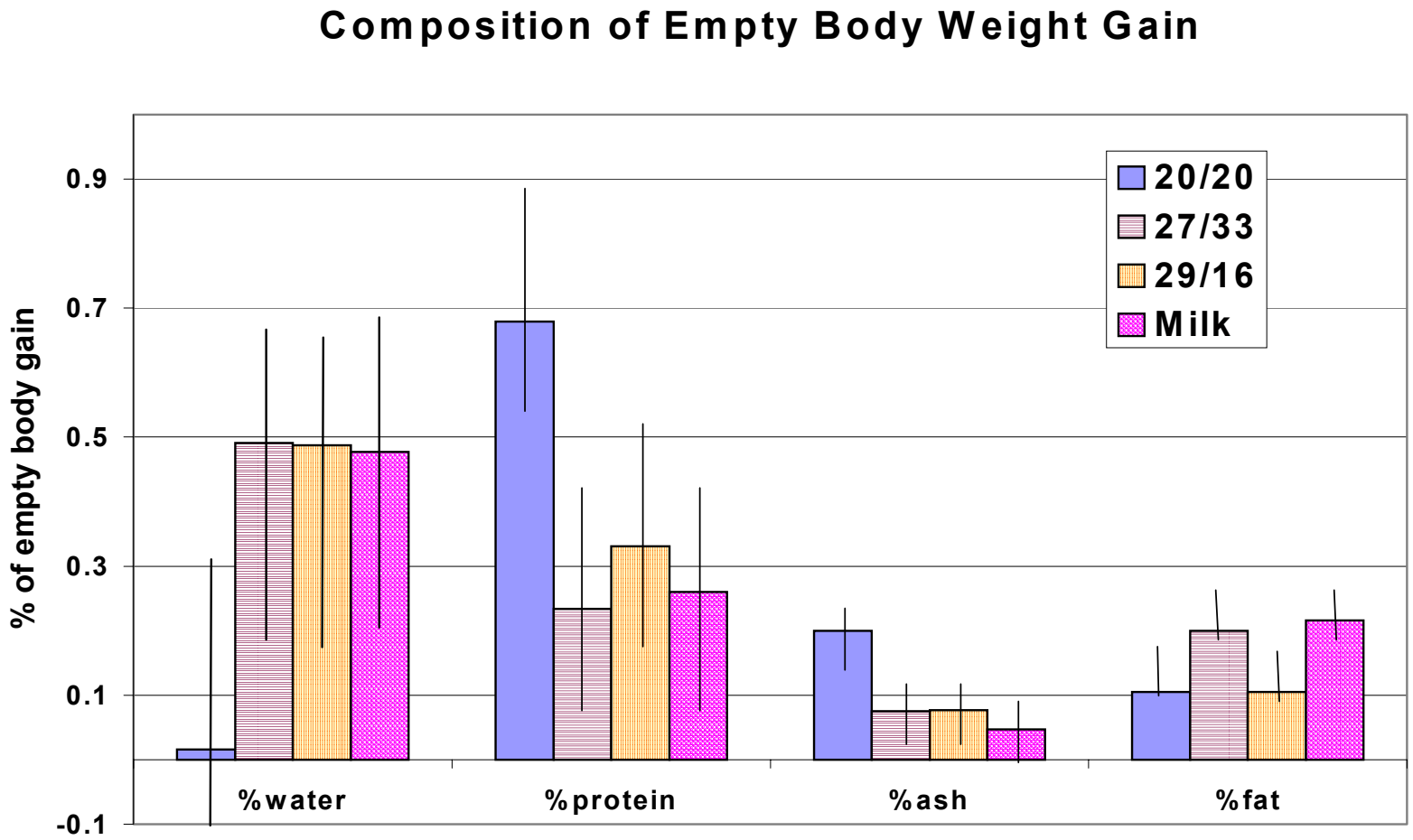


Figure 5.12. Composition of empty body weight gain.

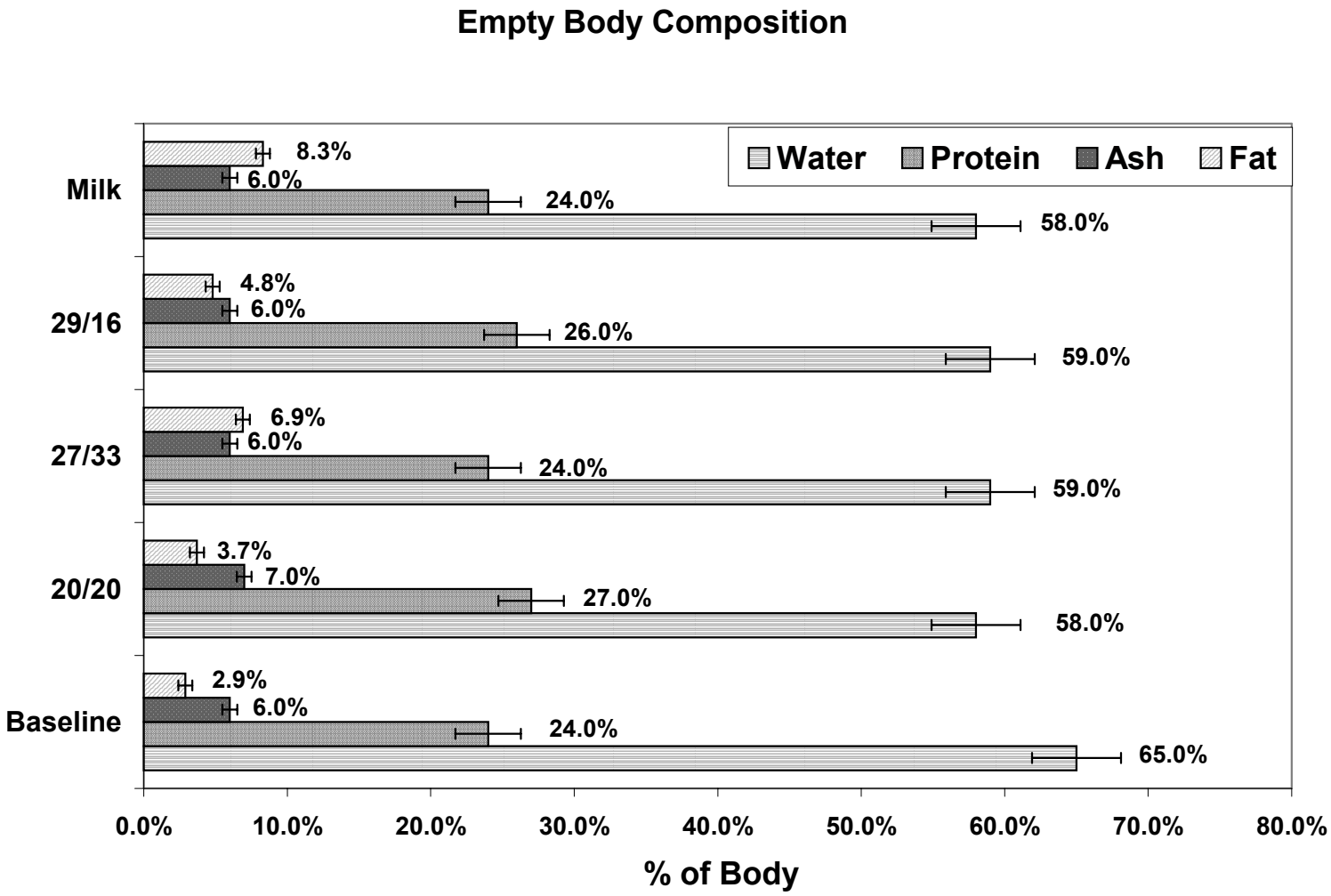


Figure 5.13. Empty body composition.

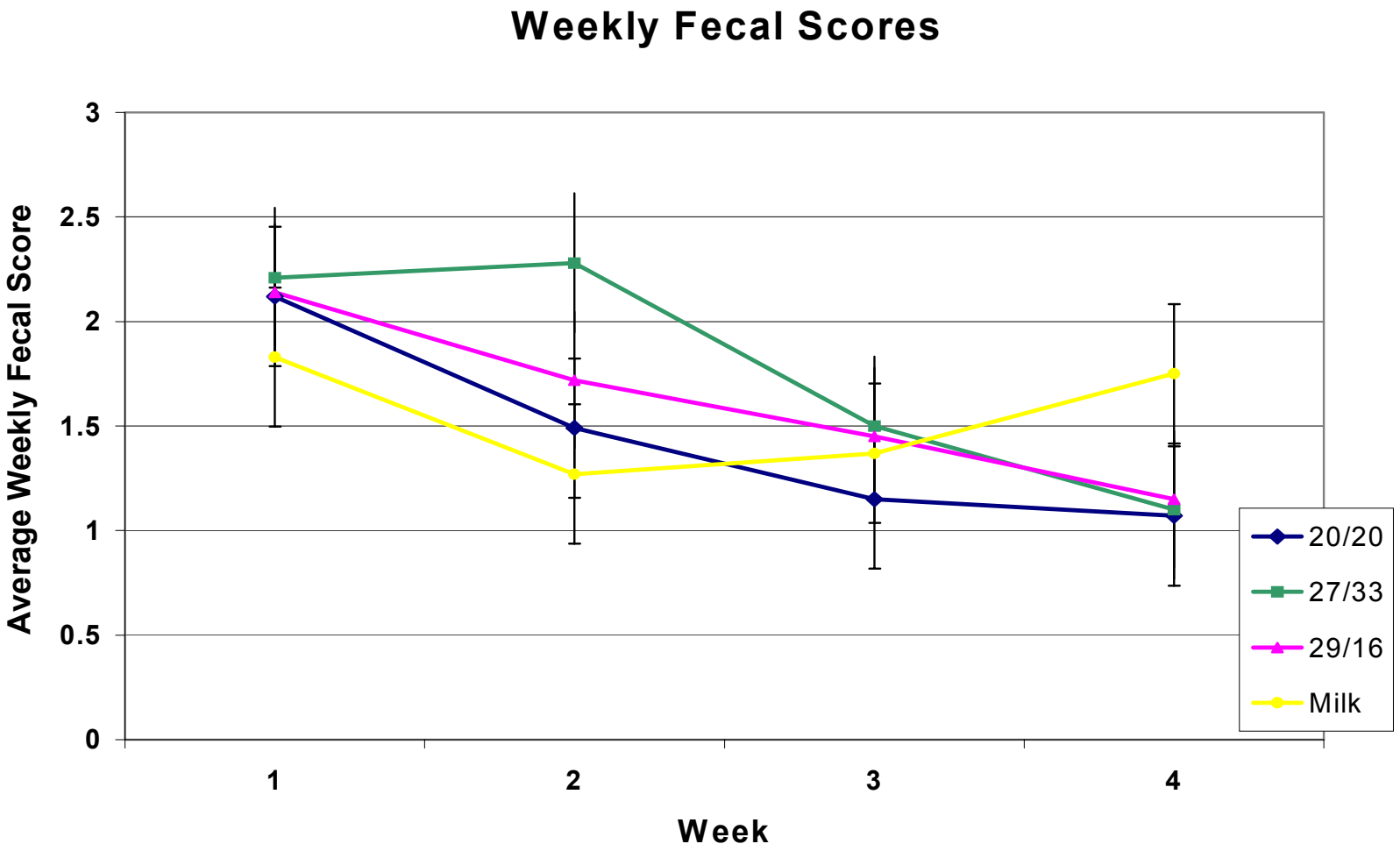

Weekly Fecal Scores
Average Weekly Fecal Score
3
2.5
2
1.5
1
0.5
0
1
2
3
4
Week
20/20
27/33
29/16
Milk

Figure 5.14. Weekly fecal scores.

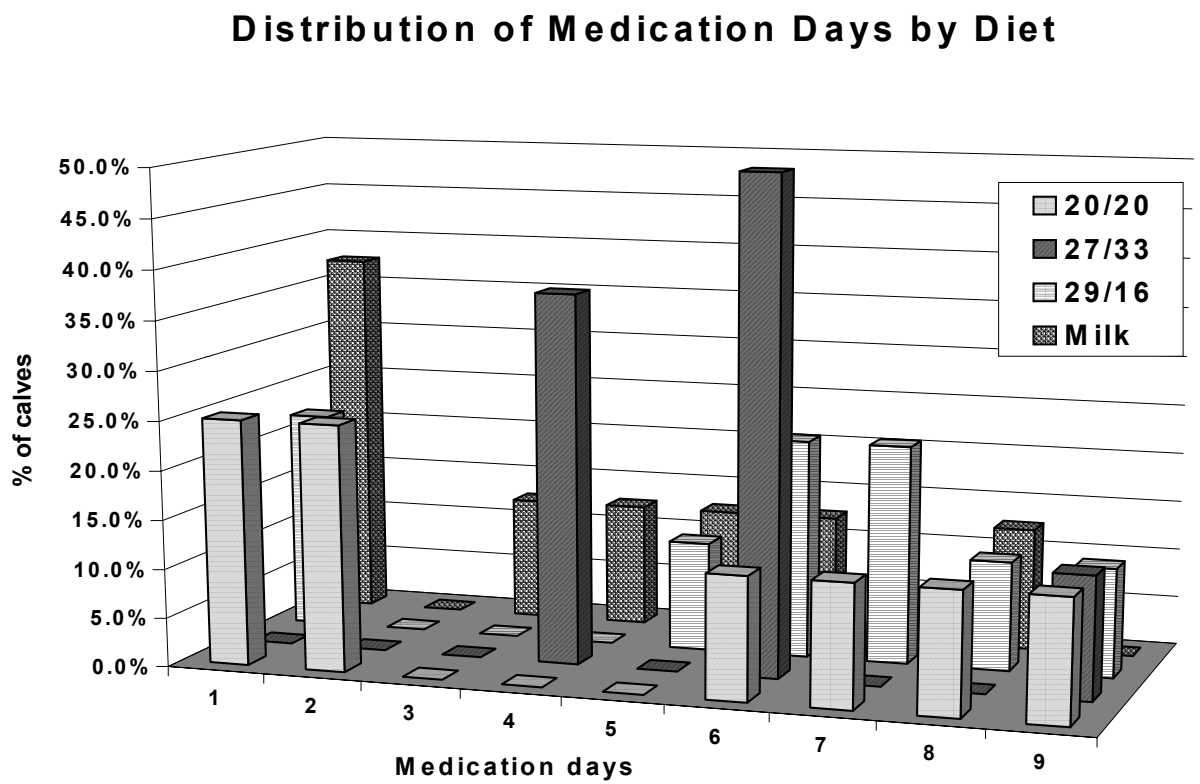


Figure 5.15. Distribution of medication days.

On the x-axis the total number of days of medication or electrolyte therapy are shown. On the y-axis the the % of calves per diet are shown.

Chapter Six
Usefulness of Dual X-ray Absorptiometry for Analyzing Composition of Calf Tissues.

Results and Discussion

Table 6.1 details the nutrient concentration of diets fed. Table 6.2 summarizes total nutrient intake of calves during the 26-d feeding period. Dual energy x-ray absorptiometry (DXA) detected differences in body composition (Table 6.3). According to DXA estimates, percentage bone mineral content (BMC) in the carcass (CAR) was greater in MILK than 21/21 and 29/16. Calves fed MILK and baseline had the lowest percentage lean in CAR. Percentage fat in the blood and organs (BO) was least in calves fed 21/21 or 29/16. No differences in BMC, percentage lean tissue, or percentage fat, due to diet were detected by DXA in the liver.

Correlations between body composition as predicted by DXA and chemical analysis (CHEM) are shown in Figures 6.1 to 6.6. Estimates of body composition by DXA were poorly correlated to CHEM (adjust R-square <0.1). The reasons for the inaccurate estimates of composition by DXA are not clear. This technology has been used successfully to estimate the composition of pigs. Mitchell et al. (1998a) reported higher correlations between DXA and CHEM estimates of percentage fat (r=0.89) and grams of fat (r=0.96) in the eviscerated body of pigs weighing between 5 and 27 kg.

Estimates of tissue mass, i.e., weight by DXA were more accurate than estimates of composition. Figures 6.7 to 6.9 show the relationship between DXA estimates of mass and mass as measured by a scale. In particular, the DXA estimate of liver mass was very close to the scale weight (adjust. R-square= 0.99). The DXA estimates of mass, i.e., weight, of calf tissues are in agreement with values reported for pigs. Mitchell et al. (1998b) reported a high correlation (r > 0.99) between DXA estimates of mean carcass weight in pigs and the scale weight of carcasses.

