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Growth performance of Holstein calves fed milk or milk replacer with or without calf starter

by

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DECLARATION

I declare that this thesis that I hereby submit for the degree MSc(Agric) (Animal Nutrition) at the University of Pretoria, has not previously been submitted by me for degree purposes at any other University.

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S.M. Grobler Date

ABSTRACT

GROWTH PERFORMANCE OF HOLSTEIN CALVES FED MILK OR MILK REPLACER WITH OR WITHOUT CALF STARTER

by

S.M. Grobler

Degree : MSc (Agric)
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Supervisor : Prof. L.J. Erasmus

This trial was conducted in two phases during the period of February 2002 – June 2003. In phase 1 of the study the growth potential of calves fed either commercial Surromel Calf® (CSM) or experimental Surromel Calf (ESM) without calf starter was evaluated. In phase 2 of the study calves were fed either experimental Surromel Calf (ESM) or full milk with starter.

High production cost and the availability of new technology prompted Clover SA to investigate other processes of manufacturing Surromel Calf®. The implementation of a new manufacturing process however, also necessitates evaluation of the end product. Twenty four Holstein heifer calves were used in a completely randomized block design. Calves were liquid fed only. For the first two weeks the milk replacer was allocated at 10% of body weight (2l fed twice daily), from week 3 to week 6 at 12.5% of body weight (2.5l fed twice daily) and during week 7 and week 8 calves received the milk replacer at 15% of body weight (3l milk fed twice daily). Water was available ad lib except for 30 minutes before and after milk replacer feedings.

Body weight and skeletal development (body length, shoulder height, shoulder width and chest diameter) were measured weekly. The fecal consistency was subjectively scored daily. Mean average daily gains were 170g/day and 176g/day for calves receiving either ESM or CSM respectively. No differences were observed between treatments (P>0.05) for any change in body stature measurements over the 56 day trial period.

If a price-competitive milk replacer could guarantee similar growth results as full milk, then milk producers would have confidence in using these replacers instead of full milk. In phase 2 of the trial calves were fed either 2l of full milk (FMS) or experimental Surromel Calf (EMSS) twice daily from birth up to 56 days. Calves had ad lib access to a commercial calf starter. Starter consumption was negligible for the first three weeks. Starter intake was 0.30kg/d and 0.34kg/d respectively at 35 days of age and 1.11kg/d and 1.10kg/d for FMS and EMSS calves respectively at 56 days (P>0.05). The average daily gain (ADG) were 370g/day and was unaffected by treatment (P>0.05). No differences were observed between treatments (P>0.05) for any change in body stature measurements.

Growth standards for dairy calves with body weight less than 100kg have been included for the first time in the NRC Dairy 2001. Many producers are reluctant to use these recommendations since these have not been validated under South African conditions. The growth prediction was only compared with the growth of calves in Phase 2. The results showed that the NRC growth predictions are in agreement from week 3 onwards with the current study‘s growth results.

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CONTENTS

LIST OF TABLES

LIST OF ABBREVIATIONS

ADG	Average daily gain
BVD	Bovine viral disease
CP	Crude protein
CSM	Commercial Surromel Calf®
EE	Ether abstract
EMSS	Experimental Surromel Calf plus starter
ESM	Experimental Surromel Calf
FM	Full milk
FMS	Full milk plus starter
Ig	Immunoglobulin
LSD	Least significant difference
ME	Metabolisable energy
SEM	Standard error of the mean

CHAPTER 1

INTRODUCTION

Milk producers are leaving the dairy industry almost weekly due to the current high feed costs and uncompetitive milk prices. From January 2005 to March 2006 a total of 324 milk producers have left the industry (Coetzee & Maree, 2006). Therefore a milk shortage in the near future is inevitable. Since 1997 the number of milk producers decreased on average by 41% and currently there are only 3899 milk producers left (Coetzee & Maree, 2007). Although the number of producers decreased, the average daily production has increased from 774 liters per producer per day in 1997 to 1 375 liters per producer per day in 2006. (Coetzee & Maree, 2006). This is in line with the international trend of fewer but larger producers with a trend towards pasture based systems, which are perceived to be more profitable than total mixed ration systems. The average daily production varies in different provinces. Currently more than 64% of all milk is produced in the Western Cape, Eastern Cape and KwaZulu-Natal areas which are predominantly pasture-based production systems. The total production of milk is divided into fresh milk and fresh milk products and concentrated products. About 60% of the total production is used for fresh milk and fresh milk products, while the rest is used to produce concentrated products (H. Olivier, Clover SA, personal communication, holivier@clover.co.za).

Raising dairy calves and heifers from birth to calving has been found to comprise the second largest expense on the dairy farm since no revenue is derived until the onset of lactation (Heinrichs, 1993). Therefore, many of the experiments involving dairy calves and heifers, have focused on ways to decrease the cost associated with the growth period or hastening the onset of the production stage. Reducing the length of the growth period through decreasing the age at first calving from 24 to 22 months could reduce the costs associated with the nonproductive period. This could be accomplished by increasing prepubertal average daily gain in the heifer or utilizing the genetic potential for growth during the liquid feeding period of calves (Hoffman, 1997). The quality of ingredients used in milk replacers, therefore, is becoming increasingly important (NRC, 2001).

The number of dairy calves born per year in South Africa comes to approximately 280 000 and the extent of the milk replacer market in South Africa is approximately 7 000ton/year, which amounts to a turnover of approximately 30-35 million Rand/year. For the past 5 years the milk replacer market was between 50% - 60% in relation to the feeding of full milk to dairy calves (H. Olivier, Clover SA, personal communication, holivier@clover.co.za). With a milk shortage coming, this percentage is highly likely to increase. Research on neonatal feeding practices and types of milk replacers utilized on dairy farms in the USA revealed that nearly 60% of US dairy farms utilize milk replacers for some or all of the feeding programs for neonatal calves (Heinrichs *et al.* 1995; NRC, 2001).

The major role players in the South-African milk replacer industry are Clover SA with its product Surromel Calf®, which is currently the market leader followed by Denkavit (Denkavit Acid® and Milkbar®) and ASA (Joosten®). These 3 companies sell 98% of all milk replacers in South Africa.

The milk replacer industry is intimately involved with the economy of the primary milk production industry and therefore changes in the producer price of milk have a direct effect on milk replacer sales. If a benefit of at least 40c/l over full milk is not realized, then most producers would rather feed full milk. Other factors affecting milk replacer consumption are the maize price, the over quota or export milk price as well as the availability of waste milk. A low maize price and a high meat price for example, would stimulate the use of milk replacer because of the increase in the number of producers raising bull calves for feedlotting purposes. If the milk price for over quota or export milk is relatively low, it would make economic sense to feed that milk to calves. Although there are many risks involved in the feeding of waste milk to calves, there are producers feeding this "free milk" to their calves. This is illustrated by the situation in June 2005 when a low milk price resulted in only 40% of calves being fed milk replacer in relation to the 60% of calves being fed full milk. In 2002 about 150 000 to 200 000 liters of milk were lost to human consumption because it had to be fed to dairy calves (H. Olivier, Clover SA, personal communication, holivier@clover.co.za).

High production cost and the availability of new technology prompted Clover SA to investigate other processes of manufacturing Surromel Calf®. Surromel Calf® is an acidified milk replacer manufactured from whey (the serum or watery part of milk that is separated from the coagulable part or curd especially in the process of making cheese and contains, vitamins, minerals, protein, lactose and traces of milk fat), Nukamix® (made from a choice of fats and whey powders, based on coconut- and palm oil, spray dried, on a whey carrier) and Sipernat® 22 (precipitated spray dried silica with high absorptive and optimized particle size spectrum, used for the conversion of liquids into powders). The pH is lowered through a scientifically formulated acid system to ensure the quality of the product in reconstituted form. It also contains an anti-bacterial agent, which prevents diarrhea and an anti-oxidant to ensure the shelf life of the powder.

The final product, Surromel Calf® can be reconstituted to be used as a fully balanced milk replacer for calves. The product complies with the requirements of the South African Act on fertilizers, farm feeds, agricultural remedies and stock remedies (Act 36 of 1947 or as repealed). The product is manufactured under strict hygienic conditions and does not contain any foreign material or known substances which may present a health risk to the calf.

The major difference between the old and the new manufacturing processes lies in the mixing of the ingredients. The traditional Surromel Calf® is mixed in dry form where all the ingredients are mixed dry in a tumbler and thereafter it is packaged in dry form. The experimental Surromel Calf (ESM) is produced by separately dissolving all the dry ingredients into liquid and all the different liquid ingredients are then mixed. Thereafter the complete product is spray-dried in a spray-dry tower and the dry product is packaged. With the new manufacturing process of experimental Surromel Calf the imported raw material is reduced by 15% resulting in a 10%-12% financial benefit for the consumer.

The implementation of a new manufacturing process however, also necessitates evaluation of the end product. One of the objectives of this study, therefore, was to evaluate in a calf growth study, the experimental Surromel Calf against the traditional Surromel Calf®.

All milk replacers, as is the case with all animal feeds, have to be registered with the Fertilizer, Farm Feeds, Agricultural Remedies and Stock Remedies Act 36 of 1947. This Act, however, has serious shortcomings in that only analyses on crude protein, moisture, fat, crude fibre, calcium and phosphorus are needed for registration. No data on quality parameters such as crude protein and fat digestibility and amino acid and fatty acid profiles are needed for registration. These shortcomings make it very difficult to distinguish between superior and poor milk replacers that are commercially available in South Africa.