Differences in body composition due to diet as detected by DXA and CHEM varied (Table 6.4). According to DXA, percentage fat in CAR was highest in baseline calves and calves fed MILK. However, CHEM detected a much lower percentage fat in CAR of baseline calves than DXA. Chemical analysis indicated that MILK and 27/33 had greatest percentage fat in CAR and baseline calves had the lowest. In the blood and organs, both CHEM and DXA detected greatest percentage fat in calves fed 27/33 and MILK. However, DXA estimates indicated that baseline calves had a similar percentage fat in the BO as calves fed 27/33 and MILK but CHEM had a considerably lower estimate of fat in baseline calves than DXA. Estimates of percentage fat in the BO and CAR baseline calves and calves fed 21/21 were higher than CHEM and may indicate that DXA overestimates percentage fat in lean animals (Table 6.4). Research with pigs has shown that DXA significantly underestimates the percentage fat in the carcass by up to 28% (Mitchell et al., 1998b). The reasons for discrepancies between CHEM and DXA in detection of body composition of tissue from baseline calves may have been the small sample size (n=2) or the smaller mass of tissues from baseline calves, or may be related to limitations of the DXA equipment. More research with a larger sample size should be conducted to determine the accuracy of DXA in estimating body composition in live calves.

Conclusions

DXA accurately estimated the mass of tissues from calves but was a poor predictor of body composition. However, refinements in the procedure, calibration, and technique may allow DXA estimates to more closely approach CHEM measurements of body composition in calves. Additional studies of accuracy using DXA to estimate body composition in calves are merited.

Table 6.1. Diet specifications on an as fed (powder) basis.

Variable	21/21	27/33	29/16	MILK
DM, %	97.3	97.3	97.3	14.0[A]
Crude protein, %	20.6	27.3	28.5	3.5
Crude fat, %	20.6	33.4	16.4	4.8
Lactose+ash, %	58.8[B]	39.3[B]	55.1[B]	5.7[B]
Crude fiber, %	0.15	0.15	0.15	
Calcium, %	0.90	0.90	0.90	
Phosphorus, %	0.70	0.70	0.70	
Iron, ppm	100	100	100	
Copper, ppm	10	10	10	
Cobalt, ppm	0.1	0.1	0.1	
Zinc, ppm	40	40	40	
Manganese, ppm	40	40	40	
Iodine, ppm	1.02	1.02	1.02	
Selenium, ppm	0.30	0.30	0.30	
Vitamin A, IU/kg	9091	9091	9091	
Vitamin D_3, IU/kg	2273	2273	2273	
Vitamin E, IU/kg	45	45	45	
Thiamine, mg/kg	6.61	6.61	6.61	
Riboflavin, mg/kg	6.61	6.61	6.61	
Niacin, mg/kg	2.64	2.64	2.64	
d-Pantothenic Acid, mg/kg	13.22	13.22	13.22	
Biotin, mg/kg	0.11	0.11	0.11	
Ascorbic Acid, mg/kg	110.00	110.00	110.00	
Pyridoxine Hydrochloride, mg/kg	6.61	6.61	6.61	
Folic Acid, mg/kg	0.55	0.55	0.55	
Vitamin B_{12}, mg/kg	0.07	0.07	0.07	
Choline Chloride, mg/kg	1322.0	1322.0	1322.0	

[A]Estimated.
[B]Lactose + Ash determined by difference.

Table 6.2. Total nutrient intake and performance of calves by diet.

Variable	21/21	27/33	29/16	MILK	SE
Number of calves	5	5	4	3	
Liquid fed, kg	88.1[a]	145.8[b]	144.0[b]	138.6[c]	1.9
DM fed, kg	11.0[a]	18.2[b]	18.0[b]	19.4[c]	2.5
Protein fed, g	2264[a]	4973[b]	5132[bc]	4904[b]	61.1
Fat fed, g	2272[a]	6089[a]	2954[d]	6683[c]	71.0

[a,b,c,d]Values in the same row with similar superscripts do not differ at $p<0.05$.

Table 6.3 Composition of tissues as estimated by DXA.

Variable	Baseline	21/21	27/33	29/16	MILK	SE
DXA %BMC CAR	0.44[ab]	0.27[a]	0.46[ab]	0.26[a]	0.67[b]	0.01
DXA %Lean CAR	79.3[a]	87.0[b]	85.5[b]	86.9[b]	84.1[a]	1.3
DXA % fat CAR	20.8[a]	12.8[b]	13.9[b]	12.6[b]	15.8[ab]	1.4
DXA %fat BO	15.4[a]	13.0[b]	14.8[a]	13.7[b]	15.4[a]	0.8

[ab]Values in the same row with similar superscripts do not differ at $p=0.05$

Table 6.4 Composition of tissues estimated by DXA or CHEM.

Variable	Baseline	21/21	27/33	29/16	MILK	SE
DXA CAR %fat	20.8[a]	12.8[b]	13.9[b]	12.6[b]	15.8[ab]	1.4
CHEM CAR %fat	4.0[a]	9.2[ac]	22.5[b]	13.9[c]	22.4[b]	2.1
DXA BO %fat	15.4[a]	13.0[b]	14.8[a]	13.7[b]	15.4[a]	0.8
CHEM BO %fat	7.6[a]	11.0[a]	27.0[b]	15.9[a]	28.4[b]	2.9

[ab]Values in the same row with similar superscripts do not differ at $p=0.05$

Figure 6.1 Chemical analysis of percentage ash in the carcass versus DXA estimates of percentage bone mineral content.

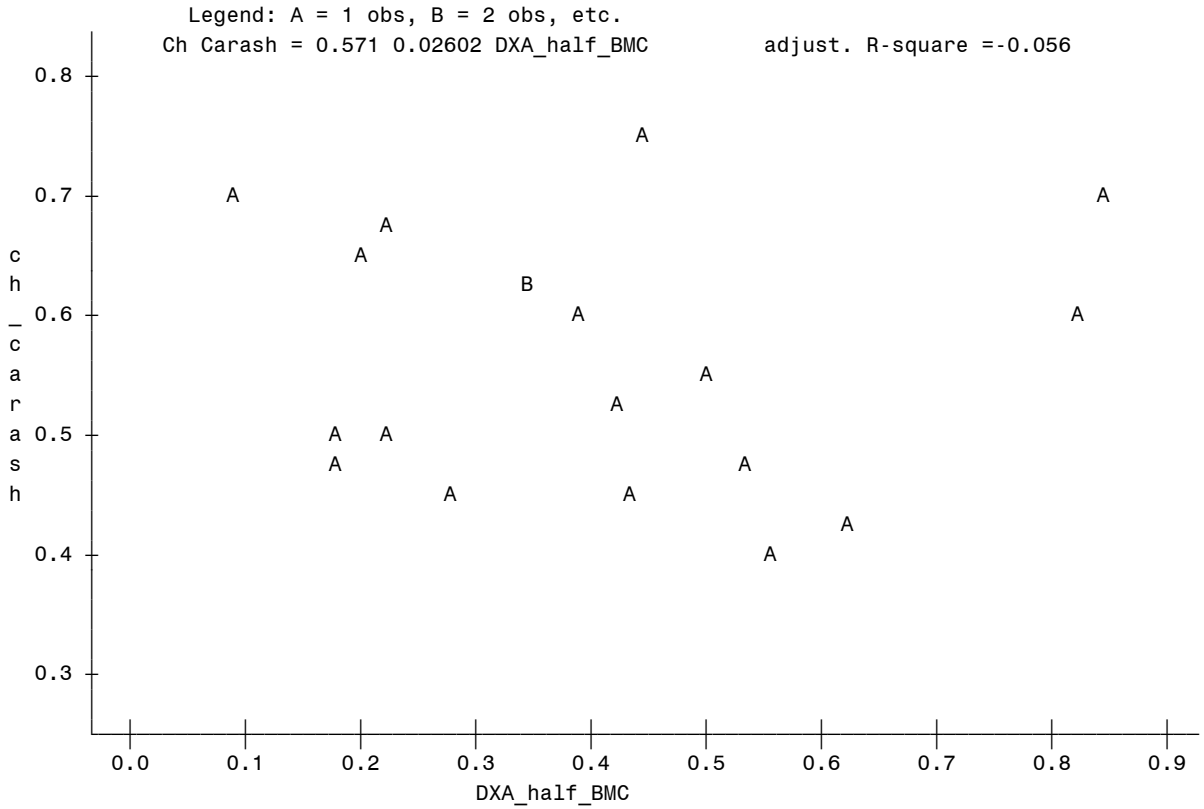


Figure 6.2 Chemical analysis of carcass percentage protein versus DXA estimates of percentage lean tissue in carcass.

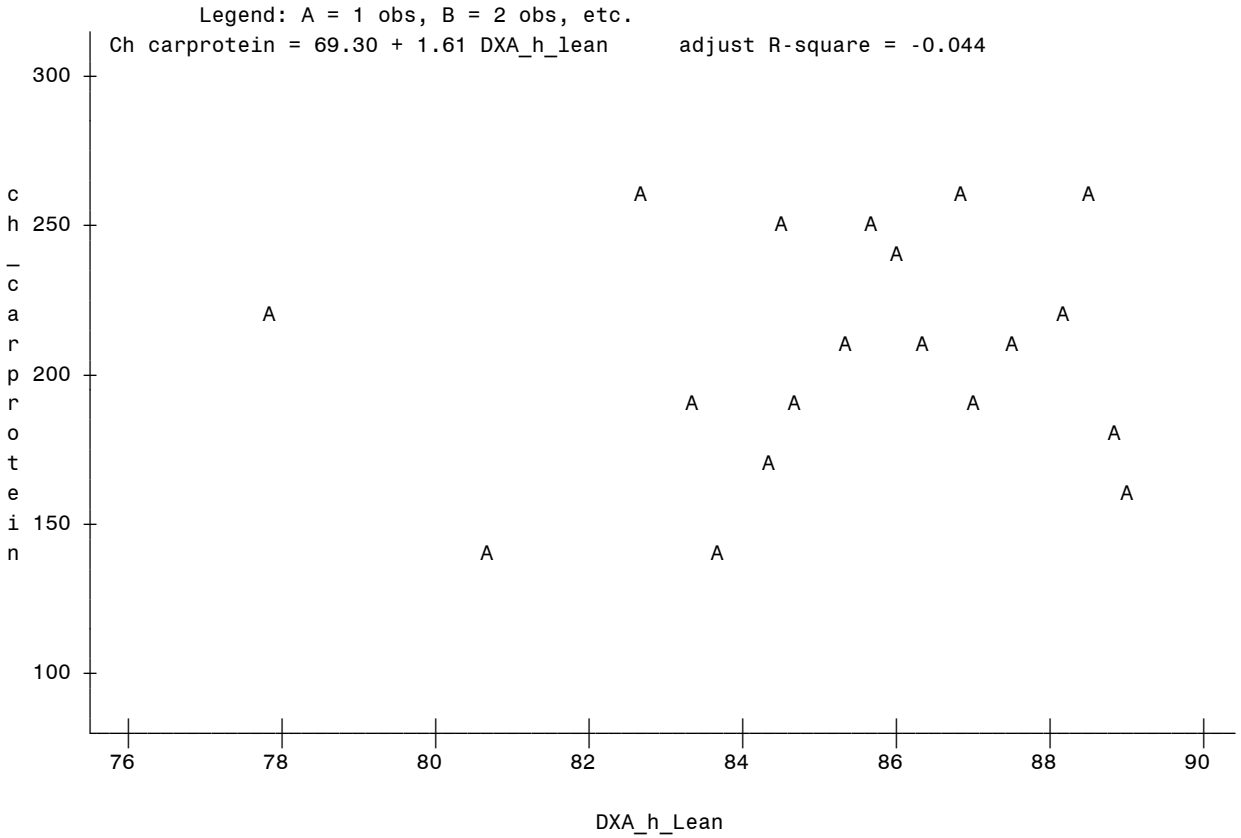


Figure 6.3 Chemical analysis of percentage water in carcass versus DXA estimate of percentage lean tissue.

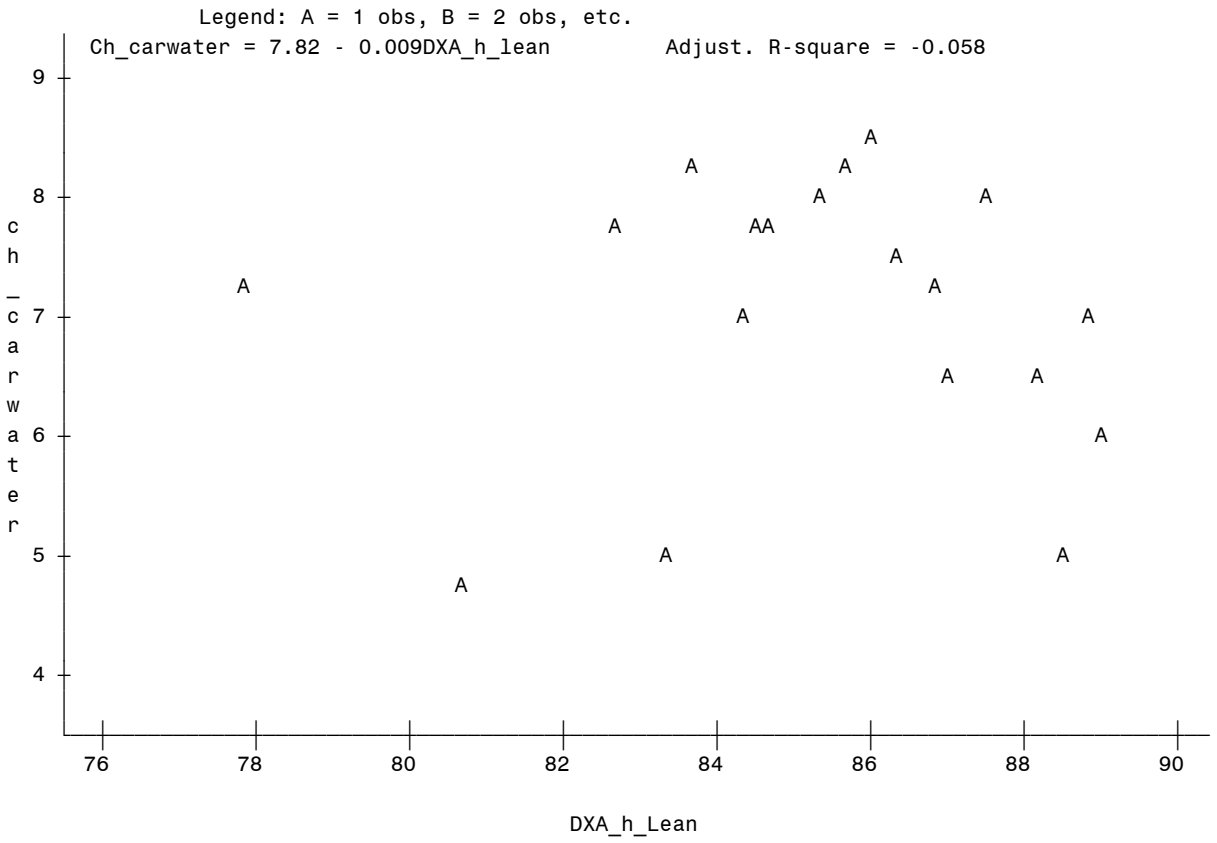


Figure 6.4 Chemical estimate of percentage fat in carcass versus DXA estimate of %fat.