This problem is exacerbated by the current exchange rate, which leads to a situation where the high quality imported milk replacers are not price competitive on the local markets. Up to a few years ago this statement was legitimate because local products did not contain the same quality animal fats that were being used in the imported products. This situation has changed dramatically since the outbreak of mad cow disease and laws worldwide have prevented the use of animal fats in milk replacers. Animal fats had to be replaced by using plant fats. Smith & Parker (1994) conducted a digestibility study where five different milk replacers were compared to milk. Only one of the milk replacers had a nutrient digestibility similar to milk, and the poorest replacer had a protein digestibility of 48.1% and fat digestibility of 67.31% in comparison to the 96.2% and 97.8% of full milk. Many producers therefore are hesitant to purchase milk replacers containing a high percentage of plant fat.

If a price-competitive milk replacer such as ESM which contains plant fats, could guarantee similar growth results as full milk and is readily available on the local market, then milk producers would have confidence in using these replacers instead of full milk. This would ensure that more milk is available for human consumption, produced at acceptable production costs. Very little research on milk replacers has been conducted in South Africa over the past decade and it is important that the latest milk replacers with different feed ingredients and where new technology has been implemented be evaluated (H. Olivier, Clover SA, personal communication, holivier@clover.co.za).

An important development in the feeding and management of dairy cattle has been the release of the NRC Dairy 2001 (NRC, 2001). Growth standards for dairy calves with body weight less than 100kg have been included for the first time. Many producers are reluctant to use the calf and heifer growth recommendations since these have not been validated under South African conditions. There is an urgent need for such validation as it would be beneficial to both the feed industry as well as the milk producer.

The objective of this study was threefold:

(i) To evaluate an experimental acidified milk replacer against an established acidified milk replacer (Surromel Calf®) in a growth study feeding only liquids. Calf starter was not fed since it would then not be possible to control starter intake and therefore nutrient intake.

(ii) To obtain growth data when feeding experimental acidified milk replacer (experimental Surromel Calf) plus calf starter in comparison with full milk feeding plus calf starter. The purpose of feeding liquids with starter is to evaluate growth in a feeding system used commonly on commercial dairy farms.

(iii) To validate the NRC Dairy (2001) calf model under South African conditions.

CHAPTER 2

OVERVIEW: GENERAL PRINCIPLES OF DAIRY CALF NUTRITION

2.1 General Introduction

The replacement heifer enterprise typically represents about 20% of the expenses on the dairy farm. This makes it the second largest expense on the dairy farm, trailing only the costs of feed for the lactating cows (Drackley, 1999). Unfortunately, neonatal mortality in dairy calves remains a major problem. The USDA National Animal Health Monitoring System's Dairy 2002 survey reported mortality of 10.8% of heifer calves born alive (National Animal Health Monitoring System, 2003). Another survey in the U.S. revealed that 7 – 10% of the calves born, die within the first three months of life (James, 2001b). Costs are incurred from the day of birth of the calf, with no economic returns until the heifer calves for the first time and enters the milking herd.

Goals of the replacement heifer enterprise should be to minimize expenses while ensuring healthy, vigorous heifers that grow rapidly and enter the dairy herd at 22 to 24 months at proper body size. Getting the heifer off to a fast start during the milk-feeding period provides the foundation for healthy, well-grown and economical heifers (Drackley, 1999). The US national average age for weaning in 1992 was 8.1 weeks. However this average is probably dropping with progressive farms leading the way toward a four-week weaning age average (Penn State College of Agricultural Science, 2004). In South Africa the average age of weaning is probably still around 6 – 8 weeks.

The choice of the type of liquid feed can have an impact upon the growth, health, and profitability of the young calf (Drackley, 1999). Research has indicated that nutrient supply can alter the body composition of neonatal calves (Diaz *et al.,* 2001). The growth rate of female calves from birth to sexual maturity determines age at first calving. Growth rate of heifers also affects milk production (Virtala, *et al.,* 1996). However, faster growth in itself is not sufficient, as it is essential that proper development also take place (Morrill, 1995).

An extensive amount of scientific literature exists in which different amounts and frequencies of liquid feeds were compared with respect to calf growth, weaning age, and health (Appleman and Owen, 1975). From these early studies came the general recommendation to limit-feed calves (Kertz *et al*., 1979). These conventional heifer calf rearing schemes rely on restricted feeding of milk or milk replacer.

A milk replacer is a powdered formula designed to substitute natural cow's milk by supplying the nutritional needs of the calf during the critical, early nursing stage of its life, typically 8 to 10% of body weight to encourage early intake of starter (Drackley, 2004). Surplus colostrum and transition milk as well as waste or discard milk are also used sometimes to rear calves (Drackley, 1999).

Many producers will use whatever non-saleable milk that is available each day to feed calves, whether excess colostrum, transition milk, or discard milk. This practice results in the calf receiving a diet that varies considerably in composition from day to day. It was reported by Foley and Otterby (1978) that such variability does not affect the incidence or severity of diarrhea or overall rates of gain. Even frequent changes between sources of colostrum or waste milk and milk replacer did not affect calves adversely in several earlier studies (Appleman and Owen, 1975). However, maintaining as much consistency as possible in the diet for young calves minimizes chances for digestive upsets. This may be particularly important when calves are raised under conditions of increased stress, such as cold or wet weather or during outbreaks of disease (Drackley, 1999).

From an economic perspective, the incentive has been to wean calves as quickly as possible, without sacrificing health, from more expensive milk or milk replacer to less expensive concentrate-based starter feeds and forages. Health of calves has also been perceived to improve once calves are weaned from milk, which is a likely factor of the extensive detoxifying ability of the rumen, the bulking effect of solid feeds in the intestine, and improvements in energy balance. Requirements for labour per calf also decrease considerably when calves no longer have to be fed liquid diets individually and can be housed in groups (Drackley, 2004).

2.2 Importance of colostrum

Colostrum is a mixture of lacteal secretions and constituents of blood serum, such as immunoglobulins (Ig) and other serum proteins that accumulate in the mammary gland during the pre-partum dry period and are collected via milking at parturition (Merrick Animal Nutrition, Inc., 2004).

Newborn calves must adapt to a new environment that include nutrition, and on top of that enter the world without disease resistance. Calves don't receive placental transfer of immunoglobulins from the dam. The calf is totally dependent on the Ig in maternal colostrum for disease protection. The newborn calf's intestines are highly efficient at absorbing Ig (Merrick Animal Nutrition, Inc., 2004). Immunoglobulins are divided into five classes namely IgG, IgM, IgA, IgD and IgE, where IgG, IgM and IgA are the three main classes. Although these classes differ in their stature and function, IgG and IgM function in systemic infections while IgA functions within internal body surfaces such as the intestine (Muller and Ellinger, 1981). Calves start producing their own Ig at approximately 10 days of age and reach normal levels by 8 weeks of age. During this time, the calf's essential dependence on maternal colostrum reinforces the need for the calf to consume colostrum as soon as possible after birth (Roy, 1980; Corbett, 1991). Calves with low levels of serum immunoglobulins are more susceptible to disease such as pneumonia and diarrhea and they are at a greater risk for mortality than calves with serum IgG levels of 10mg/ml and higher (Merrick Animal Nutrition, Inc., 2004). Colostrum also tends to flush the digestive tract and in so doing, keeps the *E. coli* bacteria from multiplying and migrating into the upper digestive tract and abomasum where a high concentration of bacteria can cause early death (Clapp, 1981).

In addition to casein and lactose, colostrum contains nutrients as well as bioactive and growth-promoting substances in higher amounts than do milk replacer and full milk. Bovine colostrum is especially rich in IGF-I, IGF-II, insulin, and prolactin (Campana and Baumrucker, 1995). It also provides enzymes which promote a chemical change in the intestines necessary for the digestion of nutrients (Clapp, 1981).

Colostrum fed early postnatally affects the metabolic profile, endocrine status and intestinal absorptive capacity of calves, and these effects, compared with those of milk replacer, are associated with better growth performance immediately after birth. Thus, colostrum is essential for sufficient passive immunity and for enhancing developmental changes and improving postnatal metabolism in calves (Kuhne *et al.,* 2000).

2.3 Milk versus milk replacers

Full milk is always the standard of comparison for feeding liquid diets to neonatal calves. Full milk was the primary liquid feed for calves before the mid-1950's (Otterby and Linn, 1981). It also contains a naturally occurring anti-bacterial system to protect calves against infection. The advantages of feeding full milk are its consistent high quality, availability, and convenience (Green, 1996). While milk obviously is a high-quality feed on which calves grow well, its primary disadvantage is that it is the most expensive liquid feed (Drackley, 1999).

In an effort to reduce costs, however, most dairy producers have changed to milk replacers. Manufacturers of most milk replacers have striven to achieve the same characteristics found in full milk (Green, 1996). In an interview with Mr. H. Olivier (2002) it was stated that if a price competitive milk replacer could guarantee similar growth results as full milk and is readily available on the local market, the milk producers would be motivated to use these milk replacers instead of full milk. This would ensure that more milk is available for human consumption, produced at acceptable production costs.

Surprisingly few direct comparisons of milk and milk replacers are available in the scientific literature, especially during the last decade when milk replacer formulation has changed dramatically. Furthermore, comparisons that have been made often have not taken into account the lower energy content of milk replacer (Drackley, 1999).

The use of milk replacers is in many situations more easily adapted to the labour and facility needs of calf-raising operations than either full or waste milk (Jaster *et al.,* 1990). When high quality milk replacers are compared with full milk diets, performance is similar (Green, 1996). Thus, good quality milk replacers are also a very good source of liquid feed for calves.

Research data demonstrate that milk replacer supports gains equivalent to those of calves fed full milk. In a trial conducted by Jaster et al. (1990) calves were fed either full milk (34% fat and 31% protein, DM) or a milk replacer with milk protein as the only source of protein (20% fat and 21% protein, DM), reconstituted to 12.5% solids. Both diets were fed at a rate of 9% of body weight, and amounts fed were adjusted weekly as calves grew. The average daily gain of calves during day 3 to day 28 of age was 99g/day and 120g/day for calves fed milk or milk replacer, respectively, and did not differ significantly between diets. However, five different milk replacers were compared to milk in a digestibility study conducted by Smith & Parker (1994). Only one of these milk replacers had a nutrient digestibility similar to milk, and the poorest milk replacer had a protein digestibility of 48.1% and fat digestibility of 67.31% in comparison to the 96.2% and 97.8% of full milk. It is known that low quality milk replacers may result in inferior performance and more diarrhea (Green, 1996).

Generally, a high quality milk replacer is preferred to full milk because of two major factors namely economics and convenience (Penn State College of Agricultural Science, 2004). Overall, the scientific literature indicates that feeding full milk or waste milk at 8-10% of body weight with calf starter and water available at all times is sufficient to produce healthy calves with good appetites for solid feed. Gains for calves fed milk replacer (reconstituted to 12.5% solids) at 10% of body weight will produce satisfactory results.

Feeding milk replacer at a rate of 10-12% of body weight is the preferred guideline for growth and health of young calves compared to the guideline of feeding 454g of powder per calf per day, as specified on many milk replacer tags. In all cases, availability of fresh, high-quality starter feed from an early age is important for rumen development and preparation for weaning (Drackley 1999).

Other considerations when comparing full milk and milk replacer include the current health status of the herd. Milk has been implicated in transfer of diseases such as paratuberculosis (Johne's disease), bovine viral diarrhea (BVD), and enzootic bovine leukosis (EBL or bovine leukemia) through the milk to the calves. Producers with eradication or prevention programs in place for those diseases should consider milk replacer as an alternative (Drackley, 1999). Likewise, mastitis milk used for raising dairy replacement heifers raises some concern if calves are housed together. Calves suckling one another after feeding can pass potentially infectious organisms, which could cause mammary infections. When feeding waste milk from antibiotic-treated cows, the antibiotic withdrawal times must be adhered to before marketing calves for meat (Green, 1996). Although waste milk, excess colostrum and transition milk is often thought of as "free feed", it is important to remember also that if waste milk was not being produced, then the "free milk" would be receiving the milk sale price. Thus, there is significant "opportunity cost" associated with excessive dumping of milk. Nevertheless, nearly all farms will have some waste milk available at times (Drackley, 1999).

Fluctuation in usage of milk or milk replacer likely reflects several economic factors within the dairy industry (Heinrichs *et al.,* 1995). In South Africa, milk producers are leaving the industry almost weekly due to the current high feed costs and uncompetitive milk prices (Coetzee and Maree, 2006). During the year 2002 about 150 000 to 200 000 litres of milk were lost to human consumption because it had to be fed to dairy calves (H. Coetzee, Clover SA, personal communication, holivier@clover.co.za).

Research on neonatal feeding practices and types of milk replacers utilized on dairy farms in the USA revealed that nearly 60% of US dairy farms use milk replacers for some or all of the feeding programs for neonatal calves. Regional differences existed in the types of liquid feeds and milk replacers fed to calves. (Heinrichs *et al.,* 1995). The use of acidified milk replacer has increased over the years, especially in Europe during the late 1980's (Woodford *et al.,* 1987). In the Netherlands 80% of calves raised for herd replacement are fed acidified milk replacers (Erickson *et al*., 1989). In a survey conducted in Sweden it was found that 55% of preweaned dairy calves were fed milk replacer alone or milk replacer combined with full milk (Hessle *et al.,* 2004).

In conclusion, high-quality milk replacers are excellent liquid feed for young calves. Reports of poor calf performance on milk replacer often are attributable to selection of an inappropriate or poor-quality milk replacer, or to underfeeding the calf. Milk replacers almost always will be a more cost effective feed for young calves than saleable full milk. Although more expensive than over-quota milk, surplus colostrum, transition milk, or waste milk - good quality milk replacers have advantages in consistency of product from day to day, ease and flexibility of storage, and disease control (Drackley, 1999).

2.4 Digestion of the neonatal calf

From birth up to approximately 2 to 3 weeks the rumen, reticulum, and omasum are inactive and the calf functions similarly to a monogastric animal (Terosky, 1997). In young milk-fed ruminants, ingested milk passes rapidly to the abomasum via closure of the oesophageal groove. The peptic cells of the gastric glands in these animals secrete, in addition to pepsinogen, the proteolytic enzyme rennin (actually secreted as the zymogen prorenin). Rennin differs from pepsin largely in its potent milk-clotting ability, although pepsin also causes some formation of milk clots (Van Ryssen, 2001). Within 10 min after feeding, a clot is formed in the abomasum as a result of the rennin, pepsin, and hydrochloric acid that act upon the casein protein in digesta (Roy, 1980). The clot consists of a casein matrix interspersed with milk-fat globules (Van Ryssen, 2001).

Rennin binds with casein protein, and the curd is slowly digested and emptied from the abomasum into the small intestine for up to approximately 24 hours. The clot contracts, and the whey proteins and lactose are released and pass quickly through the abomasum (Roy, 1980). However, when whey is present within the milk replacer, no clot is formed within the abomasum because whey is a non-clotting protein fraction (Terosky, 1997).

2.5 Importance of curd formation in the abomasum of young calves

The importance of abomasal protein clotting for optimal nutrient utilization, health and growth of milk-fed calves remains a controversial issue. In the past clotting of casein in full-, waste- and colostral milk was thought to be responsible for improved digestibility, greater daily gains and improved calf health. Milk replacers that exhibited no curd formation were characterized as inferior because of their association with poor growth rates and high incidences of diarrhea. However, research suggests that factors other than clotting are directly responsible for this decreased performance (Longenbach and Heinrichs, 1998).

In 1991 and 1992, the National Dairy Heifer Evaluation Project conducted a survey of US dairy farms to evaluate commercial milk replacers. Results of the survey suggested that only 2.1% of the milk replacers fed, formed a firm clot using the rennet coagulation test and that skim milk protein was not the major protein source in most milk replacers during this period (Heinrichs, *et al.,* 1995).

The calves' immature digestive system during the first three weeks of life indicates a physiological need for clotting in the abomasum to fully utilize complex proteins. Thus full milk proteins are suggested by some as the most suitable liquid diet for the calf age group younger than three weeks of age. Enzymatic secretion is limited up to one month of age, restricting digestion of some carbohydrate, fat and protein. After three weeks of age most calves can perform comparably when fed a clotting or a non-clotting milk replacer (Longenbach and Heinrichs, 1998). Protein sources used in non-clotting milk replacers include primarily whey and soy protein (Longenbach and Heinrichs, 1998).

Milk clotting does affect the flow of digesta from the stomach (Petit, 1987) but according to Petit, Ivan and Brisson (1988) there is no difference in digestibility between a clotting and a non-clotting milk replacer based on skim milk. In a study conducted by Lammers *et al.* (1998) it was found that the clotting effect of dried skim milk did not improve the performance of calves fed a non-clotting source of milk protein. Inhibition of coagulation with an oxalate-sodium buffer also illustrated that clotting may only affect nutrient flow and not nutrient digestibility of calf performance (Longenbach and Heinrichs, 1998).

Little work has been carried out on the effect of milk clotting per se on the flow of digesta in the small intestine and the absorption of nutrients. However, in a trial conducted by Petit, Ivan and Brisson (1989) it was found that the absence of milk replacer clotting does not affect ileal flow and digestibility of milk replacer N and fat.

Therefore, clotting may not be the fundamental element causing good or poor performance. Evidence suggests that the types of protein sources, the manufacturing methods and the inclusion of other less digestible sources of nutrients in the milk replacer may be the factors hindering the growth and health of milk replacer fed calves (Longenbach and Heinrichs, 1998).

2.6 Milk replacer ingredients

It is well-known that calf performance prior to weaning will be influenced greatly by the composition of milk replacers. The important factors that must be taken into account include source and amount of protein and energy, vitamin and mineral supplementation, and inclusion of critical nutritional additives such as emulsifiers. Unfortunately, methods traditionally used to determine milk replacer quality may not be useful with modern replacers used by calf raisers today (Quigley, 1998).

There are many high quality milk replacers available to dairy producers today. Newer technologies, using high quality proteins, provide a highly digestible source of protein and energy at a reasonable price. Determining milk replacer quality is best determined by animal performance. Some factors that are related to milk replacer quality and calf performance include: a reputable manufacturer, analysis of replacer, ingredients used, level of medication, mixability, absence of off-colored materials and its ability to stay in solution (Quigley, 1998).