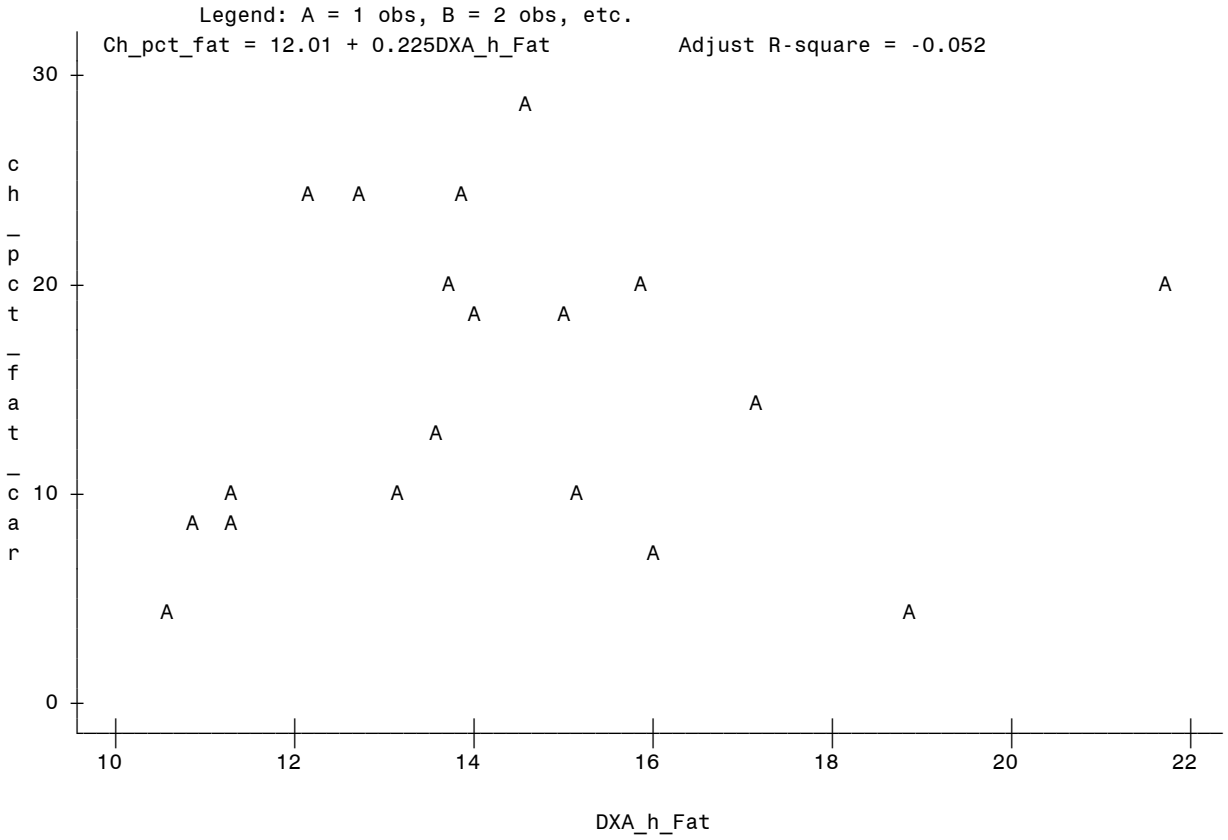


Figure 6.5 Chemical analysis of percentage water in blood and organs versus DXA estimate of percentage lean.

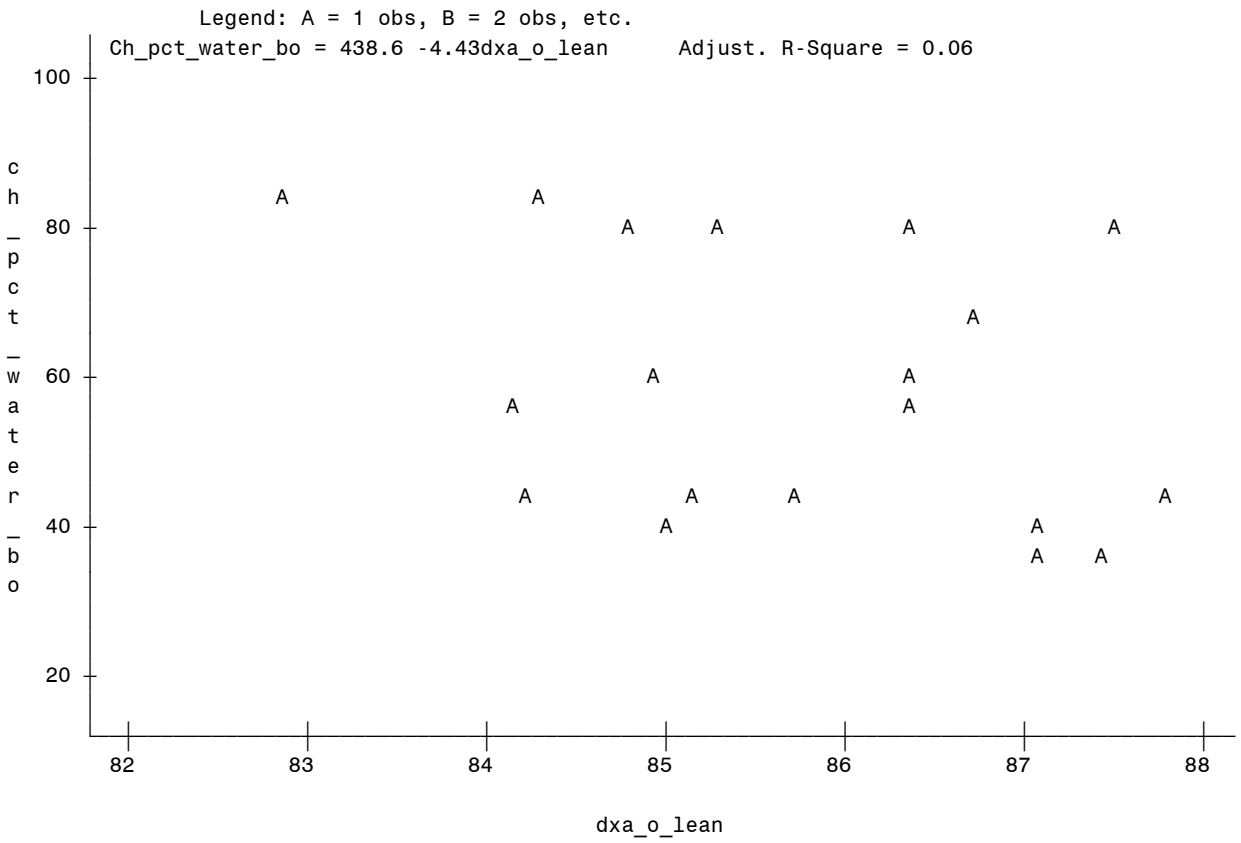


Figure 6.6 Chemical analysis of percentage protein in blood and organs versus DXA estimate of percentage lean.

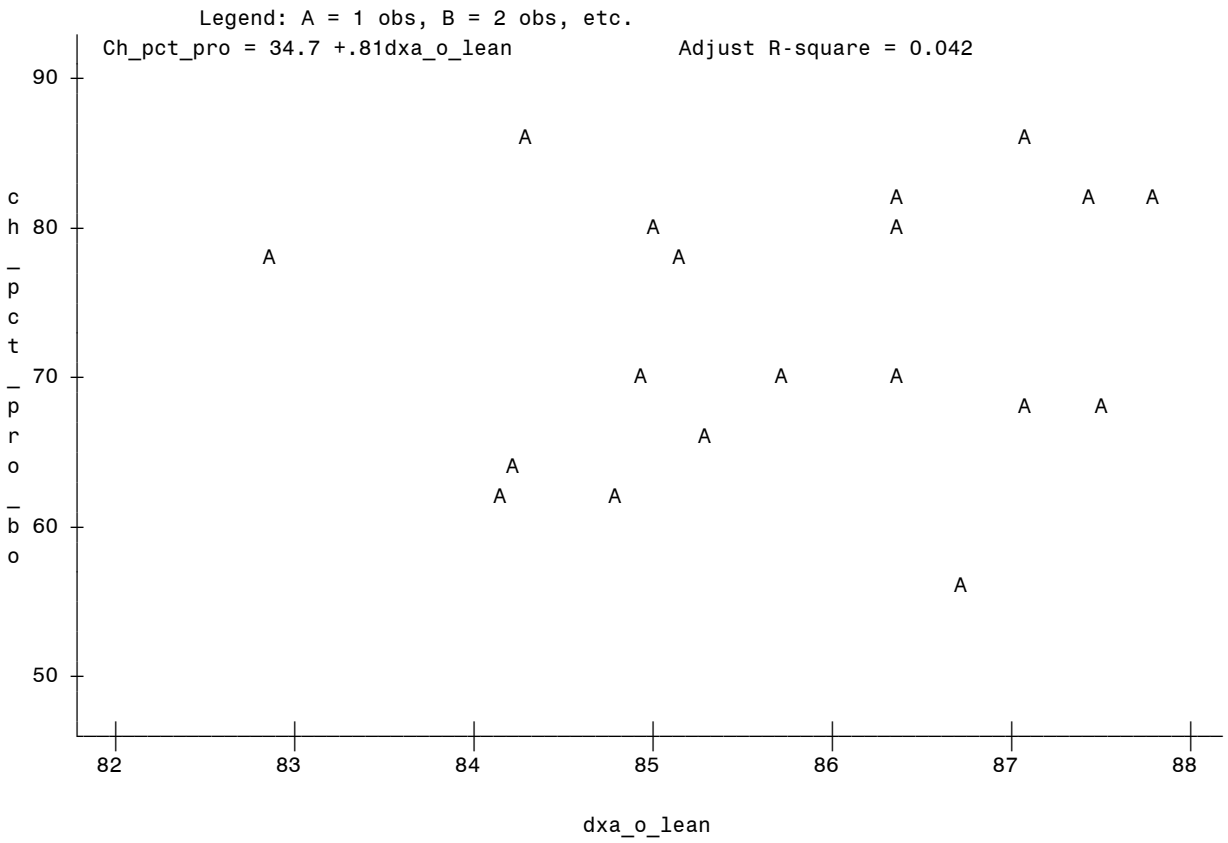


Figure 6.7 Organ mass versus DXA estimate of organ mass.

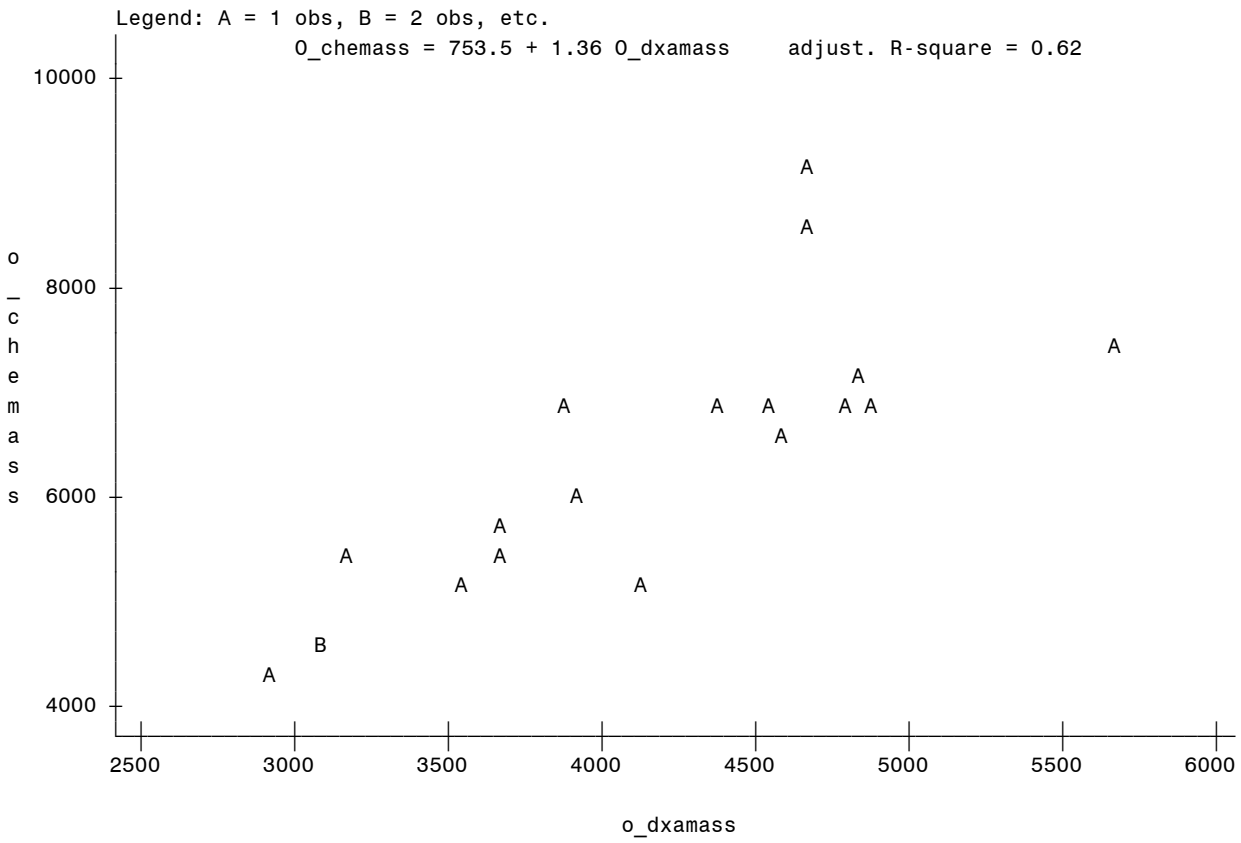


Figure 6.8 Liver mass versus DXA estimate of liver mass.

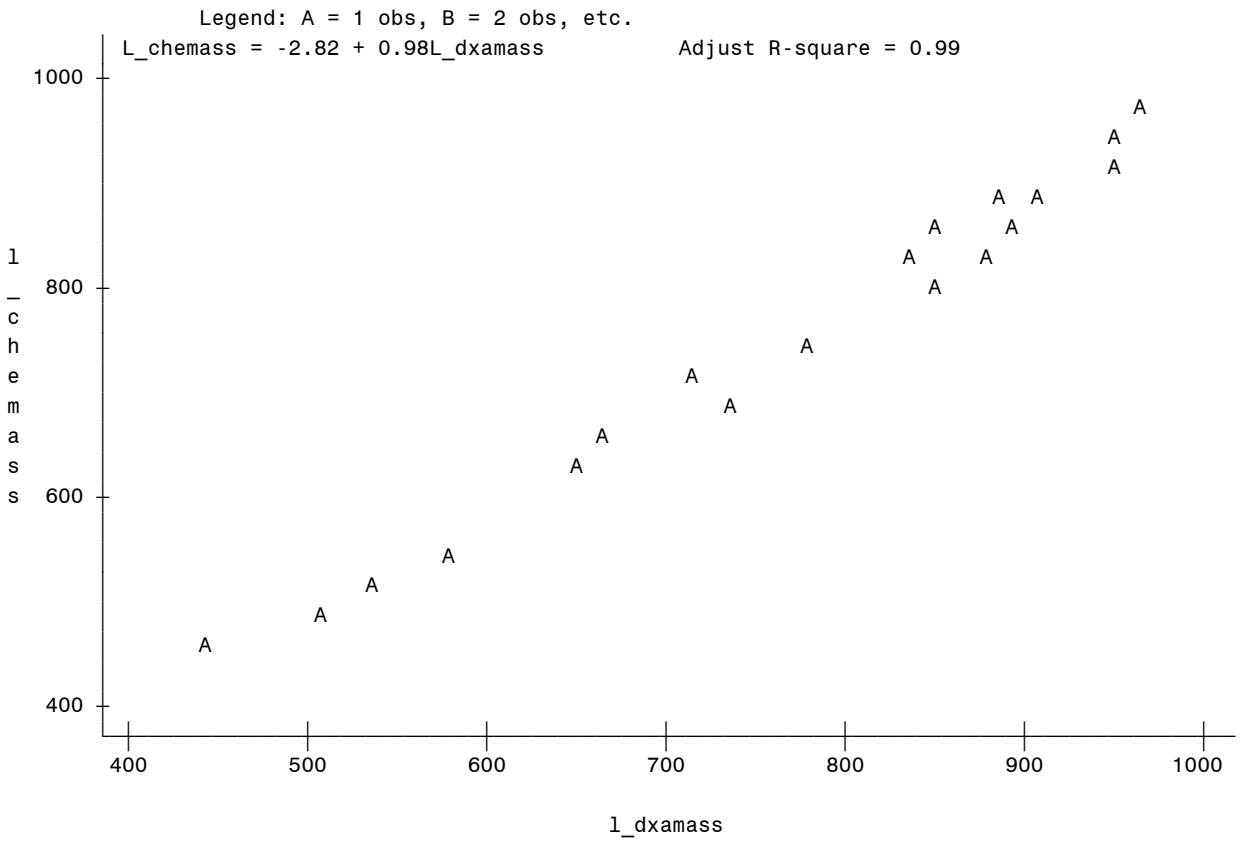
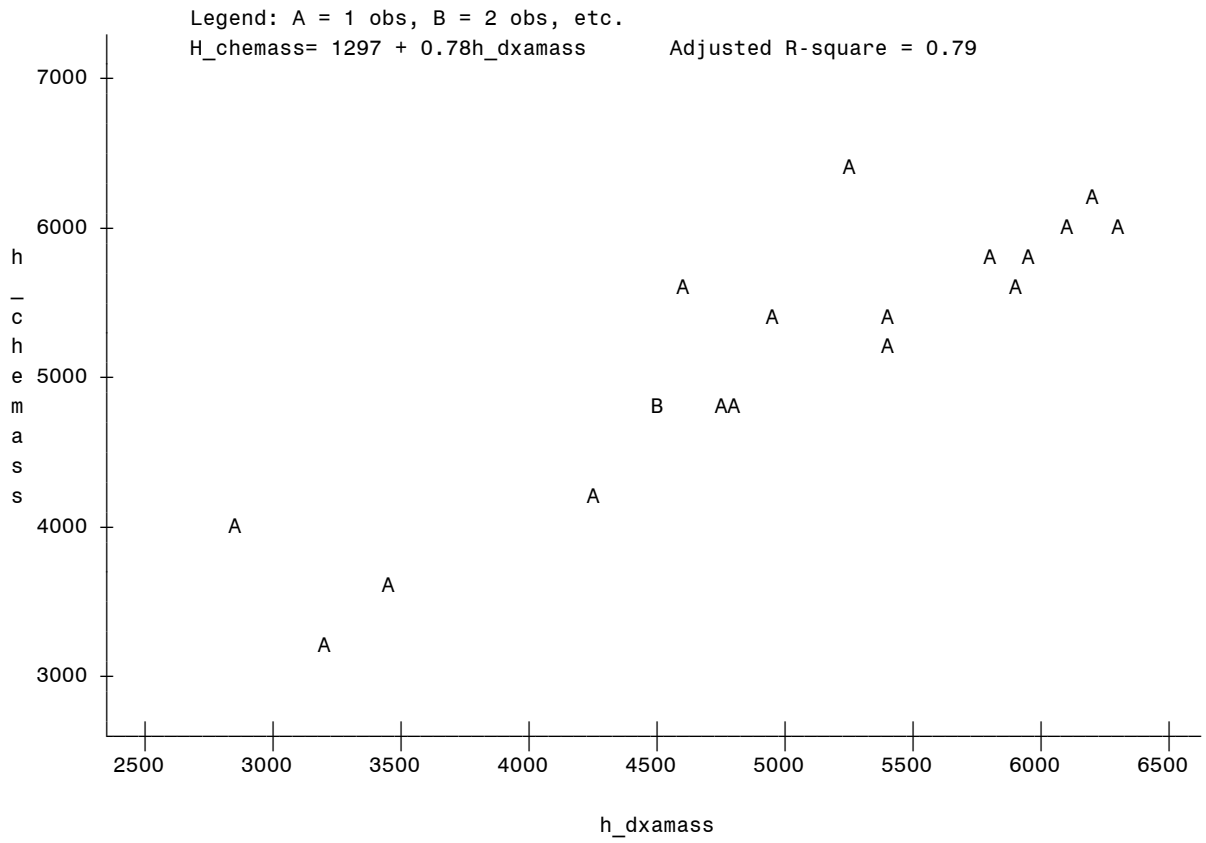


Figure 6.9 Carcass mass versus DXA estimate of mass.



Chapter Seven
Jersey calf management practices in the United States

Results and Discussion

Characteristics of herds

Herds surveyed reported 20,806 births in the 12 mo prior to the survey, of these 19,303 were Jersey calves. Only three of the herds survey reported less than 50% of births on their farm as Jersey calves. Jersey herds enrolled in American Jersey Cattle Association (AJCA) performance programs averaged 7023 kg of milk, 323 kg fat, and 251 kg of protein, actual production in 2001 (Wolfe, 2001b). Herds surveyed were representative of the US population in terms or production, averaging 7180 ±757 kg of milk, 331 ±37 kg of fat, and 256 ± 29 kg of protein, actual production. Table 7.1 summarizes the characteristics of all herds surveyed, the top ten percent of herds, and herds by region. The difference between the average and the top 10% of herds in each category indicates that the herds were diverse. Culling rate averaged 27.5 ±12.5% but herds in the tenth percentile for culling rate culled less than 11%. Over half (56%) of herds sold cows for dairy purposes. Herds surveyed sold an average of 7.8 ±12.0% of the herd for dairy purposes while the tenth percentile sold over 21%. Calving interval averaged 13.0 ±0.7 mo. and somatic cell count (1000s) averaged 232 ±111. The top herds had a calving interval of 12.2 mo and herds and the top 10% of herds had an average SCC of less than 78,000. Herds reported an average of 199 calves born while herds in the 90th percentile averaged 430 births. Herds surveyed had similar milk production, culling rate, and calving interval, and SCC regardless of region. However, herds in the **WEST** had the most births (582) and the highest level of milk production (7530 kg). Herds in the **NEAST** had the fewest births (70). Herd size differences due to region were similar to those reported by NAHMS, (1996a).

Calf mortality in the first 24 hours of life including stillbriths (M24) averaged 5.0% with the highest in **PAOHIN** (5.9%) and the lowest in **NEAST** (3.9%). The majority of herds in the **NEAST** utilized maternity pens for calving cows (Table 7.2), which may indicate prepartum cows, and newborn calves are managed more intensively due to their close proximity to the milking herd. The level of early calf mortality in the US Jersey population appears to be lower than the Holstein population. Adamec, (2002) reported calf mortality from birth to 48 h of age, including stillbirths, in the US Holstein population exceeds 7%. Winston, (1998) reported 7.1% early calf mortality (calves born dead or that died soon after birth) in PA Jersey herds, which was slightly more than observed in the current survey for PAOHIN and for the United States and may indicate a slight decline in early calf mortality in Jersey herds.

Mortality between 24 h of age and 3 mo (M3) averaged 6.7% (Table 7.2) which is lower than reported by Winston (1998) in PA Jersey herds (8.1%) or NAHMS (1996b) (11.0%). The NAHMS, (1996b) data was predominantly from Holstein herds (93% of the data). Level of mortality in the United States increased from 8.4% in 1992 to 11.0% in 1996 (NAHMS, 1996b). However, the current level of Jersey calf mortality appears to be decreasing when compared to the data reported by Winston, (1998). This could indicate that Jersey breeders are making improvements in the management and care of calves and may indicate that Jersey breeders are more aggressive managers of calves than the typical United States dairy herd.

Mortality after 3 mo of age averaged 1.3% and was slightly higher than the 0.5% reported by Winston (1998). Mortality was highest in the **SEAST** was (2.3%) and may reflect a less intensive system of managing heifers that utilizes more pasture and less confinement for rearing heifers after 3 mo of age. Mortality in **NEAST** was lower than average (0.7%).

Calving location is another important factor in calf management. Calving location varied considerably within region and by region (Table 7.2). The majority of respondents used more than one location to calve cows, depending on the season of the year and the number

of cows calving. Only 46% of respondents allowed cows to calve in a pasture but the variation was considerable with only 17% of the respondents in the **NEAST** utilizing pasture and 69% of respondents in the **SEAST** utilizing pasture. Regional variation in housing for maternity cows varied considerably across regions; 43% in **SEAST** to 74.5% in **WIS** used maternity pens as a location to calve cows. Loose housing barns were only used in the **WEST** and in **PAOHIN** as a calving location.

Management of newborns

Feeding an adequate amount of high quality colostrum to the newborn calf is critical to successful calf rearing. Colostrum should be fed soon after birth and then 12 h later. At least 1.9 L of colostrum should be fed per feeding (Roy, 1980). Overall, respondents delivered an adequate quantity of colostrum in a timely matter (Table 7.2). Average time to first colostrum feeding was 3.8 h after birth and on average 1.9 L of colostrum was fed at the first feeding. Respondents reported feeding 3.8 L of colostrum in the first 24 h of life. Timing of first colostrum feeding was comparable to NAHMS (1993), which reported 68.6% of herds fed the first feeding of colostrum in the first 6 h of life. Only 11% of producers depended on nursing for colostrum delivery. Nursing was most often used as a method of colostrum delivery in the **SEAST** where 31% of producer reported allowing calves to nurse. The higher level of nursing in the **SEAST** is likely related to extensive use of pasture as a calving location. The NAHMS (1996b) survey reported 33.5% of dairy producers relied on the calf to nurse for first feeding of colostrum, which is higher than observed among Jersey breeders.

Calf nutrition and management

Calf nutrition and management practices are summarized in Table 7.3. Respondents fed a variety of liquid diets to preweaned calves and 15% of respondents fed more than one source of liquid to calves. Producers may have changed source of liquid feed depending on season of year, others may have transitioned individual calves from one source of liquid to another, and others may have switched from one source of liquid to another based on

price and availability. The majority (57%) of respondents fed MR, 25% of respondents fed waste milk, and 47% of respondents fed salable milk. Feeding raw milk is a concern due to the risk of disease transmission (Cullor, 2000) and the presence of antibiotics in waste milk (Selim and Cullor, 1997). Use of milk and waste milk as calf feeds indicates that Jersey breeders are willing to assume risks associated with feeding waste milk, are unaware of these risks, and/or they perceive benefits from feeding these feeds. Transmission of Johne's disease in raw milk is also a concern and pasteurization has been recommended as a method of reducing the risk of transmitting Johne's disease in milk (Stabel, 2000). Only producers in the **WEST** fed pasteurized milk. Producers that fed milk reported feeding 3.1 kg of milk/calf/d while producers that fed MR reported feeding 440g of powder/calf/d. For a 27 kg calf, this is an as fed feeding rate of approximately 12% of BW. Larger frame calves are typically fed liquid at 8 to 10% of BW (Davis and Drackley, 1998). In addition to being fed more liquid, Jersey calves were weaned one week later than reported by NAHMS (1996b), i.e. 9.4 versus 8.4 wk. However, average age at weaning varied 3 wk by region with the lowest at 7.8 weeks in **WIS** and the greatest was 10.8 wk in **WEST**. Average age for weaning is considerably higher than the 35 d suggested by Quigley (1996) indicating that Jersey breeders could wean calves sooner.

Water is an important component of the calf's diet. Average age water was first offered to calves, among herds that offered water, was 9.8 d. Only 73% of respondents offered water to calves before weaning. Davis and Drackley (1998) recommended preweaned calves have fresh water available at all times. Herds in the **SEAST** were least likely to offer water supplied to preweaned calves while 100% of the herds in **WIS** offered water to calves. Producers may be reluctant to offer water to calves due to effort involved in keeping clean fresh water to calves or producers may not be aware of the importance of offering water to calves. When calves begin to scour, water intake increases (Kertz et al., 1984). Given the importance of water intake to the preweaned calf and relative ease of implementing this practice one would expect nearly 100% of producers would offer water to calves before weaning. However, only 73% of producers offering water to calves indicates this is an area where calf management could be improved.

Intake of calf starter is critical for rumen development (Warner et al., 1956). Calf starter was offered to calves at an average age of less than 8 d (Table 7.3). The variation between regions was small. Herds in **NEAST** offered starter to calves at an earlier age (6.5 d) than other regions while herds in the **SEAST** waited the longest to offer calf starter (9.8 d). Herds reported an average starter intake of 1.5 kg/d at weaning with little variation between region indicating that calves should have had well-developed rumens when they were weaned. Overall, Jersey breeders do an adequate job with calf starter management.

In addition to feeding liquid and calf starter to calves, over 50% of the herds offered some type of forage prior to weaning (Table 7.3). Herds located in **PAINOH** and the **SEAST** were least likely to feed forage before weaning and herds in **NEAST** and **WEST** were more likely to feed forage before weaning. Herds in **NEAST** and **WEST** also had a higher average age at weaning. These herds may use a more gradual method of weaning calves that includes feeding forage a week or so before weaning and could partially account for the higher rate of forage feeding prior to weaning.

Health and reproduction

The majority of respondents had a routine herd health program with their veterinarian (Table 7.4). Vaccination and disease prevention were a priority with 90% of herds reporting some type of vaccination program for the milking herd and 85% of herds vaccinated heifers. However, there was considerable variation in the vaccinations used. Only 42% of the herds surveyed dewormed the milking herd but 66% of herds dewormed heifers. Regional variation in deworming was considerable and was probably related to the use of pasture in each region. The majority of herds (90%) used some form of coccidia control. Respondents were aggressive in breeding heifers and reported a goal for average age at first calving of less than 23 mo. In the **WEST,** the goal for age at first calving was less than 22 mo.

Characteristics of primary calf feeder

The majority, 81% of respondents listed the owner (48%) or spouse (33%) as the primary calf feeder (Table 7.5). In previous studies, lower calf mortality was observed when the primary calf feeder was a female or the herd owner (Hartman et al., 1974; James et al., 1984). However, the relationship between primary calf feeder and mortality was negligible except that in herds where a child was the primary calf feeder, the incidence of mortality (M24) was increased (Table 7.6). This may indicate that more emphasis is placed on calf rearing than in the past. Perhaps the primary calf feeder has more skill, education, and dedication to calf rearing than in the past. Some farms, particularly larger farms, may have an employee whose primary responsibility is managing calves. Future studies should further examine the characteristics including education and job responsibilities of the primary calf feeder.

Mortality in the first 24 hours of life

Calving location is correlated with mortality (M24) (Table 7.6). Herds that utilize pasture as a calving location had a higher incidence of mortality (M24). The higher level of mortality in these herds may have been do to less intensive management of the maternity cows. Herds that used a bedding material other than sawdust or straw in the maternity area had a lower incidence of mortality (M24). These herds varied considerably in the source of bedding used but the low level of mortality indicates these herds provided a superior environment for the newborn calf. The higher incidence of mortality when heifers calve in tie stalls indicates that tie stalls are a less than ideal form of housing for heifers.

In addition to providing a superior calving environment herds with lower levels of mortality (M24) fed more milk to calves, used Bovatec^{TM} to control coccidiosis, balanced rations for dry cows, had a lower goal for age at first calving, and had higher rolling herd average for milk production (Table 7.6). These factors are indicators of level of herd management as is level of calf mortality (M24).

Herds with higher levels of mortality (M24) were found in herds that used Deccox for coccidiosis control, reported a child was the primary calf feeder, and reported less than 100% of the herd was registered (Table 7.6). It is difficult to pinpoint the relationship between these factors and mortality (M24). The factors may be confounded with other management practices or may be an indirect indicator of intensity of management. Disease and health were associated with herds with higher mortality (M24). The following health related factors were reported in herds with an increased incidence of mortality (M24), the predominant disease in calves was a disease other than digestive or respiratory, heifers were wormed, vaccinated for leptospirosis, and more than 50% of calves suckled each other (Table 7.6). Herds that vaccinated for leptospirosis or wormed heifers may have been at a greater risk for these diseases. Vaccination and worming may have been used to manage risk and the higher level of mortality (M24) may have been a result of a preexisting problem. The increased incidence of mortality (M24) in herds were more than 50% of calves suckled each other may be due to calf-to-calf contact. Miller (1980) reported that respiratory disease was clustered within calf crops, indicating that calf-to-calf contact may play a role in spreading respiratory infections.

Mortality in the first 3 months of life

Mortality (M3) was lower in herds that fed forage earlier (Table 7.6). The traditional recommendation is to not feed forage before weaning since there appears to be little benefit in rumen development (Warner et al., 1956). However, NAHMS (1993) also reported lower mortality in herds that fed forage to calves prior to weaning. The relationship between age at first forage feeding and mortality may be confounded with other factors. One possible explanation is that calves may consume bedding or other materials when forage is not available. Diaz et al., (2001) reported calves offered only a liquid diet consumed bedding material and calves fed a diet designed to support 500 g of ADG consumed more bedding material than calves fed more aggressive diets. Respondents surveyed observed that calves ate bedding so they provided quality forage to discourage calves from ingesting bedding materials. It is possible that feeding forage to calves early

in life reduces the consumption of pathogenic organisms that could be present in the bedding material.

Other factors associated with herds reporting lower mortality (M3) include a older age at weaning, cows and heifers calving in maternity pens, and 100% of heifers bred with AI (Table 7.6). These factors indicate higher levels of management as does lower mortality (M3). The relationship between calving location and mortality was similar for both M3 and M24 indicating that the calving location is a critical in calf management. Herds that fed more colostrum in the first 24 h of life or used colostrum supplements reported a higher incidence of mortality. Herds that fed more colostrum or used a supplement may have used these practices in an attempt to reduce calf mortality that was the result of other factors. It is possible that respondents that used colostrum supplements had poor colostrum management and the higher incidence of mortality (M24) was related to management and not the colostrum supplement. Some colostrum supplements have been shown to provide similar levels of immunity to calves as colostrum (Mowrey, 2001) but others have been shown to be inferior to colostrum (Zaremba et al., 1993) . The results reported here indicate that the colostrum supplements used were inferior to colostrum as measured by calf mortality.

Interpreting Correlations

It is important to note that the correlations between mortality and management factors are not always a cause-effect relationship. For example, the use of Bovatec™ to control coccidiosis is correlated with lower M24 but it is not likely that the use of Bovatec™ directly lowers calf mortality because this additive is used in preweaned calves and heifers but not routinely used in dry cows. Therefore, the proper interpretation of this correlation is that herds that feed Bovatec™ are more likely to utilize management practices that reduce the incidence of calf mortality.