2.7 Protein in milk replacers

Protein ingredients in milk replacers contribute significantly to the overall expense of these products. Protein sources used in milk replacers are generally classified as either milk protein or non-milk protein (NRC 2001). Most protein in milk replacers is provided by ingredients derived from milk, including whey protein concentrate, dried whey and dried skim milk. Alternative sources of proteins include soybean, fish, animal plasma and others (Quigley, 1996). The proportion of total energy intake provided by protein can have an impact upon growth rates and body composition in many species. Requirements for protein in calves are directly related to the growth rate, because maintenance requirements for protein are small (Bartlett *et al.,* 2004).

The ability of these protein sources to supply an adequate amount and profile of amino-acids for growth of pre-ruminant calves depends on the amino-acid profile of the protein, quality control during the manufacturing process, and the ability of the calf to digest protein. The utilization of protein is affected by the digestibility, amino-acid balance and the presence of antinutritional factors in the protein source (Davis and Drackley, 1998). Dietary crude protein (or protein to energy ratio), but not feeding rate, has a pronounced effect on composition of whole-body gain in young calves (Bartlett *et al.,* 2004).

Milk protein is generally more digestible than non-milk protein (Davis and Drackley, 1998). It consists of approximately 78% casein (mainly alpha and beta casein), 17% milk serum or whey protein (mainly albumin and globulin) and 5% non-protein nitrogen fractions. The amino-acid composition of milk protein is ideal to supply the needs of the growing calf, i.e. it has a biological value of 100% (Van Ryssen. 2001)

There is a lack of knowledge on amino-acid requirements of young calves and this severely hampers the interpretation of published research on protein sources, as well as the formulation of least-cost milk replacers (Davis and Drackley, 1998). Estimates from the limited amount of research that has been conducted indicate that lysine and methionine are first limiting and cysteine the second limiting amino acid for growth (Davis and Drackley, 1998)

The proteolytic digestive system of the calf is immature at birth, and until about 3 weeks, the calf is less able to digest most non-milk protein. Therefore, for optimal growth during the first 3 weeks of life, it is recommended that only all milk protein milk replacers are used. Ericson *et al.* (1989) found that replacers containing soy protein concentrate or large amounts of whey may need to be supplemented with additional methionine to maximize rate of gain. In a study conducted by Drackley *et al*. (2004), it was found that calves fed a milk replacer in which 60% of the milk protein was replaced by soy protein concentrate had lower average daily gains, lower gain:feed intake and altered intestinal morphology than calves fed an all-milk milk replacer.

Until the late 1980's "all-milk protein" milk replacers contained dried skim milk as the main protein source. Technological developments and processing improvements since the mid 1980's have resulted in dramatic changes in the ingredients available for use in milk replacer formulation (Glas, 1987). Ultra filtration of whey produces a product, whey protein concentrate that has essentially the same chemical composition as dried skim milk. In addition, whey protein concentrate is roughly 40% of the price of dried skim milk (Lammers, *et al.,* 1998).

In the United States, whey protein concentrates became the principal source in all-milk-protein milk replacers during the late 1980's in response to the markedly increased market price for dried skim milk. European use of all-whey-protein milk replacer also increased tremendously during the mid 1980's especially in the Netherlands (Glas, 1987). Consequently, much of the scientific literature on calf growth is based on results with milk replacers containing dried skim milk, in which the principal protein is casein (Davis and Drackley, 1998). The major protein source in the milk replacer used in the current study was whey powder. Early studies indicated that whey could not consistently make up over 30% of milk replacers without causing diarrhea or decreased performance (Roy, 1980). In contrast, many researchers reported that average daily gain and health of calves were satisfactory when calves were fed replacers containing all or large portions of the protein as whey.

Concerns were raised when the milk replacer industry changed from the use of skim-milk powder to whey protein, because these milk replacers did not form a coagulum or "clot" in the abomasum. Only casein forms a coagulum in the abomasum. The fact that whey protein does not clot in the abomasum is irrelevant for calf digestion because whey protein is naturally digested in the small intestine without action of abomasal proteases (Davis and Drackley, 1998). According to Heinrichs *et al.* (1995) whey protein concentrate has essentially the same proximate analysis as dried skim milk, and according to Lammers *et al.* (1998) whey protein concentrate has a better amino acid profile for growing calves than do dried skim milk and casein.

Studies with foals determined that diets that were predominantly composed of whey caused significant increases in mean body weight over time (Buffington *et al.,* 1992). Terosky *et al.* (1997*)* found under the conditions of his study that whey protein concentrate is nutritionally acceptable and also a more economically feasible replacement than dried skim milk in dairy calves that are 1 to 8 weeks of age. Furthermore, the use of whey protein concentrate as the major protein source was found by Lammers *et al*. (1998) to be better than or equal to the use of dried skim milk.

Milk replacers vary widely in protein content. Crude protein usually varies between 18% - 24% whereas milk contain approximately 25% - 26% crude protein on a dry matter basis (Van Horn and Wilcox, 1992). According to the

NRC (1989), milk replacers should contain at least 22% crude protein on a dry matter basis. The best milk replacers contain at least 20% crude protein on an as fed basis from primary milk sources. Milk replacers that use soy as the main source of protein should be avoided, since the soy contains anti-nutritional factors and the protein settles out of solution.

According to Act 36 of 1947 the crude protein content of an acidified milk replacer should be a minimum of 20%. The amounts of crude protein in milk replacers containing non-milk protein generally is higher than the protein in all milk-protein milk replacers, in an attempt to compensate for decreased protein digestibility and amino acid utilization (Davis and Drackley, 1998). However, the content of protein necessary for calf growth depends on the amount fed, the amount of starter feed consumed, the energy density of the milk replacer and starter as well as the source of protein.

2.8 Carbohydrates in milk replacers

The newly born calf has large quantities of the enzyme lactase in its intestine, which can hydrolyze the milk sugar lactose. With advancing age lactase levels gradually decline (Van Ryssen, 2001). During the first 3 to 4 weeks of age, the enzymatic system of the calf is still developing, and the calf cannot digest starch, sucrose, or maltose (Jenkins, 1982), because the young calf does not possess enzymes such as maltase, sucrase or amylase. The only carbohydrates that are tolerated by the calf and will not upset the calf's stomach are lactose, glucose and galactose.

However, calves can utilize starch in the form of heated or hydrolyzed starch and dextrose (Van Ryssen, 2001). Processing by cooking to cause pregelatinization and partial enzymatic hydrolysis of the starch does also result in increased utilization (Toullec *et al*., 1980).

A variable but substantial proportion of starch digestion in young calves occurs through fermentation in the lower small intestine and the large intestine. The end products of this lower tract fermentation (in the form of volatile fatty acids) are usable by the calf with efficiency equal to that of glucose. Small amounts of pregelatinized or partially hydrolyzed starch can be included in milk replacers without major decreases in growth or nutrient digestibility and with little or no increase in incidence of diarrhea (Davis and Drackley, 1998).

Lactose from whey products is the main carbohydrate source in milk replacers. The maximum amount of lactose that the calf can digest is not well defined and depends on feeding patterns. Walker and Faichney (1964) suggested a limit of 9g of hexose equivalents per kilogram of live weight per day as the level of intake beyond which diarrhea is likely to be a problem. Roy (1969) suggested a higher limit of 12g hexose equivalents per kg live weight per day if fat intake is at least 5.5g/kg per day. These estimates would translate to lactose intakes of 405 – 540g/day for a 45kg calf, with a fat intake of at least 248g/day. At a feeding rate of 10% of bodyweight, a 45kg calf will consume approximately 220g/day of lactose and 166g/day of fat from full milk or 260 – 300g/day of lactose and 62 – 115g/day of fat from milk replacer. Consequently, the digestive capacity for lactose is unlikely to be exceeded under typical practices of limit-feeding milk replacer twice daily (Davis and Drackley, 1998).

2.9 Lipids in milk replacers

Fat is a concentrated source of energy. It supplies essential fatty acids, contains limited amounts of vitamin A and vitamin D and possesses the ability to reduce the laxative effect of other feeds (Van Ryssen, 2001). Milk fat is highly digestible ranging from 95% to 97% (Toullec *et al*., 1990). Dried full Friesland milk contains about 30% fat and 23MJ/kg which is higher than the fat levels (10%-20%) that are generally found in milk replacers (Van Ryssen, 2001). Milk replacers are usually formulated to contain 10%, 15% or 20% fat.

Fat globule size is a critical factor that affects absorption in the digestive tract. Globule size varies between 0.1 to 10 μ in diameter in milk fat, though breed differences exist. The result is that milk fat cannot be replaced satisfactorily by other fats or oils except if homogenized or emulsified with soy lecithin or glyceryl mono-stearate to reduce the size of the fat globules to 3 – 4 μ. At an older age bigger particle sizes can be tolerated.

Fats that have been successfully used in milk replacers include tallow, lard, coconut oil, peanut oil and palm oil. The melting point should not exceed 48°C to 50 °C. Hydrogenation is sometimes practiced (Van Ryssen, 2001).

Historically, most milk replacers that were commercially available contained 10% fat. However, over the past 10 to 15 years, 20% fat formulations have become the standard, and fewer 10% and 15% fat milk replacer formulations are produced. The amount of fat in milk replacers that is best for a particular farm depends in large part on the level of management (Quigley, 1997).