On the other hand, some of the correlations between mortality and management factors may be directly related. For example, calving location and the use of bedding in the

calving area are correlated to mortality. Several researchers noted the importance of the calving location and environment in promoting health in both the newborn calf and her dam (Davis and Drackley, 1998; Donovan, 1992; Crowley et al., 1991).

Regression equations to predict mortality

In addition to correlations, regression equations were developed to predict M3 and the natural log transformation of M3 [nlog(M3+1)] (Table 7.7) and M24 and the natural log transformation of M24 [nlogM(24+1)] (Table 7.8). The equations to predict nlog(M3+1) and M3 had R^2 of 0.17 and .10, respectively. The equation to predict nlog(M24+1) and M24 had R^2 of 0.26 and 0.19, respectively. These equations predict calf mortality in a herd, based on a selected group of management factors but the R^2 of these equations are low indicating variation in calf mortality between herds is only partially explained by these factors.

Table 7.7 shows the equations to predict M3 and nlog(M3+1). The interaction between volume of colostrum fed in the first feeding and the age calf starter was first offered is shown in Figure 7.1. As the volume of colostrum fed increased and the age when calf starter was first offered increased the incidence of mortality (M3) increased. When calves are limit fed milk or milk replacer, calf starter provides nutrients so that the calf can maintain itself and grow. When calf starter was first offered at 7 d of age or less, as volume of colostrum fed in the first feeding increased from 1.0 L to 3.0 L, the incidence of mortality increased by less than 1% but when starter was first offered at 20 d of age the incidence of mortality increased by more than 3% (Figure 7.1). This relationship illustrates the importance of offering calf starter to calves in the first 7 d of life and shows that increasing the volume of colostrum fed in the first feeding was not adequate to offset the increase in mortality associated with delayed calf starter feeding. The relationship between increased level of colostrum feeding and increased mortality runs contrary to

conventional wisdom, which suggests feeding more colostrum in the first feeding is optimum for the calf. Herds that are experiencing high levels of calf mortality may feed more colostrum in an attempt to reduce mortality and thus explain the relationship between higher mortality and increased colostrum feeding.

The prediction equation for M24 showed that herds with the lowest mortality registered 100% of animals with the AJCA, had a lower goal for age at fist calving, did not need to vaccinate heifers for leptospirosis, and housed calves in the winter is housing other than calf hutches (Table 7.8). Vaccinating against leptospirosis probably does not increase calf mortality. However, herds that vaccinate against leptospirosis may be at an increased risk of this disease and implement this practice in an attempt to prevent the disease. Herds that have lower ages at first calving and register 100% of their calves may take a greater interest in their calves due to the value of these calves and execute practices to reduce mortality. The relationship between the winter calf housing and mortality is more difficult to interpret. Perhaps the use of calf hutches in the winter is confounded with one or more other factors that influences calf mortality.

The usefulness of the regression equations is that they identify groups of factors that collectively are associated with herds that have lower levels of mortality. However, like the correlation coefficients, these factors do not necessarily have a direct relationship to calf mortality.

Conclusions

Jersey calf mortality is lower than what has been previously reported for the United States calf population. This may be due in part to the superior colostrum management and nutritional practices on Jersey herds. Calving location influences mortality, herds that take utilize maternity pens to deliver calves have lower levels of mortality. Herds that register 100% of their calves and have a lower goal for age at first calving report lower levels of

mortality indicating these herds manage calves more aggressively. Opportunities for improvements in management calf management include offering calf starter and water to calves at an early age, and use of well-managed maternity pens.

Table 7.1. Characteristics of the herds surveyed by region of country.

	US		South East	PAOHIN[B]	North East	Wisconsin	West
	Mean	Top 10%[A]	Mean	Mean	Mean	Mean	Mean
General Info							
Number of herds	88		16	25	17	8	22
Completed Lactations	153	284	102	93	54	102	410
Milk, lactation average, kg	7180	8197	7110	7070	7085	7107	7530
Fat, lactation average, kg	331	376	327	329	329	338	339
Protein, lactation average, kg	256	295	249	252	253	254	272
Left herd, %	27.5	10.6	33.7	31.1	28.1	28.8	25.3
Left herd for dairy, %	7.8	21.4	12	8.9	7.9	7	6.5
Calving Interval, mo	13.0	12.2	13.4	13.6	13.2	13	13.3
Somatic Cell Score, 1000	232	77.6	313	231	230	307	227
Calves born	199	430	139	134	70	154	582
Mortality							
<24h	5.0	1.0	4.8	5.9	3.9	4.7	5.0
24h - 3 mo	6.7	0.0	5.0	6.9	3.5	9.5	7.7
>3 mo	1.3	0.0	2.3	1.7	0.7	1.1	1.0

[A]The 90th percentile for complete lactations, production, left for dairy, and calves born and the 10th percentile for left herd, calving interval, and somatic cell score.
[B]Herds located in PA, OH, and IN.

Table 7.2. Calf mortality and management of newborn calves.

	US	South East	PAOHIN[A]	North East	Wisconsin	West
Calving location						
Pasture, % of herds	46	69	25	17	50	22
Maternity pen (milking barn), % of herds	33	6	32	53	62	18
Maternity pen separate barn, % of herds	29	37	32	12	12.5	59
Loose housing, % of herds	25	-	32	-	-	9
Colostrum feeding						
Nurse, % of herds	11	31	-	12	-	4.5
Assist in nursing, % of herds	3	6	-	6	-	-
Bottle feed, % of herds	89	75	87.5	94	92	95
Tube feed, % of herds	14	25	25		9	14
Age at first feeding, hours	3.8	5.3	3.7	3.1	2.8	3.5
Volume at first feeding, L	1.9	1.8	1.8	1.7	2.1	2.3
Volume fed in first 24 h, L	3.8	3.8	3.5	3.6	4.1	4.2

[A]Herds located in PA, OH, and IN.

Table 7.3. Nutrition and feeding management.

Calf nutrition	US	South East	PAOHIN[A]	North East	Wisconsin	West
Liquid diet						
Whole milk, % of farms	48	62	40	53	50	36
Waste milk, % of farms	25	44	24	12	-	45
Pasteurized milk, % of farms	6	-	-	-	-	23
Milk Replacer, % of farms	57	38	60	65	88	45
Feeding program						
Milk fed/d, kg	3.1	2.8	2.7	2.9	2.7	3.1
Milk replacer powder fed/d, kg	0.4	0.4	0.4	0.4	0.5	0.4
Calf starter consumed/d at weaning, kg	1.5	1.5	1.4	1.3	1.3	1.5
Calf nutrition						
Age starter offered, d	7.9	9.8	7.4	6.5	6.9	9
Forage fed before weaning, % of herds	52	38	36	71	50	59
Water before weaning, % of herds	73	68	72	71	100	87
Age at weaning, wks	9.4	9	8.6	9.8	7.8	10.8

[A]Herds located in PA, OH, and IN.

Table 7.4. Health and reproductive management.

	US	South East	PAOHIN[A]	North East	Wisconsin	West
Health Programs						
Routine Veterinarian visit, % of herds	80	50	84	82	100	77
Deworm milking herd, % of herds	42	50	32	38	88	32
Deworm heifer herd, % of herds	66	88	60	59	100	50
Use Coccidia control, % of herds	90	88	96	82	100	82
Reproductive management						
Age at 1st calving, mo	22.7	22.8	22.9	23.0	23.5	21.5
Natural service only on heifers, % of herds	9.0	6.0	16	0.0	12.5	4.5

[A]Herds located in PA, OH, and IN.

Table 7.5. Primary calf feeder

	US	South East	PAOHIN[A]	North East	Wisconsin	West
Primary calf feeder						
Owner, % of herds	48	56	68	59	12.5	32
Spouse, % of herds	33	25	24	47	75	18
Child, % of herds	9	6	8	6	25	18
Herdsman, % of herds	5	-	8	-	-	9
Hired help, % of herds	16	25	24	6	0	23

[A]Herds located in PA, OH, and IN.

Table 7.6. Correlations between management and calf mortality.

Mortality in the first 24 hours of life

	Correlation	Mean[A]
Volume of Milk fed/day	-0.32	1.9 L
Use Bovatec for coccidiosis control	-0.22	40%
Use Deccox for coccidiosis control	0.20	33%
Child is primary calf feeder	0.20	11%
Rolling herd average for milk	-0.25	7181 kg
Balance Dry cow rations	-0.24	57%
Cows calve on pasture	0.33	45%
Heifers calve on pasture	0.30	55%
Heifers calve in tie stalls	0.19	7%
Maternity area bedded with bedding other than straw, shavings, or sawdust	-0.22	10%
Predominant calf disease not digestive or respiratory	0.28	6%
Goal for age at first calving	0.26	22.7 mo
Heifers vaccinated against Leptospirosis	0.19	82%
Heifers wormed	0.19	66%
More than 50% of calves suckle each other	0.33	10%
More than 50% but less than 100% registered	0.23	14%

Mortality in first 3 months of life

	Correlation	Mean[A]
Age forage first offered	0.33	17 d
Age calves are weaned	-0.20	9.4 wk
Cows calve in maternity pen in milking herd barn	-0.21	31%
Heifers calve in maternity pen in milking herd barn	-0.22	30%
Heifers place in precalving group	0.19	68%
Heifers calve in loose housing	0.26	23%
Volume of colostrum fed in first 24 hours	0.20	3.8 L
Use colostrum supplement	0.21	27%
Heifers bred 100% AI	-0.22	55%

[A]Mean or percent of herds reporting

Significant correlations ($P<0.10$) between management and calf mortality.

Table 7.7. Coefficients to predict mortality in first 3 months.

Mortality in the first 3 months of life

	M3[A]	NlogM3[B]
Intercept	3.89	1.04
Interaction of volume of colostrum fed in first feeding and age starter offered	0.06	0.03
Separate calves at birth before nursing	1.31	0.39
Breed heifers only with AI	-1.98	-0.44
R-square	0.10	0.17

[A]Mortality in the first 3 months of life
[B]Natural Log of (Mortality +1) in the first 3 months of life

Table 7.8 Coefficients to predict mortality in first 24 hours of life.

Mortality in the first 24 hours of life

	M24	NlogM24
Intercept	-12.76	-2.59
Vaccinate heifers for Leptosporisis	2.06	0.28
Use hutches for housing in winter	1.51	0.52
Goal for age at first calving	0.70	0.17
100% of herd registered	-1.57	-0.33
R-square	0.19	0.26

[A]Mortality in the first 24 hours of life
[B]Natural Log of (Mortality +1) in the first 24 hours of life

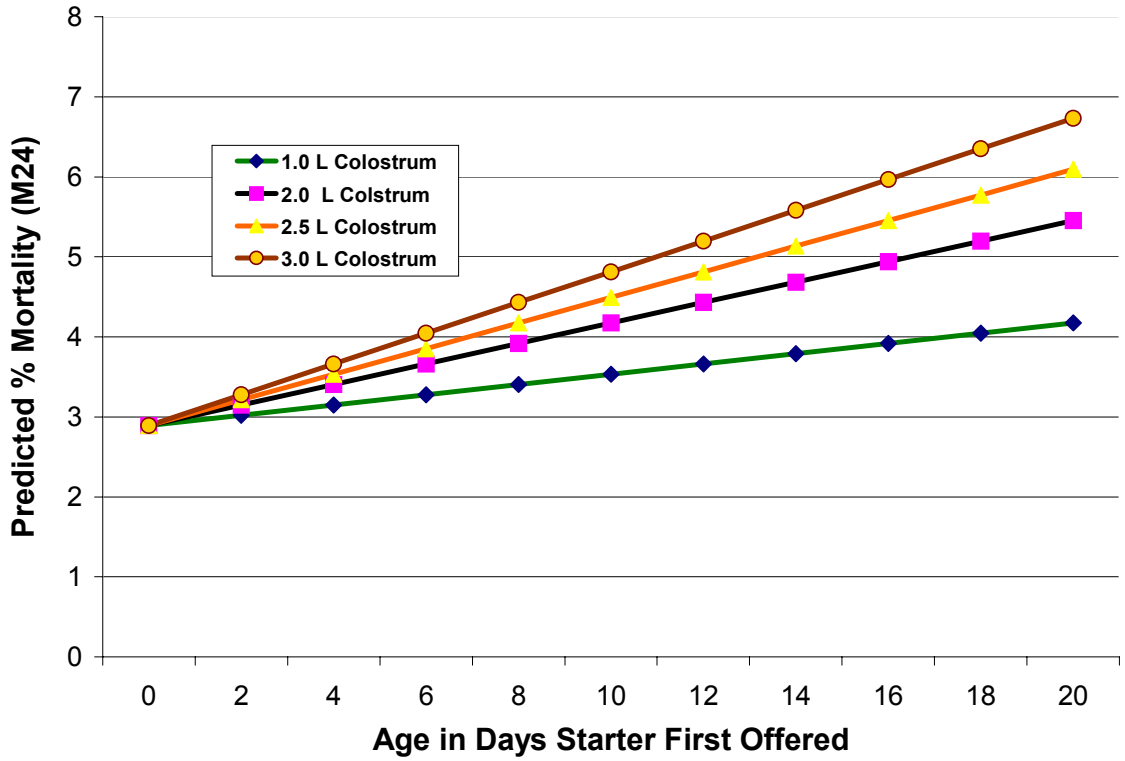


Figure 7.1. The interaction between volume of colostrum fed in first feeding and age calf starter first offered.

Chapter Eight

Conclusions

Conclusions

Overall, calves fed MILK showed superior performance, i.e., feed efficiency, ADG, total weight gain, and increase in hip height. These calves also deposited more body fat than calves fed 29/16 or 21/21**.** Feeding Jersey bull calves a 21/21 MR at 15% of BW is not advisable given that the calves fed 21/21 were inferior to the other diets in feed efficiency, ADG, and total BW gain. When Jersey bull calves were fed at or near ad libitum levels there was no advantage in feeding a 27/33 MR over feeding a 29/16 MR in feed efficiency, ADG, or total BW gain. However, calves fed 29/16 had no more body fat % than baseline calves indicating that higher levels of fat may be beneficial to Jersey bull calves particularly during environmental or weaning stress.

The metabolism of high fat MR in calves needs to be examined in future studies to identify the mechanisms that results in elevated NEFA when high fat MR are fed.

Optimum body composition of Jersey bull calves is not clear. In older pre-pubertal heifers, lean growth is desired because of the positive relationship between lean growth and mammary development. Often it is assumed that lean gains are desirable in young calves for similar reasons. However, the relationship between body composition and mammary development in neonatal calves is not well established. Neonatal calves have relatively low body fat stores. During prolonged periods of stress due to disease, weaning, or environmental conditions intake of dietary energy may be insufficient to maintain the calf and support growth. Therefore, a moderate level of body fat may be desirable in the young calf. Longer-term studies should be conducted to determine optimum body composition

in the preweaned calf for future performance and profitability. Non-invasive methods to estimate body composition, like DXA, would be useful in assessing the impact of body composition in the young calf and on lactation potential. However, refinements in the DXA techniques used in this experiment are needed so that DXA estimates of composition more closely approach CHEM measurements of body composition in calves. Mass of tissues was accurately estimated by DXA. However, DXA was a poor predictor of body composition. Additional studies using DXA to estimate body composition in calves are merited.

Jersey calf mortality is lower than what has been previously reported for the US calf population. This maybe in part due to the superior colostrum management and nutritional practices on Jersey herds. Herds with the lowest level of mortality use maternity pens to calve cows and heifers, feed more milk to calves, offer calf starter to calves in the first week of life, have a lower goal for age at first calving, and register 100% of calves.

Synthesis

Jersey breeders feed calves milk and milk replacer at more than 8 to 10% of BW. Feeding Jersey calves a 21% CP and 21% fat milk replacer supports only modest weight gains, does not increase the deposition of body fat, and feed efficiency is marginal even when fed at 15% of BW. Therefore, Jersey calves would benefit from feeding a milk replacer with a different nutrient profile than 21% CP and 21% fat. Feeding Jersey calves at or near ad lib intake a 27 to 29% CP milk replacer appeared to provide sufficient CP to support growth. However, neither a 16% fat nor a 33% fat milk replacer were satisfactory. The 16% fat milk replacer did not increase body fat percentage above baseline calves or calves fed a 21% CP, 21% fat milk replacer. While feeding the 33% fat milk replacer resulted in an increase in body fat percentage rate of weight gain and feed efficiency was not different from calves fed 16% fat and calves fed 33% fat had elevated NEFA. We also observed that calves fed 33% fat MR were a bit reluctant to consume it and suspect that palatability could be an issue with high fat MR. We surmise that a 28 to 29% CP and 25% fat milk

replacer would be the optimum formulation for feeding Jersey calves fed an intensified program. Appendix E shows the development of the logic for this formulation.

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Appendix A

Assignment to Treatments

Calf ID	Treatment	Farm	Sacrificed	Crate	DXA	Date of Birth
3	21/21	A	1	1	0	12-Aug-01
14	21/21	A	1	0	1	30-Sep-01
18	21/21	A	1	0	1	24-Sep-01
23	21/21	A	1	1	1	7-Sep-01
27	21/21	A	1	0	0	13-Sep-01
30	21/21	A	1	1	1	17-Sep-01
37	21/21	VPI	0	1	0	8-Sep-01
39	21/21	VPI	0	1	0	15-Sep-01
7	27/33	A	1	1	0	21-Aug-01
13	27/33	A	0	1	0	29-Sep-01
17	27/33	A	1	0	1	24-Sep-01
21	27/33	A	1	0	1	1-Sep-01
26	27/33	A	1	1	1	10-Sep-01
32	27/33	A	1	1	1	21-Sep-01
36	27/33	VPI	1	1	1	21-Aug-01
41	27/33	VPI	0	1	0	18-Sep-01
2	29/16	A	1	0	0	11-Aug-01
8	29/16	A	1	0	0	22-Aug-01
11	29/16	A	1	1	1	5-Oct-01
16	29/16	A	1	1	1	26-Sep-01
22	29/16	A	1	0	1	12-Sep-01
28	29/16	A	0	1	1	13-Sep-01
31	29/16	A	1	1	1	18-Sep-01
34	29/16	VPI	1	1	0	10-Aug-01
42	29/16	VPI	0	1	0	19-Sep-01
5	baseline	A	1	0	0	18-Aug-01
10	baseline	A	1	0	1	5-Oct-01
20	baseline	A	1	0	0	28-Aug-01
25	baseline	A	1	0	1	13-Sep-01
35	baseline	VPI	1	0	0	11-Aug-01
40	baseline	VPI	1	0	0	17-Sep-01
4	*DIED*	A	-	-	-	14-Aug-01
6	*DIED*	A	-	-	-	18-Aug-01
9	*DIED*	A	-	-	-	24-Aug-01
1	milk	A	1	1	0	11-Aug-01
12	milk	A	0	1	0	6-Oct-01
15	milk	A	1	0	1	26-Sep-01
19	milk	A	0	1	0	28-Aug-01
24	milk	A	1	0	1	9-Sep-01
29	milk	A	0	1	0	13-Sep-01
33	milk	VPI	1	1	0	7-Aug-01

38	milk	VPI	1	0	1	10-Sep-01

Appendix B
Sample Body Composition Calculation

Sample Calculation of Composition

Calf # 33, diet **milk**

	Initial BW	Final BW	BO	HHFT	CAR	EBW[A]	Gut fill	EBW/BW [B]
Weight, kg	26.0	41.0	8.3	18.9	11.5	38.8	0.9	96.9%

Composition

	BO	HHFT	CAR		
% water	39.2	69.3	66.5		
DM, g [C]	5063	5815	3869		
Ether extract, % DM	31.2	18.4	21		
CP, % DM	59.6	63	66		
Ash, % DM	6.9	18.5	14.2		
GE kcal/g, DM	5.79	4.86	5.32	Total	%EBW
Water, g [D]	3265	13126	7680	24070	62.0
Ether extract, g [D]	1580	1070	812	3462	8.9
CP, g [D]	3018	3663	2553	9234	23.8
Ash, g [D]	349	1076	549	1974	5.1
GE, mcals [E]	29.3	28.3	20.6	78.2	

Baseline Calf Average

GE, mcal/kg	Water, %	Ether Extract, %	CP, %	Ash, %	Gut fill, kg	EBW/BW [A]
1.44	66.94	2.90	24.77	5.99	0.594	98.5%

Estimated Initial Composition of Calf #33

Estimated EBW[F]	Water, g [G]	Ether extract, g [G]	CP, g [G]	Ash, g [G]	GE, mcals [G]
25.0	16752	725	6199	1499	36.0

Change in Body Composition

	EBG, kg	Water, kg	Ether extract, kg	CP, kg	Ash, kg	GE, mcals
Gain [H]	13.6	7.3	2.7	3.0	0.5	42.1
comp of gain, % [I]		53.9	20.2	22.4	3.5	

(A) EBW = BO + HHFT + CAR

(B) EBW/(Live BW-Gut fill)

(C) $DM_{(x)}$ = Weight $fraction_{(x)}$ * (1- % $Water_{(x)}$); where (x) is BO, HHFT, or CAR

(D) $C_{(x)}$ = DM $fraction_{(x)}$ * % $C_{(x)}$ in $fraction_{(x)}$; where (x) is BO, HHFT, or CAR

(E) $GE_{(x)}$ = DM $fraction_{(x)}$ * % GE in $fraction_{(x)}$; where (x) is BO, HHFT, or CAR

(F) Estimated initial EBW = (Initial BW – gut $fill_{baseline}$) * $EBW/BW_{baseline}$

(G) C'= Estimated initial EBW * % C in baseline

(H) Gain = final composition – estimated initial composition

(I) Comp of Gain = C'/EBG

Appendix C
Jersey Calf Management Survey

responses (total herds or mean) shown in red

1. In the last 12 months:

How many calves were born (assumes heifers and bulls)? 225 ±287

How many of these calves were born dead or died within 24 hours? 5.0 ±6.3 %

How many of these died....

<3 months of age 6.4 ±8.6%

>3 months of age 1.3 ±1.7%

All Questions are based on management practices used during the past 12 months. Listed below are practices you may have used in the care of the dam. Indicate whether or not you used the practice in the last year.

Yes No

2 Worm the milking herd y=36
3 Vaccinate against leptospirosis y=77
4 Vaccinate against respiratory disease y=78
5 Vaccinate against BVD y=79
6 Body Condition Score dry cows y=14

Calving Facilities

7. What were the main types of calving facilities (maternity) you used for your milking herd (not heifers)? Rank answers if more than one.

A. Pasture 40
B. Dry lot 10
C. Maternity Pens-Housed with Milking Herd 27
D. Maternity Pens-Housed Separately 30
E. Stanchions or Tie Stalls 4
F. Free Stall Area-Housed with Milking Herd 2
G. Free Stall Area-Not Housed with Milking Herd 0
H. Loose Housing Area 18
I. Other 0

8. What types of bedding did you use in the maternity area? Rank answers if more than one.
   A. Straw 54
   B. Hay 7
   C. Sawdust-wet 11
   D. Sawdust-kiln dry 16
   E. None 4
   F. Other 9

Colostrum Feeding

9. Did you wash the cows udder after calving? (before calf nursed or colostrum was milked)
   A. Allow calf to nurse dam 10
   B. Assist calf feeding from dam 2
   C. Feed from open or nipple bucket or bottle (not allow calf to nurse dam) 79
   D. Esophagael feeder 11
   E. Other 0

10. Did you usually wash the cow's udder after calving? (before calf nursed or colostrum was fed)
   A. No 22
   B. Yes 66

11. When did calves first receive colostrum? (what is normal, not the exception)
   3.8 ± 3.0 hours

12. How much colostrum did you normally feed the calf at the first feeding?
   2.0 ± 0.6 quarts

13. How much colostrum did you normally feed the calf in the first d of life?
   3.8 ± 1.2 quarts

14. Did you use any frozen colostrum supplement for newborn calves?
   A. No 30
   B. Yes 58

if yes,
   A. Problem cases only (included pre-partum milking) 42
   B. Offspring of all first calf heifers 12
   C. All calves 5

15. Did you use a colostrum supplement for newborn calves?
   A. Yes 24
   B. No 60

16. When did you usually separate the calf from its dam?
   A. At birth before nursing 65
   B. Following one nursing 15
   C. Following ____ d of age. 9

17. At what age did you start feeding grain (starter or other grain) to calves?
   8 ±5.9 d

18. Did you feed forage to calves before weaning?
    A. No 44
    B. Yes 44
    if yes, what age 11 ± 17 d
19. Did calves have access to drinking water before weaning?
    A. No 20
    B. Yes 67
    if yes, at what age did you start? 9.8 ± 14.3 d.

Other Aspects of Raising Young (Pre-Weaned calves)

20. What are the major types of pre-weaned calf raising facilitity(s) that you used in the winter and the summer of last year? (Check appropriate ones) Rank answers if more than one.

	Winter	Summer
Hutches (individual)	45	41
Group pens (outdoors)	0	0
Group pens (indoors, in dairy barns)	6	5
Group pens (outdoors, in separate barns)	6	5
Elevated stalls – wood (in dairy barns)	0	0
Elevated stalls – wood (in separate barns)	1	1
Elevated stalls – metal (in dairy barns)	0	0
Elevated stalls – metal (in separate barns)	2	2
Individual pens (in dairy barns)	14	17
Individual pens (in separate barns)	18	22
Tied	7	8
Other	1	1

21. What are the primary types of bedding used in your calf raising facility (where applicapable)?
    Rank answers
    A. Straw/hay 56
    B. Sand 2
    C. Sawdust/wood shavings 41
    D. Newspaper 2
    E. Corn cobbs/stalks 0
    F. Other 10

22. How old are calves when you usually wean them?
    9.4 ± 3.2 weeks

23. How do you decide when to wean calves? List primary criterion.
    A. Size 17
    B. Age 55
    C. Grain intake 28
    D. Other (specify) 11

Replacement Herd Health

24. What is the predominant disease problem with calves less than 3 months of age in your herd?
    A. Digestive 63
    B. Respiratory 24
    C. Other (specify) 5

25. What is the source of liquid feed fed to preweaned calves?
    A. Whole milk 41
    B. Waste milk 25
    C. Pastuerized milk 5
    D. Fermented colostrum 3
    E. Milk Replacer 49

26. Does the liquid diet contain any additive?
    A. Antibiotics 33
    B. Decox 10
    C. Rumensin 2
    D. Bovatec 1
    E. Other (specify) 7

27. Do you feed a probiotic to preweaned calves?
    A. No 58
    B. Yes 29

28. Listed below are some vaccinations you might have used with your calves and heifers in the past year. For each measure, check the appropriate box.

	Yes	No	frequency before calving
Brucellosis	86		
IBR	75		
BVD	74		
PI3	74		
BRSV	70		
Leptospirosis	72		
Virus calf scours	29		
Other	33		

29. Did you worm heifers during the past year?
    A. No 29
    B. Yes 58

30. Do you use a coccidiostat or coccidocide for coccidosis control?
    A. No 10
    B. Yes 78

31. If yes, what product do you use?
    A. Bovatec 35
    B. Corrid 14
    C. Deccox 29

D. Other 16

Reproductive Management

32. What is your goal for age at first calving?
22.7 ± 0.5 months

33. What is the determing factor for when you decide a heifer is ready to be bred for the first time?
A. Age 22
B. Weight 11
C. Both age and weight 54
D. Other 2

34. What method of breeding heifers do you use?
A. AI only 48
B. AI first time, then bull 7
C. AI first and second time, then bull 27
D. Other (specify) 1

35. What types of bulls are used for heifers?
A. Dairy-same breed as cows? 87
B. Dairy-different breed as cows? 2
C. Beef 0

36. Did you use estrus synchronization in heifers in the past year?
A. No 50
B. Yes 36
if yes, what product did you use?
A. Prostaglandin 29
B. Synchro-mate B 3
C. Other 4

37. Do you routinely check heifers prior to breeding for reproductive infection?
A. No 76
B. Yes 11
if yes, what age 10.3 mo

38. Where did your heifers calve (check all that apply) Rank if more than one response.
A. Pasture 48
B. Dry lot 10
C. Maternity Pens-Housed with Milking Herd 26
D. Maternity Pens-Housed Separately 26
E. Stanchions or Tie Stalls 6
F. Free Stall Area-Housed with Milking Herd 0
G. Free Stall Area-Not Housed with Milking Herd 0
H. Loose Housing Area 20
I. Other 1

39. Are heifers placed in a pre-calving group prior to calving?
A. No 28
B. Yes 60

40. Are your first calf heifers grouped by themselves in the milking herd?
    A. No 68
    B. Yes 13

    Do you allow first calf heifers a longer d to first breeding than older cows?
        A. No 50
        B. Yes 16
        If yes, how much longer? 19.4 d

Milking Management and Mastitis Prevention

41. Did calves suckle each other prior to weaning?
        A. No 77
        B. Yes (>5%) 9

42. Did heifers have access to a pond or lagoon?
        A. No 72
        B. Yes 16

43. Have any heifers been milked pre-partum during the past 12 months?
    A. No 47
    B. Yes, what % 41, 7.9%

44. During the past twelve months, did you routinely treat heifers with antibiotics for mastitis prevention prior to calving?
    A. No 66
    B. Yes 20

If yes, what type of product did you use?
    A. Lactating 11
    B. Non-Lactating product 11
    How long before expected calving were heifers treated? ___weeks

Replacement Herd Culling Practices

45. What percentage of heifers were sold
    A. For extra income _11.5__ %
    B. For beef __0.3__%

46. Which of the following most closely describes replacement culling practices in your herd?
    A. No culling-all replacements raised and entered the milking herd. 38
    B. Excess heifers were sold as baby calves 9
    C. Excess heifers were sold as open heifers 25
    D. Excess heifers were as springers 13

47. Which of the following most closely describes your milking herd size within the past twelve months.
    A. Increased by more than 5% 31

B. Decreased by more than 5% 9
C. Stayed with in +/- 5% 46

48. What was the criteria used to make heifer culling decisions.
A. Heifers ETA (Estimated Transmitting Ability) 12
B. Heifer's Type 9
C. Dam's performance in herd 12
D. Sire's PTA (Predicted Transmitting Ability) 5
E. Other (specify) 15
F. No culling was done 39

Records

49. Is the herd currently enrolled in DHI's Heifer Management Option?
A. No 46
B. Yes 30

50. What percentage of the herd is registered?
A. 0% 0
B. 1-49% 3
C. 50-99% 12
D. 100% 73

Nutrition
Pre-weaned Calves

51. Feed
A. Lbs milk fed per d 6.6 ±2.0
B. Lbs milk replacer fed per d 0.96±.35
C. Lbs calf starter consumed at weaning 3.1±1.6
D. Lbs forage consumed at weaning 2.5±2.2

52.Who is primarily responsible for feeding baby cavles?
A. Owner 41
B. Spouse 28
C. Child 10
D. Herdsman 4
E. Hired help 16
F. Other 3

Other

53. Do you have a routine herd health prog with your Veterinarian?
A. No 19
B. Yes 69

if yes, frequency
A. Weekly 3
B. Bi-weekly 17
C. Monthly 41
D. Other, specify 10

54. Do you have a routine vaccination program for the lactating herd?

A. No 10
B. Yes 77

55. Do you have a routine vaccination prog for the dry cows?
A. No 26
B. Yes 55

56. Do you work with a Nutritionist or Nutritional Consultant?
A. No 18
B. Yes 70

if yes, who provides the service
A. Private consultant 21
B. Feed company 48
C. Veterinarian 7
D. Other, specify 3

57. Do you balance rations for dry cows?
A. No 34
B. Yes 50

58. Do you balance rations for dry cows in the first 60 d of their Dry Period?
A. No 35
B. Yes 47

59. Do you feed a different ration in the last 2 to 3 weeks of their dry period?
A. No 47
B. Yes 34

60. If yes, Do you have a separate ration for these cows?
A. No 52
B. Yes 33

61. Do you feed anionic salts or BioChlor or SoyChlor
A. No 49
B. Yes 32

Appendix D

Statistical Models

Glucose

Source	DF	Type III SS	Mean Square	F Value	Pr > F
glucose0	1	2937.622641	2937.622641	6.62	0.0198
farm	1	24.005850	24.005850	0.05	0.8189
diet	3	838.918110	279.639370	0.63	0.6055
diet*farm	3	2206.010639	735.336880	1.66	0.2138
Error	17	7544.828791	443.813458		

Source	DF	Type III SS	Mean Square	F Value
week	3	2198.27186	732.75729	2.63
week*glucose0	3	2317.53646	772.51215	2.77
week*farm	3	384.95233	128.31744	0.46
week*diet	9	3583.86581	398.20731	1.43
week*diet*farm	9	2337.11734	259.67970	0.93
Error(week)	51	14213.30632	278.69228	

Tests of Hypotheses Using the Type III MS for trt*farm as an Error Term

Dependent Variable: glucose1

Source	DF	Type III SS	Mean Square	F Value	Pr > F
diet	3	1406.452064	468.817355	0.64	0.6382