Skimmed milk as well as milk too high in fat may upset the stomach of the calf. No advantage has been observed with a fat content above 10% (on dry matter basis) except where fat deposition is required, e.g. veal production – 15 to 25% fat (Van Ryssen, 2001). Intake of calf starter is also negatively correlated with energy intake from milk replacer. As a result, calves fed higher energy milk replacers tend to begin consuming calf starter at a later age than calves consuming a lower energy milk replacer. This may delay rumen development and weaning, which can slow growth in the long term (Quigley, 1997). Kuehn *et al.* (1994) found that calves receiving low fat milk replacer gained more weight than did calves on high fat milk replacer. Fat in the milk replacer depressed dry matter intake and digestible energy intake of starter up to weaning.

2.10 Acidification of milk replacers

Acidified milk replacers were first developed as by-products of the Gouda cheese industry in the Netherlands (Stobo, 1983). During 1989, eighty percent of calves raised for herd replacement in the Netherlands were fed acidified milk replacers (Erickson *et al.* 1989). The milk replacer market realized between 50% - 60% in relation to the feeding of full milk to dairy calves in South Africa over the past 5 years, whereof the largest part of this market was mainly acidified milk replacers (H. Olivier, Clover SA, personal communication, holivier@clover.co.za).

The original commercial interest arose from attempts to preserve milk replacers so that large quantities could be mixed and stored at one time to allow *ad lib* feeding. Such products generally have a pH of around 5.0 (Tomkins & Jaster, 1991). The primary benefit of acidification may be its preservative effect, which allows reconstituted replacer to be stored up to 3 days, increasing convenience and saving labor (Woodford *et al*, 1987; Erickson *et al*., 1989). This interest increased further because of reports of greater feed intake, enhanced digestion and improved health (Fallon & Harte, 1980).

With acidified milk replacers, the lowered pH minimum before casein will clot and create curds in the bucket before feeding, is 5.7 (Van Ryssen, 2001). Products that contain no casein will not clot in the abomasum and they usually contain strong acids, giving a pH of about 4.2 in the final mix (van Ryssen, 2001). In the past it has become more common for milk replacers to be fortified with low concentrations of organic acids, resulting in a pH of 5.4-5.6 after reconstitution (Tomkins and Jaster, 1991).

The most common organic acids utilized are citric-, formic-, and propionic, although malic-, sorbic-, and fumaric acids have also been used. It has been proposed that dietary acidification lowers the pH in the upper digestive tract, thereby suppressing bacterial growth in the small intestine and improving enzymatic digestion. Although acidification of milk replacers does lead to decreased abomasal pH after feeding, it is likely that secretion of bile and pancreatic juice into the upper small intestine quickly neutralizes this greater acidity (Stobo, 1983).

The advantage of using an acidified milk replacer is the establishing of a more desirable pH in the gastrointestinal tract, which may aid digestion, and the lower pH in the alimentary tract is credited for reduced incidence of infectious diarrhea (Hand, *et al*., 1985). Feeding of an acidified milk replacer at 10% of body weight twice a day may be beneficial, although further experiments are needed (Jaster, *et al,* 1990). It has also been suggested that acidification inhibits growth of pathogenic organisms in the digestive tract and, in conjunction with frequent small meals, enhance digestion (Stobo, 1983).

In a study conducted by Nocek and Braund (1986), fecal consistency was lower for calves fed acidified milk replacer in relation to calves fed an all-milk protein milk replacer, but the days calves were treated for diarrhea were less. In another study acidification of milk replacer, fed restricted or at *ad libitum* intake, gave similar performance including nutrient digestibility, compared with unacidified replacers (Jaster, *et al,* 1990).

2.11 Rumen development

Development of the rumen generally occurs during the first 4 to 8 weeks after birth (Quigley, 2001). At birth, the rumen and reticulum are under-developed and nonfunctional (Quigley, 1997). Liquid feeds are shunted past the reticulorumen via the esophageal groove. Prior to weaning, the primary source of nutrients is liquid. Before solid feed is consumed, the abomasum is the primary stomach compartment and both energy and protein are derived from liquid dietary sources. During the transition period, both liquid and solid feeds provide nutrients to the calf. After weaning, only solid feed is available, the rumen has become an important compartment of the stomach, and all feed consumed is exposed to bacterial fermentation prior to reaching the abomasum (Table 2.1). A net result of this fermentation is a change in the type of energy and protein available to the calf (Quigley, 1997).

Table 2.1: Composition of the ruminant stomach at various ages

Compartment % of total	Birth	28 days	56 days	84 days
Reticulorumen	35	52	60	64
Omasum	13	12	13	14
Abomasum	49	36	27	22

Adapted from Church (1976)

There are five requirements for ruminal development. These include: establishment of bacteria in the rumen; liquid in the rumen; outflow of material from the rumen (muscular action); absorptive ability of the tissue and available substrate (Quigley, 1997). When the calf is born, the rumen is sterile. However, by one day of age, a large concentration of bacteria can be found which is mostly aerobic bacteria. Thereafter, the numbers and types of bacteria change as dry feed intake occurs and the substrate available for fermentation changes (Quigley, 1997). The change in bacterial numbers and types in the rumen is a function of intake of substrate (Lengemann and Allen, 1959)

To ferment substrate, rumen bacteria must live in an aqua environment. Without sufficient water, bacteria cannot grow and ruminal development is hampered. Most of the water that enters the rumen comes from free water intake (Quigley, 1997). According to Kertz (1984) free water intake has been shown to increase rate of body weight gain and reduce diarrhea. It is also important to note that milk or milk replacer does not constitute “free water” because milk or milk replacers will by-pass the rumen by closure of the esophageal groove (Quigley, 1997). Therefore water must be offered to calves from an early age, preferably from day 4 onwards.

The absorption of end products of fermentation is an important criterion of ruminal development. The end products of fermentation, particularly the volatile fatty acids namely acetate, propionate and butyrate are absorbed into the rumen epithelium, where propionate and butyrate are metabolized in mature ruminants. The volatile fatty acids or end products of metabolism (lactate and β-hydroxybutyrate) are transported to the blood for use as energy substrates. However, there is little or no absorption or metabolism of volatile fatty acids in neonatal calves. Therefore, the rumen must develop this ability prior to weaning (Quigley, 1997).

Many researchers have evaluated the effect of various compounds on the development of the epithelial tissue in relation to size and number of papillae and their ability to absorb and metabolize volatile fatty acids. Results of these studies indicate that the primary stimulus to development of the epithelium is the volatile fatty acids, particularly propionate and butyrate where butyrate is most important in papillae development. Milk, hay and grain added to the rumen are all fermented by the resident bacteria to these acids (Quigley, 1997).

Development of the rumen epithelium is primarily controlled by chemical, not physical means. Therefore, ruminal development is primarily driven by the availability of dry feed, particularly starter, in the rumen. To promote early weaning, the key factor is early consumption of a starter to promote growth of the ruminal epithelium and ruminal motility. Because grains provide fermentable carbohydrates that are fermented to propionate and butyrate, they are a good choice to ensure early rumen development.

On the other hand, the structural carbohydrate of forages tends to be fermented to a greater extent to acetate, which is less stimulatory to ruminal development. Forage is important to promote the growth of the muscular layer of the rumen and to maintain the health of the epithelium. Rumen papillae can grow too much in response to high levels of volatile fatty acids; when this happens, they may clump together, reducing the surface area available for absorption. Also, some 'scratch' is needed to keep the papillae free of layers of keratin, which can also inhibit volatile fatty acid absorption (Quigley, 1997).

There are a few reasons why calves are not fed hay prior to weaning. The first is voluntary intake. Most calves do not eat significant amounts of hay if grain is also offered. Another reason is the high-energy requirement of young calves relative to their ability to consume dry feed. Therefore, if calves consume significant amounts of hay, their intake of starter will be limited, and this leads to a reduction in growth. Finally, most hay has too little energy for calves. The energy requirement for calves can usually be met only when calves are fed milk or high quality milk replacer, and/or excess colostrum and calf starter. Even good quality legume hay generally has too little energy to support growth of preweaned calves (Quigley, 1997).

2.12 Calf starter

The consumption of calf starter by young calves at an early age is important for the development of a functioning rumen and to achieve optimal growth. By the fourth week of life, calves should be consuming more nutrients from calf starter than from milk or milk replacer, which increases the importance of feeding a nutritious, highly palatable starter (O'Brien *et al.,* 2004).

Several studies have reported on the appropriate protein percentages in calf starters for optimal growth of young calves. In many instances, starter diets containing various percentages of crude protein, ranging from about 13% to 18% dry matter, promoted similar body weight gains. But, in other cases, when incremental crude protein in starter diets was tested, live body weight gains were improved when the protein content was 17% to 18% of dry matter, except when starter consumption was restricted (Akayezu *et al.,* 1994).

It is suggested by Crowley *et al.* (1983) that calf starters for dairy replacement heifers should contain 15 to 20% crude protein on a dry matter basis. If calves are weaned early at 3 to 4 weeks of age, then a starter containing 20% high quality protein is essential.

The NRC recommendations for protein content in calf starter DM increased from 16% in 1978 (NRC, 1978) to 18% in 1989 (NRC, 1989), based on dry matter intake of about 2.6% of body weight. Field reports before the latest NRC dairy (NRC 2001) were published suggested protein higher than NRC recommendations, but the beneficial effects of calf starters containing high amounts of protein have not been clearly shown (Akayezu *et al.,* 1994).