Dependent Variable: glucose2

diet	3	329.2460262	109.7486754	0.16	0.9180

Dependent Variable: glucose3

diet	3	154.7335434	51.5778478	0.94	0.5202

Dependent Variable: glucose4

diet	3	2532.352289	844.117430	24.99	0.0127

PUN

Source	DF	Type III SS	Mean Square	F Value	Pr > F
pun0	1	75.6274916	75.6274916	4.28	0.0499
diet	3	140.9303684	46.9767895	2.66	0.0720
farm	1	0.1298195	0.1298195	0.01	0.9324
diet*farm	3	7.7356261	2.5785420	0.15	0.9311
Error	23	405.9680621	17.6507853		

Source	DF	Type III SS	Mean Square	F Value
week	3	6.9501698	2.3167233	0.26
week*pun0	3	9.0909303	3.0303101	0.34
week*diet	9	47.7246465	5.3027385	0.59
week*farm	3	8.7471050	2.9157017	0.33
week*diet*farm	9	50.0725671	5.5636186	0.62
Error(week)	69	617.2337636	8.9454169	

Tests of Hypotheses Using the Type III MS for diet*farm as an Error Term

Dependent Variable: pun1

Source	DF	Type III SS	Mean Square	F Value	Pr > F

diet	3	72.62153644	24.20717881	10.43	0.0428
Dependent Variable: pun2					
diet	3	27.46615480	9.15538493	25.89	0.0120
Dependent Variable: pun3					
diet	3	51.62573050	17.20857683	38.21	0.0069
Dependent Variable: pun4					
diet	3	36.94159324	12.31386441	0.76	0.5854

NEFA

Source	DF	Type III SS	Mean Square	F Value	Pr > F
nefa0	1	4661.6169	4661.6169	0.22	0.6449
diet	3	813007.3868	271002.4623	12.69	<.0001
farm	1	53990.8782	53990.8782	2.53	0.1260
diet*farm	3	44020.3294	14673.4431	0.69	0.5694
Error	22	469670.3747	21348.6534		

Source	DF	Type III SS	Mean Square	F Value
week	3	3405.556	1135.185	0.06
week*nefa0	3	14635.923	4878.641	0.25
week*diet	9	133538.066	14837.563	0.77
week*farm	3	15819.515	5273.172	0.27
week*diet*farm	9	88286.330	9809.592	0.51
Error(week)	66	1267557.622	19205.419	

Tests of Hypotheses Using the Type III MS for diet*farm as an Error Term

Dependent Variable: nefa1					
Source	DF	Type III SS	Mean Square	F Value	Pr > F
diet	3	235099.0999	78366.3666	9.22	0.0504
Dependent Variable: nefa2					
diet	3	277392.8637	92464.2879	10.13	0.0445
Dependent Variable: nefa3					
diet	3	401210.9615	133736.9872	6.96	0.0726
Dependent Variable: nefa4					
diet	3	32842.52740	10947.50913	1.51	0.3722

MR Fed, kg

Dependent Variable: kgfed kgfed

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Diet	3	18372.10947	6124.03649	222.32	<.0001
Error	29	798.83306	27.54597		
Corrected Total	32	19170.94253			

Protein Fed, g

Dependent Variable: gpro gpro

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Diet	3	45879942.65	15293314.22	511.77	<.0001
Error	29	866616.17	29883.32		
Corrected Total	32	46746558.82			

Fat Fed,g

Dependent Variable: gfat gfat

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F

Diet	3	119459575.0	39819858.3	986.87	<.0001
Error	29	1170139.9	40349.7		
Corrected Total	32	120629714.9			

DM Fed, g

Dependent Variable: gdm gdm

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	353127102.3	117709034.1	243.26	<.0001
Error	29	14032372.5	483874.9		
Corrected Total	32	367159474.9			

Gain to Feed ratio

Dependent Variable: gain_feed gain_feed

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	3	0.59593017	0.19864339	18.39	<.0001
farm	1	0.00245313	0.00245313	0.23	0.6378
diet*farm	3	0.02609428	0.00869809	0.81	0.5028
Error	25	0.27001451	0.01080058		
Corrected Total	32	0.95590155			

BW Gained, kg

Dependent Variable: kggained kggained

Source	DF	Type I SS	Mean Square	F Value	Pr > F
diet	3	440.6461490	146.8820497	45.65	<.0001
farm	1	0.8884111	0.8884111	0.28	0.6039
diet*farm	3	7.5704183	2.5234728	0.78	0.5140
Error	25	80.4404762	3.2176190		
Corrected Total	32	529.5454545			

Water intake, l

Dependent Variable: ctotal ctotal

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Diet	3	386274440.0	128758146.7	2.00	0.1368
farm	1	401770950.0	401770950.0	6.24	0.0186
Error	28	1802459287	64373546		
Corrected Total	32	2608168380			

Average Daily Gain

Dependent Variable: ADG ADG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	3	0.46767548	0.15589183	37.98	<.0001
farm	1	0.00105171	0.00105171	0.26	0.6171
diet*farm	3	0.00965615	0.00321872	0.78	0.5140
Error	25	0.10260265	0.00410411		
Corrected Total	32	0.67544063			

Weekly Water Intake

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diet	3	1828169.513	609389.838	1.57	0.2213
farm	1	2419121.451	2419121.451	6.24	0.0195
Diet*farm	3	1279951.992	426650.664	1.10	0.3677
Error	25	9698738.376	387949.535		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
week	3	485201.96	161733.99	1.20	0.3173
week*Diet	9	877381.98	97486.89	0.72	0.6885
week*farm	3	170310.13	56770.04	0.42	0.7394
week*Diet*farm	9	975397.14	108377.46	0.80	0.6164
Error(week)	75	10146157.40	135282.10		

Tests of Hypotheses Using the Type III MS for Diet*farm as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Dependent Variable: water1					
Diet	3	378640.5647	126213.5216	0.73	0.5988
Dependent Variable: water2					
Diet	3	1219482.594	406494.198	0.90	0.5336
Dependent Variable: water3					
Diet	3	563374.3458	187791.4486	1.64	0.3478
Dependent Variable: water4					
Diet	3	544053.9922	181351.3307	14.52	0.0272

Girth

Source	DF	Type III SS	Mean Square	F Value	Pr > F
girth0	1	64.4585992	64.4585992	2.60	0.1206
diet	3	240.0925904	80.0308635	3.23	0.0412
farm	1	8.7063442	8.7063442	0.35	0.5593
diet*farm	3	65.1978079	21.7326026	0.88	0.4679
Error	23	570.5247699	24.8054248		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
week	3	33.0463535	11.0154512	1.28	0.2877
week*girth0	3	30.4302981	10.1434327	1.18	0.3239
week*diet	9	65.9778807	7.3308756	0.85	0.5711
week*farm	3	9.5294439	3.1764813	0.37	0.7753
week*diet*farm	9	101.1941068	11.2437896	1.31	0.2490
Error(week)	69	593.2627710	8.5980112		

Tests of Hypotheses Using the Type III MS for diet*farm as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Dependent Variable: girth1					
diet	3	64.05176697	21.35058899	1.53	0.3682
Dependent Variable: girth2					
diet	3	28.81792507	9.60597502	0.44	0.7403
Dependent Variable: girth3					
diet	3	89.28069756	29.76023252	3.84	0.1492
Dependent Variable: girth4					
diet	3	123.9200815	41.3066938	3.45	0.1681

Hip Height

Source	DF	Type III SS	Mean Square	F Value	Pr > F
hip0	1	73.1119173	73.1119173	6.26	0.0196
diet	3	67.4673975	22.4891325	1.92	0.1526
farm	1	0.3149834	0.3149834	0.03	0.8710
diet*farm	3	47.6748691	15.8916230	1.36	0.2789
Error	24	280.5044069	11.6876836		

Source	DF	Type III SS	Mean Square	F Value

week	3	7.0829711	2.3609904	1.16
week*hip0	3	6.1438113	2.0479371	1.00
week*diet	9	34.6320435	3.8480048	1.88
week*farm	3	13.3118555	4.4372852	2.17
week*diet*farm	9	26.5337368	2.9481930	1.44
Error(week)	72	147.1224912	2.0433679	

Tests of Hypotheses Using the Type III MS for diet*farm as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Dependent Variable: hip1					
diet	3	0.65159428	0.21719809	0.07	0.9711
Dependent Variable: hip2					
diet	3	11.53035219	3.84345073	1.45	0.3827
Dependent Variable: hip3					
diet	3	29.79777305	9.93259102	0.80	0.5712
Dependent Variable: hip4					
diet	3	60.11972154	20.03990718	3.02	0.1941

Wither Height

Source	DF	Type III SS	Mean Square	F Value	Pr > F
wither0	1	93.3443365	93.3443365	15.96	0.0005
diet	3	72.1207415	24.0402472	4.11	0.0173
farm	1	6.2705665	6.2705665	1.07	0.3107
diet*farm	3	61.7843191	20.5947730	3.52	0.0302
Error	24	140.3418896	5.8475787		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
week	3	0.4549750	0.1516583	0.05	0.9857
week*wither0	3	0.4130819	0.1376940	0.04	0.9876
week*diet	9	59.9429368	6.6603263	2.13	0.0372
week*farm	3	14.4759707	4.8253236	1.55	0.2099
week*diet*farm	9	29.0310483	3.2256720	1.03	0.4222
Error(week)	72	224.6757344	3.1204963		

Tests of Hypotheses Using the Type III MS for diet*farm as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Dependent Variable: wither1					
diet	3	2.54883642	0.84961214	0.55	0.6801
Dependent Variable: wither2					
diet	3	12.06290265	4.02096755	0.63	0.6411
Dependent Variable: wither3					
diet	3	59.90645237	19.96881746	1.34	0.4070
Dependent Variable: wither4					
diet	3	57.54548683	19.18182894	2.54	0.2317

Weekly weight

Source	DF	Type III SS	Mean Square	F Value	Pr > F
wt0	1	471.7243760	471.7243760	50.47	<.0001
diet	3	627.3554946	209.1184982	22.37	<.0001
farm	1	2.0418482	2.0418482	0.22	0.6444
diet*farm	3	34.9392979	11.6464326	1.25	0.3150
Error	24	224.3128264	9.3463678		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
week	3	5.3277254	1.7759085	1.49	0.2235
week*wt0	3	4.4762506	1.4920835	1.26	0.2963

week*diet	9	110.5591575	12.2843508	10.33	<.0001
week*farm	3	0.0968679	0.0322893	0.03	0.9939
week*diet*farm	9	5.3919777	0.5991086	0.50	0.8670
Error(week)	72	85.5877375	1.1887186		

Tests of Hypotheses Using the Type III MS for diet*farm as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Dependent Variable: weight1					
diet	3	35.57547910	11.85849303	7.08	0.0711
Dependent Variable: weight2					
diet	3	119.8226893	39.9408964	6.50	0.0792
Dependent Variable: weight3					
diet	3	211.1876646	70.3958882	30.71	0.0094
Dependent Variable: weight4					
diet	3	371.3288190	123.7762730	37.11	0.0072

Body Length

Source	DF	Type III SS	Mean Square	F Value	Pr > F
length0	1	150.5803600	150.5803600	7.19	0.0130
diet	3	158.6979582	52.8993194	2.53	0.0814
farm	1	4.3043833	4.3043833	0.21	0.6543
diet*farm	3	39.2588138	13.0862713	0.63	0.6058
Error	24	502.5121318	20.9380055		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
week	3	4.9199939	1.6399980	0.14	0.9356
week*length0	3	4.3225925	1.4408642	0.12	0.9462
week*diet	9	43.4573442	4.8285938	0.41	0.9245
week*farm	3	32.9608454	10.9869485	0.94	0.4265
week*diet*farm	9	78.5623719	8.7291524	0.75	0.6658
Error(week)	72	842.6299186	11.7031933		

Tests of Hypotheses Using the Type III MS for diet*farm as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Dependent Variable: length1					
diet	3	13.81594791	4.60531597	1.07	0.4781
Dependent Variable: length2					
diet	3	69.99442169	23.33147390	2.63	0.2241
Dependent Variable: length3					
diet	3	43.55087116	14.51695705	1.28	0.4217
Dependent Variable: length4					
diet	3	74.79406168	24.93135389	1.69	0.3389

% N retained

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	3	0.12943247	0.04314416	3.74	0.0366
farm	1	0.00803656	0.00803656	0.70	0.4181
diet*farm	3	0.02727766	0.00909255	0.79	0.5206
Error	14	0.16161973	0.01154427		
Corrected Total	21	0.32615540			

Tests of Hypotheses Using the Type III MS for diet*farm as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
diet	3	0.12943247	0.04314416	4.74	0.1166

G of N Retained Per kg of Gain

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	3	562.1619517	187.3873172	1.26	0.3253
farm	1	467.4127465	467.4127465	3.15	0.0977
farm*diet	3	363.8870132	121.2956711	0.82	0.5057
Error	14	2078.336442	148.452603		
Corrected Total	21	3709.139680			

Tests of Hypotheses Using the Type III MS for farm*diet as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
diet	3	562.1619517	187.3873172	1.54	0.3647

Percent N digested

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	3	0.01085233	0.00361744	0.91	0.4606
farm	1	0.00064563	0.00064563	0.16	0.6928
farm*diet	3	0.00233049	0.00077683	0.20	0.8976
Error	14	0.05558003	0.00397000		
Corrected Total	21	0.08559909			

Tests of Hypotheses Using the Type III MS for farm*diet as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
diet	3	0.01085233	0.00361744	4.66	0.1193

Percent Fat digested

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	3	0.00165614	0.00055205	1.01	0.4185
farm	1	0.00049040	0.00049040	0.90	0.3601
farm*diet	3	0.00056736	0.00018912	0.35	0.7931
Error	14	0.00766968	0.00054783		
Corrected Total	21	0.00979087			

Tests of Hypotheses Using the Type III MS for farm*diet as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
diet	3	0.00165614	0.00055205	2.92	0.2012

APE_fat

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	3	0.19080989	0.06360330	4.08	0.0214
farm	1	0.03613936	0.03613936	2.32	0.1441
Error	19	0.29584174	0.01557062		
Corrected Total	23	0.48959069			

APE_protein

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	3	0.33478760	0.11159587	0.33	0.8049
farm	1	0.03393197	0.03393197	0.10	0.7555
Error	19	6.45768242	0.33987802		
Corrected Total	23	6.84502839			

APE GE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F

diet	3	0.09491589	0.03163863	1.17	0.3456
farm	1	0.05168949	0.05168949	1.92	0.1820
Error	19	0.51176315	0.02693490		
Corrected Total	23	0.67923295			

Carcass as_percent_ebw

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	4	0.00106600	0.00026650	0.28	0.8899
farm	1	0.00000646	0.00000646	0.01	0.9354
Error	25	0.02308860	0.00092354		
Corrected Total	29	0.02416157			

Organs_percent_ebw

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	4	0.00658497	0.00164624	2.84	0.0463
farm	1	0.00000077	0.00000077	0.00	0.9713
Error	24	0.01390647	0.00057944		
Corrected Total	29	0.02050451			

hhft_percent_ebw

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	4	0.01247201	0.00311800	6.46	0.0011
farm	1	0.00001168	0.00001168	0.02	0.8777
Error	24	0.01157812	0.00048242		
Corrected Total	29	0.02410312			

Water_percent of ebw

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	4	0.02336979	0.00584245	0.98	0.4380
farm	1	0.00007827	0.00007827	0.01	0.9098
Error	24	0.14338202	0.00597425		
Corrected Total	29	0.16691105			

Crude Protein percent of ebw

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	4	0.00442968	0.00110742	0.34	0.8477
farm	1	0.00021744	0.00021744	0.07	0.7981
Error	24	0.07798752	0.00324948		
Corrected Total	29	0.08243512			

Fat percent of ebw

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	4	0.01098097	0.00274524	18.41	<.0001

farm	1	0.00002055	0.00002055	0.14	0.7137
Error	24	0.00357855	0.00014911		
Corrected Total	29	0.01463417			

Ash percent of ebw

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	4	0.00065000	0.00016250	0.95	0.4540
farm	1	0.00007962	0.00007962	0.46	0.5023
Error	24	0.00411751	0.00017156		
Corrected Total	29	0.00476827			

GE in Carcass, kcal

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	4	2.21902361	0.55475590	4.64	0.0064
farm	1	0.01685287	0.01685287	0.14	0.7106
Error	24	2.86827365	0.11951140		
Corrected Total	29	5.17398242			

GE BO kcal

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	4	2.83976915	0.70994229	2.47	0.0722
farm	1	0.59590650	0.59590650	2.07	0.1632
Error	24	6.91001320	0.28791722		
Corrected Total	29	10.32754196			