In a study conducted by O'Brien *et al.* (2004) calves fed a 18% protein, 5% fat starter had a greater average daily gain, higher feed intakes from week 3 through the end of the trial (at least 42 days of age), earlier weaning age and greater average weekly weights than calves fed a 18% protein, 3% fat starter feed. Addition of 2.5%, 5% and 10% tallow to limit-fed starters did not affect dry matter intake, but improved feed efficiency (Johnson *et al.,* 1956). Calves fed starters *ad lib* containing 10% fat consumed 38% less dry matter and gained 28% less body weight than calves fed starter without fat. Starters containing 20% fat reduced starter consumption and body weight gains even further (Kuehn *et al.,* 1994). Calves receiving a starter with a high percentage of fat (6%) did not differ in feed intake, body weight gains, or ratio of feed to gain compared with those calves fed low fat (2%) and raised in mild winter conditions (Stewart, 1984). Kuehn *et al.* (1994) found no benefit in calf growth or performance from inclusion of additional fat in either milk replacer or starter. After weaning, fat in the starter depressed dry matter intake but not digestible energy intake. Calves that gained the most were fed a low fat starter.

2.13 The new NRC Dairy feeding standards

The new NRC feeding standards for dairy cows has been released. Growth standards for dairy heifers' weighing less than100kg have been included for the first time (NRC 2001). Future enhancements to the NRC will depend on the availability of published research related to young calves – their nutrient requirements under varying environmental, nutritional and management conditions, the composition of diets fed, the environmental conditions within which calves are raised, as well as the immunological state of the animal, when it enters the operation.

The new NRC publication is a dramatic improvement over previous versions (Quigley, 2005). It provides reasonable estimates of the animal's nutrient requirements and is consistent with the remainder of the publication regarding tabular values and estimates of nutrient requirements. The estimates of energy requirements for young calves are more consistent with existing literature and can provide nutritionists and other dairy professionals with legitimate means to model dairy animal growth and select management strategies to optimize profitability (Quigley, 2005). The latest edition of the NRC uses metabolizable energy for expressing energy requirements of calves (NRC, 2001). This system is the most commonly used method of calculating an animal's energy requirement and the energy content of feeds.

The NRC divides calves into four categories and considers requirements for each: young replacement calves fed milk or milk replacer, young replacement calves fed milk or milk replacer and starter, veal calves and ruminant calves from weaning to 100kg of body weight. Some research on dairy calves in South Africa has been conducted in the past (Cruywagen, 1990; Dugmore, 1995). However, there has not been any recent research and up to date information on dairy calves is lacking. It should thus be clear that there is a need for new South African data concerning growth and nutrition of dairy calves.

CHAPTER 3

MATERIALS AND METHODS

This trial was conducted in two phases during the period of February 2002 – June 2003 at the Dairy Production Unit of the Livestock Business Division of the ARC, Irene. The experimental protocol was approved by the ARC Ethics Committee. In phase 1 of the study the growth potential of calves fed either commercial Surromel Calf® (CSM) or experimental Surromel Calf (ESM) without starter were evaluated. In phase 2 of the study calves were fed either experimental Surromel Calf (ESM) or full milk with starter.

3.1 Phase 1

3.1.1 Animals and Experimental design

Twenty four Holstein heifer calves were used in a completely randomized block design to compare an experimental milk replacer (experimental Surromel Calf) with a commercial milk replacer, Surromel Calf®. The calves were blocked according to body weight at birth and randomly allocated to one of the two treatments within each block for an experimental period of 56 days. The birth weight of the calves varied between 34.5 and 43.0kg. The differences in weight of the 2 calves within each block were less than 1kg.

3.1.2 Feeding

The purpose of the trial was to evaluate the growth potential of the calves fed experimental milk replacer. The calves were liquid fed only and no calf starter was offered to reduce variation in terms of nutrient intake.

Calves were hand fed 2l of colostrum within 6 hours after birth and another 2l within 12h after birth. Colostrum feeding continued until day three when calves were switched over to the experimental treatments. Calves were bucket fed 2l of milk replacer (experimental Surromel Calf or commercial Surromel Calf®) twice daily at 08h00 and 15h00. For the first two weeks the milk replacer was allocated at 10% of body weight (2l milk replacer fed twice daily), from week 3 to week 6 at 12.5% of body weight (2.5l milk replacer fed twice daily) and during week 7 and week 8 calves received the milk replacer at 15% of body weight (3l milk replacer fed twice daily). Great care was taken to feed the milk replacer at the same temperature (30ºC) every day. Water was available *ad lib* except for 30 minutes before and after milk replacer feedings.

The milk replacers contained 20% crude protein and 12% fat and the chemical composition was identical for both the experimental Surromel Calf and the commercial Surromel Calf®. The chemical composition is shown in Table 3.1. Because of a confidentiality agreement the ingredient composition cannot be published.

Table 3.1: Composition of both Surromel Calf® and experimental Surromel Calf

Ingredients	%DM
Moisture	≤ 5.0%
Fat content	≥ 12.0%
Protein	≥ 20.0%
Lysine	≥ 1.4%
Methionine and Cysteine	≥ 0.9%
Minerals (Ash)	≤ 8.0%
Fibre	≤ 0.5%
Calcium	1.3 – 1.5%
Phosphorus	0.8 – 0.9%
Magnesium	0.06%
Copper	10mg/kg
Manganese	50mg/kg
Cobalt	18mg/kg
Iron	60mg/kg
Vitamin A	40 000 IU/kg
Vitamin C	120mg/kg
Vitamin D3	10 000 IU/kg
Vitamin E	50mg/kg
Virginiamysin	60mg/kg
Anti-oxidant	35mg/kg
pH	3.9 – 5.0
Sediment(Disc)	≤ 22.5mg / 25g
Solubility index	≤ 5.0ml

(Clover SA, Reg. Nr. V7174 Act 36/1947)

3.1.3 Housing and Management

Calves were moved to individual pens at day one of age. The pens were 6m x 2.5m each. One third of each pen was roofed and the floor consists of concrete, the remainder being soil surface. Every pen had a platted rubber matt on the concrete floor to function as bedding for the young calves.

After birth the calves' navels were disinfected with an Iodine solution to prevent navel ill and other infections and extra teats were removed. No dehorning was done during the trial period to minimize stress. Because it was the dairy's practice not to vaccinate calves, no vaccinations were given to trial animals.

The only illness found during the trial was diarrhea. All sick animals were treated according to the diagnosis by the local veterinarian. When the fecal score was higher than 2 and the rectal temperature exceeded 39.5°C antibiotics were administered for 3 days. When calves were visibly dehydrated electrolytes were given to the calves twice daily at 10h00 and 13h00. Milk feeding continued as usual.

3.1.4 Parameters measured

3.1.4.1 Body weight

Calves were weighed at birth and thereafter every week until 56 days when the trial ended.

3.1.4.2 Body Stature

When heifers calve for the first time they should not only have achieved a target body weight but also a target body size. It is therefore essential to monitor skeletal development alongside body weight. The following body stature measurements were made weekly when weighing the calves.

(i) Shoulder height – Measured at the highest point of the calf's withers.
(ii) Body length – Measured straight from the shoulder joint to the hip joint.
(iii) Chest diameter – Measured snug but not too tight around the heart girth just behind the front legs and shoulder blade.
(iv) Body depth – Measured from just behind the front legs to the calf's withers.
(v) Shoulder width – Measured at the widest part of the two shoulder joints.

All measurements were taken while the calves were standing comfortably on a clean, hard, level surface with their heads upright and looking forward.

3.1.5 Fecal consistency

The fecal consistency was subjectively scored every morning before feeding in order to assist in the evaluation of the health status of the calf as well as the treatment of diarrhea. A scoring system from 1 to 4 as described by Larson *et al.* (1977) was used with:

1 firm, well-formed feces
2 soft pudding like feces
3 runny pancake batter (beginning of diarrhea)
4 watery-liquid like substance feces that can be described as severe diarrhea.

3.1.6 Statistical analysis

The experiment was designed as a completely randomized complete block, blocking calves according to weight. ANOVA was used to test for differences in calf performance, where each calf received either the experimental milk replacer or the commercially available Surromel Calf in phase one; or receiving either full milk or the experimental milk replacer with calf starter in phase two. The data was acceptably normal, with homogeneous treatment variances. Tukeys honest least significant difference (LSD) was used to separate means at the 5% level.

3.2 Phase 2

The materials and methods followed during phase 2 of the study differed from phase 1 only in the following aspects:

3.2.1 Feeding

Calves were fed either 2l of full milk or experimental Surromel Calf twice a day for the full duration of the trial (56 days). Additionally the calves had *ad lib* access to a commercial calf starter (Meadow Calf Starter - Tiger milling & feeds LTD, Reg. No. V 12012). The chemical composition of the calf starter is shown in Table 3.2.

Table 3.2: Nutrient composition of the commercial calf-starter[1]

Ingredients:	g/kg
Protein(Min)	180
Fat (Min)	25
Fibre (Max)	150
Moisture (Min)	120
Phosphorus (Min)	3.5
Calcium (Max)	8.0
Medication:	
Albac[2]	15ppm/100g/t
Romensin[3]	15ppm/75g/t

[1]Tiger milling & feeds LTD, Reg. No. V 12012, [2]Zinc Bacitracin (Insta Vet), [3]Monensin, monosodium salt (Elanco Animal Health)

CHAPTER 4

RESULTS AND DISCUSSION

Recent research data has shown that the traditional calf rearing programs may be limiting the growth potential of calves. The young calf is extremely efficient at converting dietary protein to body protein deposition with efficiencies of close to 60% compared to protein deposition efficiencies in bred heifers of 15%. Therefore, if dairy producers strive to improve heifer growth and calve heifers 15 – 30 days earlier, the greatest opportunity to achieve this lies in the very early phases of growth. Because of this and the interest in accelerated growth systems, numerous recent studies have been conducted on milk replacers, in accelerated growth systems, especially in the USA (Hoffman, 2005).

The growth rate of dairy heifers from birth to sexual maturity determines age at first calving. It also affects future milk production and therefore, proper growth in neonatal calves is of utmost importance to establish a good platform from the start for a productive future.

4.1. Phase 1: Growth study with calves fed only milk replacer

4.1.1 Body weight and average daily gain

Calves received either commercial Surromel Calf® (CSM) or experimental Surromel Calf (ESM) for 56 days without a calf starter. Milk replacer was offered at 10% of birth weight (500g DM/day) for the first two weeks, 12.5% (625g DM/day) of birth weight for week 3 to week 6 and 15% (750g DM/day) of birth weight for week 6 to week 8 when the trial ended. All calves readily consumed the total volume of milk replacer offered during each feeding; the ESM therefore did not contribute to a palatability problem. Although there was a difference in ingredients and in the manufacturing process, the nutrient composition for both the experimental Surromel Calf (ESM) and commercial Surromel Calf® (CSM) were the same (Table 3.1). Nutrient intake and dry matter intake, therefore, were the same for both groups.

The weekly average body weight of the 2 experimental groups is shown in Table 4.1. Mean body weights at the initiation of the study were 39.5kg and 39.4kg respectively and were not significantly different between the two treatment groups receiving either experimental Surromel Calf or commercial Surromel Calf® (P>0.05).

Because the calves received only restricted amounts of milk replacer and no starter, it resulted in a lower growth rate than commercially raised calves, where a calf starter is usually fed *ad libitum*, or in accelerated growth systems where milk intake is not restricted and the nutrient density of the replacer is higher resulting in a higher DMI.

Table 4.1: Weekly body weight means for calves receiving either experimental Surromel Calf or commercial Surromel Calf.

	Body weight		
Day	**ESM[2] (± SEM)[1]**	**CSM[3] (± SEM)[1]**	**P value**
0	39.5(±0.1)	39.4(±0.1)	0.47
7	38.4(± 0.4)	38.0(±0.4)	0.60
14	38.0(±0.4)	38.0(±0.4)	0.94
21	39.9(±0.4)	39.5(±0.4)	0.50
28	40.8(±0.7)	40.9(±0.7)	0.90
35	42.7(±0.7)	42.5(±0.7)	0.79
42	44.5(±0.6)	44.4(±0.6)	0.83
49	46.9(±0.6)	46.5(±0.6)	0.71
56	49.0(±0.6)	49.3(±0.6)	0.82

[1]SEM: standard error of the mean, [2]ESM: experimental Surromel Calf, [3]CSM: commercial Surromel Calf

Average body weight decreased (P>0.05) during the first two weeks when compared to birth weight, but it did not differ significantly between commercial Surromel Calf® (CSM) and experimental Surromel Calf (ESM). During the first week average body weight decreased by 1.15kg and 1.34kg (P>0.05) respectively for calves receiving either ESM or CSM when compared to birth weight. Similarly, in a study conducted by Kühne *et al.* (2000) calves' body weight decreased by 0.67kg during the first week of life in one of the treatments where milk replacer was given at a rate of 5.20g dry matter intake per kg body weight. However the milk replacer used in this study consisted of 12% fat and 20% crude protein whereas the milk replacer used in the study conducted by Kühne *et al.* (2000) contained of 21% fat and 22% crude protein. Quigley and Wolfe (2003) also found a decrease in body weight of 0.50kg from week 1 to week 2 in a trial where milk replacer (21%CP; 21% fat) was fed at a rate of 454g/day for the first week with a starting body weight of 47.3kg. However, in other liquid fed growth studies, calves did not lose weight during the first two weeks after birth (Terosky *et al*., 1997; Diaz *et al*., 2001). In general, the initial decrease in body weight could be attributed to stress, dietary change and other environmental factors.

Weekly mean body weight and body weight gain increased as age increased from week two onwards (P>0.05) when compared to birth weight. The final mean body weight gains for calves fed either ESM or CSM were 9.54kg ± 2.52 and 9.88kg ± 1.99 respectively over the eight week period. In a study conducted by Terosky *et al.* (1997) mean body weight changes of between 18.6kg (milk replacer: 21.1%CP; 19.85kJ/g GE) and 20.4kg (milk replacer: 20.6%CP; 19.85kJ/g GE) were found in calves fed only milk replacer. However, these were Holstein bull calves housed in an environmentally controlled room for the duration of the trial. Room temperature was maintained between 19.5 and 21°C. Humidity, air movement and light were also regulated. Akayezu *et al.* (1994) also found that bull calves gained weight faster than heifer calves up to weaning. This could have contributed to the poor growth performance in this study when compared to the growth rates reported by Terosky *et al.* (1997).

When evaluating results, it is important to compare results on the basis of nutrient intake because fat and protein content of milk replacers vary and in most instances milk contains more fat than milk replacers (Davis and Drackley, 1978).

Weekly least square means of body weight and body weight gain were unaffected by milk replacer composition (Table 4.1). The mean difference between starting and end body weight and mean average daily gain (ADG) over the 56 day experimental period is shown in Table 4.2.

Table 4.2: Body weight gain and average daily gain of calves fed either experimental Surromel Calf or commercial Surromel Calf

Item	ESM[1](± SEM)[3]	CSM[2] (±SEM)[3]	P value	CV%[4]
Change in body weight (kg)	9.5 (± 0.73)	9.9 (± 0.57)	0.71	22.5
Average daily gain (kg)	0.2 (± 0.01)	0.2 (± 0.01)	0.79	22.2

[1]ESM: experimental Surromel Calf, [2]CSM: commercial Surromel Calf, [3]SEM: standard error of the mean, [4]CV%: coefficient of variance

Mean body weight increased by 9.5 and 9.9kg over the 56 day experimental period and did not differ between treatments (P>0.05). Mean average daily gains were 170g/day and 176g/day for calves receiving either ESM or CSM respectively and did not differ between treatments (P>0.05).

Calves on both treatments gained weight slowly. ADG were lower than expected for calves of similar age fed milk replacers only, when compared with other studies. In a study reported by Lammers *et al*. (1995) where calves were fed milk replacer (21%CP; 17%fat) only up to six weeks of age, the ADG differed between 190g/d and 261g/day. It is however important to note that these milk replacers contained more protein and fat than the milk replacers (20%CP; 12%fat) used in the current study where a ADG of 170g/day and 180g/day were achieved respectively for ESM and CSM. In a study conducted at the University of Illinois, calves were assigned to one of three different milk replacers without a starter and housed in hutches bedded with straw. They were fed at 10% body weight from day three to day 10 after birth and at 12% of body weight from day 10 onwards. The average daily gain was 280g/day with milk replacer (19%CP; 15.1% fat), 340g/day with milk replacer (20.9%CP; 15% fat) and 280g/day with milk replacer (19%CP and 15.1% fat) respectively (Drackey et al., 2004). In an experiment conducted by Tomkins *et al*. (1995) bull calves were fed isocaloric nonmedicated milk replacers differing in crude protein content from 14% to 24%. No calf starter was fed and the ADG for calves fed the milk replacer (14%CP; 22% fat) averaged 320g/day from day five to day 42 after birth. These calves were also housed in a temperature controlled and humidity-controlled veal barn.

It is important to note that calves in the current study were not housed in an environmentally friendly environment and only autumn and winter heifer calves were included in phase 1 of the trial (Table 4.3).

Table 4.3: Average monthly Maximum and Minimum temperature (ºC) as measured by the Irene weather station (South African Weather Service, 2002) and percentage of calves receiving only milk replacer during subsequent months.

	Feb '02	Mar '02	Apr '02	May '02	Jun '02	Jul '02	Aug '02	Sep '02
Min[1]	13.8	13.5	12	7.8	5.1	3.8	8.9	9.7
Max[2]	25.2	25.6	25.7	22	17.7	18.6	21.7	24.3
% calves in trial	3.1	13.2	24.6	24.1	13.3	8.9	8.6	4.1

[1]Average Monthly Minimum Temperature (°C) Data for station [0513385A2] – IRENE WO Measured at 08:00
[2]Average Monthly Maximum Temperature (°C) Data for station [0513385A2] – IRENE WO Measured at 08:00.

The colder months of the year could be a possible cause for the lower growth rate found in the first phase of this trial. The calves also received only milk replacer and no starter which could have resulted in a slower growth rate than commercially raised calves, where a calf starter is usually fed *ad libitum*, or where milk intake is not restricted and dry matter intake is higher. The ANOVA indicated no significant seasonal effects (P = 0.345) for ADG of calves raised in autumn or winter (Table 4.4).