GE HHFT kcal

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	4	2.75326721	0.68831680	7.78	0.0004
farm	1	0.02542636	0.02542636	0.29	0.5968
Error	25	2.14785840	0.08591434		
Corrected Total	29	4.88689204			

Empty BW

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	4	654.4009068	163.6002267	27.50	<.0001
farm	1	0.0295777	0.0295777	0.00	0.9444
Error	24	142.7732168	5.9488840		
Corrected Total	29	797.8927699			

GE Empty Body Intial

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	4	161.3593898	40.3398475	2.18	0.1019
farm	1	21.6655928	21.6655928	1.17	0.2900
Error	24	444.2269571	18.5094565		
Corrected Total	29	607.1811905			

GE Empty Body Final

Source	DF	Sum of

Source	DF	Squares	Mean Square	F Value	Pr > F
diet	3	1446.593852	482.197951	1.94	0.1569
farm	1	382.959773	382.959773	1.54	0.2292
Error	19	4714.345305	248.123437		
Corrected Total	23	6367.276491			

GE gained

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	3	1236.808122	412.269374	1.97	0.1524
farm	1	357.902757	357.902757	1.71	0.2064
Error	19	3972.548309	209.081490		
Corrected Total	23	5341.288890			

Fat gained

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	3	14.02449501	4.67483167	21.10	<.0001
farm	1	0.53411349	0.53411349	2.41	0.1370
Error	19	4.21052343	0.22160650		
Corrected Total	23	18.56350866			

Ash gained

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	3	0.07833784	0.02611261	0.12	0.9458
farm	1	0.00656494	0.00656494	0.03	0.8626
Error	19	4.05480157	0.21341061		
Corrected Total	23	4.13512682			

Water gained

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	3	53.28404987	17.76134996	1.93	0.1585
farm	1	20.45738404	20.45738404	2.23	0.1521
Error	19	174.5910388	9.1890020		
Corrected Total	23	279.7582604			

Protein gained

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	3	6.61733924	2.20577975	0.50	0.6897
farm	1	1.07725707	1.07725707	0.24	0.6284
Error	19	84.57898621	4.45152559		
Corrected Total	23	91.26102017			

Weekly Average Fecal Score

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Diet	3	1.25811073	0.41937024	2.25	0.1071
farm	1	0.17390773	0.17390773	0.93	0.3431
Diet*farm	3	0.84602909	0.28200970	1.51	0.2352
Error	25	4.65607264	0.18624291		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
week	3	9.61244872	3.20414957	15.87	<.0001

week*Diet	9	4.92989551	0.54776617	2.71	0.0086
week*farm	3	1.37463540	0.45821180	2.27	0.0873
week*Diet*farm	9	2.93060298	0.32562255	1.61	0.1269
Error(week)	75	15.14139793	0.20188531		

Tests of Hypotheses Using the Type III MS for Diet*farm as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Dependent Variable: fecal1					
Diet	3	0.48803530	0.16267843	0.33	0.8045
Dependent Variable: fecal2					
Diet	3	3.36806419	1.12268806	1.69	0.3389
Dependent Variable: fecal3					
Diet	3	0.43890980	0.14630327	3.46	0.1676
Dependent Variable: fecal4					
Diet	3	1.89299694	0.63099898	9.96	0.0455

Percent Ash in Gain

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	3	0.07356723	0.02452241	2.12	0.1312
farm	1	0.00018870	0.00018870	0.02	0.8997
Error	19	0.21959095	0.01155742		
Corrected Total	23	0.30334925			

Percent fat in gain

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	3	0.05796133	0.01932044	2.59	0.0831
farm	1	0.01391273	0.01391273	1.86	0.1882
Error	19	0.14186305	0.00746648		
Corrected Total	23	0.20291665			

Percent Protein in Gain

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	3	0.69926672	0.23308891	1.25	0.3200
farm	1	0.02294381	0.02294381	0.12	0.7298
Error	19	3.54696411	0.18668232		
Corrected Total	23	4.40542937			

Pecent Water in Gain

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
diet	3	0.92765507	0.30921836	0.87	0.4746
farm	1	0.08018020	0.08018020	0.23	0.6405
Error	19	6.76422475	0.35601183		
Corrected Total	23	8.00052224			

Appendix E
Development of a milk replacer for Jersey calves

Assumptions:

- ◇ Calves fed whole milk (4.7% fat, 3.5% protein) attained an ADG of 496 g/day. This provides a realistic estimate of ADG Jersey calves on intensified diets can obtain. Therefore, we assumed that Jersey calves fed 'intensified' milk replacer programs would attain ADG of no more than 500g/day.

- ◇ We assumed that 28% CP in the MR is the appropriate level of protein to support rapid growth. Recent work from lab supports this assumption (Diaz et al., 2001; Bartlett, 2001).

- ◇ We also assumed that our calves were housed in an environment that was within their thermal-neutral zone and that their maintenance energy requirement was not influenced by environmental factors

Observations:

Refer to Table E.1

- ◇ The total GE intake of our calves was calculated by multiplying the total intake of dietary fat, protein, and lactose by 9.21, 5.86, and 3.95 Mcals/g, respectively (Brisson et al., 1957; Lister, 1971). Gross energy was multipled by 0.79 to convert to NE (NRC 2001). *This method was used to arrive at the "VPI high estimate of NEm."*

◇ GE in the MR fed was also determined by bomb calorimetry. Gross energy was multiplied by 0.79 to convert to NE (NRC 2001). *This method was used to arrive at the "VPI low estimate of NEm."*

◇ The Dairy NRC (2000) equations for NEm and NEg were applied to our data to estimate total energy intake of our calves. However, the total intake of NE of our calves exceeded the NRC estimate of NEm + NEg indicating that Jersey calves have a greater requirement for NE than estimated by NRC. This is further explained when we compare the target ADG of 650 g with the actual gains of the calves. Our calves were fed for a target ADG of 650 g but calves fed milk, 29/16, and 27/33 had observed ADG of 457, 368, 357 g, respectively..

◇ We made the assumption Jersey calves had a much higher requirement for maintenance energy than reported by NRC but we assumed the equation adopted by NRC (i.e. Toullec equation) is accurate for Jersey calves. The NEm equation used by NRC assumes that calves require 0.100 Mcal/kg of metabolic body weight.

◇ We 'back calculated' to determine the maintenance energy requirement in Jersey calves using the following equation: (equation 1) NEintake – NEm + NEg = 0. The Toullec equation was used to calculate NEg and NEg and Neintake were used to estimate NEm. Then the following equation (equation 2) NEm = A * $BW^{.75}$ was solved by adjusting the value of A until the average of for all calves on our trial equaled = Neintake – NEm + Neg = 0. We determined that A= 0.139 for the "VPI high estimate of NEm" and A= 0.121 for the "VPI low estimate of NEm." Our new equation for maintenance energy: VPI High NEm = .139 *

$BW^{.75}$ and VPI Low NEm = 0.121 * $BW^{.75}$. Therefore, we estimate Jersey calves require 21 to 39% more energy for maintenance than indicated by NRC.

Development of a 'Jersey' Milk Replacer

Nutrient densities

- ◇ We assumed the following nutrient densities for GE energy in milk replacer: 3.95, 5.86, and 9.21 per g of lactose, protein, and fat, respectively. Gross Energy was converted to NE using the following formula: NE = .79 * GE

- ◇ We set CP to 28% based on work by Diaz (2001) and Bartlett (2001).

    1. Lactose was calculated with the following equation: lactose=100-(CP + Fat), we ignored ash in our calculations for simplicity.

Calf parameters

- ◇ Used a 'model' Jersey with the following assumptions
  30 kg of weight.
  Target ADG of 500 g.
  Environmental factors were in it's thermal neutral zone.

Model

- ◇ Calf values were entered into Toullec equation and in the VPI NEm equation.

- ◇ Back calculated to get adequate fat level in milk replacer to support 500g ADG,

- ◇ Result was a 28% fat and 25.35% fat milk replacer with the calf consuming 2.2% of bodyweight as powder or 17% of body weight as fed when milk replacer is reconstituted to 12.5% powder, when we used the "VPI high estimate of NEm"

- ◇ When the "VPI low estimate of NEm" was used 20% fat in the MR was adequate.

- ◇ It is advisable to include 25% fat in a MR for Jersey calves to provide additional energy for times of stress such as disease, environmental stress, or other stresses that would increase maintenance energy requirements.

Important considerations

- ◇ We did not observe a difference in ADG between the calves fed 29/16 and 27/33 diets on our feeding trial. The calves on 27/33 had elevated NEFA indicating they may have metabolized the fat in their diet differently than the calves fed the other diets. The calves fed Milk had a higher level of fat in their diet but they did not have elevated NEFA and ADG were 497 g, which indicates there may be a difference in metabolism of edible lard and butterfat when they are fed at high levels (i.e. so that the diet is 33% on a DM basis).

- ◇ It is possible that dietary protein limited the gains of our calves but NRC indicates that enough protein was supplied to support 660 and 700g of ADG for 27/33 and 29/16, respectively. The protein retention of our calves was similar to the protein retention reported by Diaz et al.

◇ Our assumption of high NEm requirements for Jersey is calculated very indirectly. Measuring fasting heat production of these calves would provide a much more accurate indication of maintenance requirements.

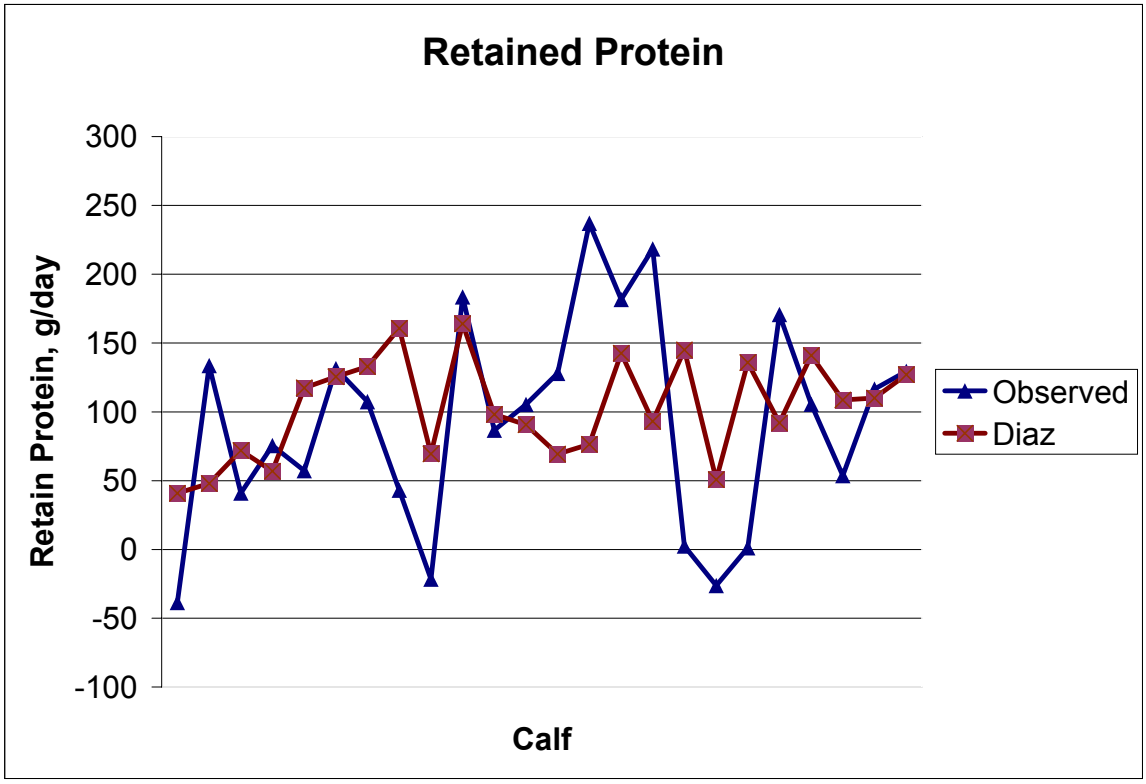

Figure E.1. Protein retention of Jersey calves. Comparison of the actual protein retention and the predicted protein retention using the Diaz equation.

Table E.1

calf id	diet	LW kg	LWG kg/day	Observed gain mcals GE/day	Calculated NE intake mcals/day	NE intake mcals/day[1]	NEm, mcal/day			NEg[5] mcal/day	intake-NRC[6] mcal/day	Difference[7] mcal/day	Difference[8] mcal/day
							Dairy NRC[2]	VPI high Estimate[3]	VPI low Estimate[4]				
3	20/20	32.96	0.154	0.129	1.853	1.595	1.376	2.622	1.664	0.307	0.170	-0.366	-0.376
14	20/20	29.96	0.173	0.162	1.771	1.524	1.281	2.441	1.550	0.342	0.148	-0.351	-0.368
18	20/20	27.47	0.058	0.201	1.718	1.479	1.200	2.287	1.452	0.089	0.429	-0.038	-0.061
23	20/20	34.46	0.154	0.190	2.001	1.722	1.422	2.711	1.721	0.312	0.266	-0.288	-0.311
27	20/20	31.46	0.173	0.834	1.853	1.595	1.328	2.532	1.607	0.348	0.176	-0.341	-0.360
30	20/20	34.46	0.135	0.699	2.083	1.793	1.422	2.711	1.721	0.266	0.395	-0.159	-0.194
7	27/33	37.46	0.308	1.279	3.486	3.107	1.514	2.886	1.832	0.739	1.233	0.643	0.537
17	27/33	40.95	0.327	1.750	3.588	3.198	1.619	3.086	1.959	0.820	1.149	0.518	0.419
21	27/33	36.96	0.327	0.300	3.384	3.017	1.499	2.857	1.814	0.791	1.094	0.511	0.412
26	27/33	42.95	0.442	2.079	3.489	3.110	1.678	3.198	2.030	1.199	0.613	-0.041	-0.119
32	27/33	38.95	0.462	0.478	3.531	3.147	1.559	2.972	1.887	1.219	0.752	0.145	0.041
36	27/33	36.96	0.327	0.645	3.355	2.990	1.499	2.857	1.814	0.791	1.065	0.481	0.386
2	29/16	36.46	0.423	0.096	2.921	2.514	1.484	2.828	1.795	1.073	0.365	-0.213	-0.353
8	29/16	39.95	0.327	0.423	2.976	2.562	1.589	3.029	1.923	0.813	0.574	-0.045	-0.174
11	29/16	36.96	0.288	1.311	2.944	2.534	1.499	2.857	1.814	0.681	0.765	0.181	0.040
16	29/16	35.96	0.404	0.541	2.950	2.539	1.468	2.799	1.777	1.009	0.472	-0.100	-0.247
22	29/16	39.45	0.423	1.645	2.908	2.503	1.574	3.001	1.905	1.103	0.230	-0.383	-0.505
31	29/16	37.46	0.250	0.154	2.838	2.443	1.514	2.886	1.832	0.576	0.748	0.158	0.035
34	29/16	40.95	0.481	1.433	3.016	2.596	1.619	3.086	1.959	1.303	0.094	-0.536	-0.666
1	Milk	38.95	0.519	0.297	3.690	3.690	1.559	2.972	2.972	1.404	0.727	0.120	-0.686
15	Milk	39.95	0.596	1.389	3.716	3.716	1.589	3.029	3.029	1.672	0.455	-0.164	-0.985
24	Milk	39.95	0.404	0.878	3.592	3.592	1.589	3.029	3.029	1.048	0.955	0.336	-0.485
33	Milk	40.95	0.538	0.424	3.724	3.724	1.619	3.086	3.086	1.493	0.612	-0.018	-0.854
38	Milk	36.96	0.519	1.143	3.414	3.414	1.499	2.857	2.857	1.378	0.537	-0.047	-0.821
											average	0.000	-0.237

[1]GE of MR determine by bomb calirometery, GE in Milk calculated.

[2]Calculated using Davis and Drackley equation: NEm (Mcal/d) = 0.100 * $LW^{.75}$

[3]Calculated using the equation: NEm (Mcal/d) = 0.139 * $LW^{.75}$

[4]Calculated using the equation: NEm (Mcal/d) = 0.121 * $LW^{.75}$

[5]Calculated using Toullec equation: NEg (Mcal/day) = (0.84 * $LW^{.355}$) * ($LWG^{1.2}$)

[6]Calculated using equation: difference (Mcal/d) = calculated intake - (NRC NEm + Energy in gain)

[7]Calculated using equation: difference (Mcal/d) = intake - (VPI high NEm + Energy in gain)

[8]Calculated using equation: difference (Mcal/d) = intake - (VPI low NEm + Energy in gain)

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