Table 4.4: Body weight gain for autumn and winter calves fed only milk replacer

Season	Autumn[1]	Winter	P value	CV%[3]
ADG (±SEM)[2]	0.18 (± 0.01)	0.17 (± 0.01)	0.35	22.9
Sample size	10	14		

[1]The few spring heifers were combined with winter, [2]SEM: standard error of the mean, [3]CV%: coefficient of variance

According to the NRC (2001) prediction, the calves were supposed to grow at a rate of 234g/day at 20ºC. However, they grew at a rate of 170 – 180g/day. This aspect is discussed in more detail in chapter 5. Winter temperatures well below 20ºC could have contributed to the lower growth rate (See Table 4.3).

Environmental temperature has a major effect on the nutritional requirements of calves. The published nutrient requirements, that are considered to be the standard for the calf, are usually calculated assuming that the calf is in a thermoneutral environment (Corbett, 2003). The thermoneutral zone for calves has been defined to be the environmental temperature range in which the amount of body heat produced is balanced with the amount of heat lost from the body through convection, radiant, and evaporative heat loss (Macdonald *et al.,* 1995). This thermoneutral range has been determined to be 10ºC to 20ºC. Temperatures above and below this range will affect the calf's efforts to maintain a constant level of body heat (Corbett, 2003)

When temperatures drop below 10ºC, more energy is required for the increased heat production necessary to maintain body temperature. Cold temperatures also decrease the calf's ability to digest dry matter. The dairy calf also has a much greater surface area per kg of weight than do larger animals. This results in a rapid increase in heat production when temperatures drop, especially in calves being more vulnerable to the stresses of low temperatures (Corbett, 2003). Therefore energy level in the calf's diet must be increased when temperature drops in order to compensate for the increased demands of heat production to maintain body core temperature (Corbett, 2003; Hoffman, 2004).

Increasing the energy level of the calf's diet can be accomplished in the following ways:

1. Increasing the percent solids when mixing the milk replacer, adding full milk to the milk replacer or switching to full milk.
2. Adding additional fat to the milk replacer or full milk.
3. Increasing the feeding frequency from 2 to 3 times per day.

During cold conditions, the solids content of milk replacer can be increased to 15% to 18%. Concentrations above 18% may tend to cause an osmotic diarrhea. Several supplements are available that contain 60% fat which can be added to full milk or milk replacer to increase its energy density. A third feeding may be necessary in order to provide the energy level required by the calf to maintain its body temperature without losing weight. Calves raised at an environmental temperature of 3ºC had a 32% increase in energy requirement compared to calves raised at 10ºC (Corbett, 2003).

If the extra energy is not supplied, such as in the current study, the calf must utilize its own fat stores for energy. Fat deposits in young calves are usually not very large and once they are depleted the calf starts breaking down muscle protein for heat production and energy. Calves receiving insufficient energy in their diet start losing weight and become severely stressed. They then become more susceptible to disease and have much higher morbidity and mortality rates than do calves receiving the required energy and protein levels. If they survive, they are often stunted and require more feed and time before reaching their breeding size as replacement heifers (Corbett, 2003).

4.1.2 Body stature measurements

Understanding heifer growth is facilitated by the use of body measurements and how different treatments affect growth. Wither height, hip width and body length reflect skeletal growth and are important functions to consider because those body dimensions are not often influenced by body condition or degree of fatness (Heinrichs *et al.,* 1992). Skeletal measurements are also related to first lactation yield and dystocia (James, 2001a). The optimal growth condition for dairy heifers has been defined as that regimen that will allow a dairy heifer to develop to her full lactation potential at a desired age with minimal expense (Heinrichs *et al.,* 1992). Growth rates and body stature determine body weight at calving and age at calving, which have an impact on the milk-producing ability of the lactating cow. (Foldager & Sejrsen, 1987).

A study by Davis *et al.* (1961) already showed interrelations among the growth of various body parameters. Much of the data used to establish the current recommended body size for the growing dairy heifer has been achieved through the measurement of large numbers of animals in field surveys on commercial establishments. This data has been complemented with the addition of many data sets from research stations (Heinrichs *et al.,* 1992*;* James, 2001a).

Historically, body size has been measured only by body weight (James, 2001a). Growth standards used in the 6th revised edition of the Nutrient Requirements for Dairy Cattle were questioned as they represented data collected 30 to 50 years ago from a limited number of experiment stations. In addition, recommendations for heifer growth are considered in determining nutrient requirements (NRC, 1989). Only within the past 10 years has sufficient data on wither height been collected to enable workers to evaluate the relationship of height to weight and its association with first and later lactation performance (James, 2001a).

Heinrichs and Hargrove (1987) studied 6 000 Holstein heifers in 148 herds located in 33 different counties in Pennsylvania from 1983 to 1985 in an effort to better describe body size and relate it to herd performance under field conditions. They found heifers to be larger, on average, in nearly every age as compared to previously quoted standards. The rolling herd average for milk yield was positively correlated with height (+.41) and weight (+.34) and negatively with age at first calving (-.22) (James, 2001a). Later in 1992, as a part of the National Animal Health Monitoring System survey in the U.S., Heinrichs and Losinger (1998) examined data collected on heart girth and wither height measurement on over 650 Holstein dairy farms from across the U.S. The data showed a slight increase in height and weight in current heifers as compared to those measured years ago. This increase in weight and height of Holstein calves happened over the past 30 years. This can be attributed mainly to the increase in size and stature when selecting bulls for the AI industry. The study also showed a strong positive association between heifer growth and rolling herd average milk production. They also found that differences in size were attributed to differences in feeding strategies (James, 2001a).

The following body stature measurements were made weekly when weighing the calves.

(i) Shoulder height – Measured at the highest point of the calf's withers.

(ii) Body length – Measured straight from the shoulder joint to the hip joint.

(iii) Chest diameter – Measured snug but not too tight around the heart girth just behind the front legs and shoulder blade.

(iv) Body depth – Measured from just behind the front legs to the calf's withers.

(v) Shoulder width – Measured at the widest part of the two shoulder joints.

The weekly means of changes in body stature (height, length, width, depth and chest diameter) are shown in Table 4.5.

Table 4.5: Effect of feeding commercial Surromel Calf or experimental Surromel Calf on body stature measurements[1] (cm) of calves from birth to 56 days

Day	Height (±SEM)[4]		Length (±SEM)[4]		Width (±SEM)[4]		Depth (±SEM)[4]		Heart girth (±SEM)[4]	
	ESM[2]	CSM[3]	ESM[2]	CSM[3]	ESM[2]	CSM[3]	ESM[2]	CSM[3]	ESM[2]	CSM[3]
0	75.5(±0.61)	75.8(±0.61)	66.9(±0.53)	66.8(±0.53)	19.1(±0.32)	19.3(±0.32)	29.8(±0.36)	29.8(±0.36)	82.4(±0.53)	81.8(±0.53)
7	76.4(±0.56)	76.8(±0.56)	68.5(±0.61)	68.1(±0.61)	19.3(±0.41)	19.4(±0.41)	30.2(±0.24)	29.8(±0.24)	82.8(±0.62)	82.5(±0.62)
14	76.8(±0.46)	77.0(±0.46)	68.8(±0.45)	69.1(±0.45)	19.9(±0.12)	19.8(±0.12)	29.8(±0.33)	30.1(±0.33)	82.8(±0.58)	83.4(±0.58)
21	77.3(±0.68)	77.0(±0.68)	69.8(±0.56)	69.8(±0.56)	20.2(±0.27)	20.3(±0.27)	30.6(±0.34)	30.8(±0.34)	83.9(±0.48)	83.5(±0.48)
28	78.3(±0.57)	78.2(±0.57)	70.6(±0.35)	70.5(±0.35)	20.3(±0.26)	20.5(±0.26)	31.4(±0.27)	30.8(±0.27)	84.4(±0.57)	85.1(±0.57)
35	79.1(±0.42)	79.1(±0.42)	71.4(±0.50)	71.3(±0.50)	20.8(±0.18)	20.8(±0.18)	31.8(±0.24)	31.2(±0.24)	85.1(±0.64)	84.9(±0.64)
42	79.8(±0.48)	79.8(±0.48)	72.3(±0.55)	72.0(±0.55)	20.9(±0.16)	21.2(±0.16)	32.3(±0.22)	32.3(±0.22)	86.6(±0.70)	86.6(±0.70)
49	80.8(±0.48)	80.5(±0.48)	72.5(±0.72)	72.8(±0.72)	21.0(±0.22)	21.3(±0.22)	32.6(±0.27)	32.9(±0.27)	88.0(±0.77)	88.7(±0.77)
56	81.5(±0.50)	81.2(±0.50)	73.6(±0.48)	74.0(±0.48)	21.4(±0.29)	21.6(±0.29)	33.1(±0.29)	33.3(±0.29)	89.6(±0.77)	90.5(±0.77)

[1]Body stature: Shoulder height – Measured at the highest point of the calf's withers.
Body length – Measured straight from the shoulder joint to the hip joint.
Shoulder width – Measured at the widest part of the two shoulder joints.
Body depth – Measured from just behind the front legs to the calf's withers.
Heart Girth – Measured snug but not too tight around the heart girth just behind the front legs and shoulder blade

[2]ESM: experimental Surromel Calf , [3]CSM: commercial Surromel Calf,
[4]SEM: standard error of the mean

Although the body stature changes increased over time, there were no significant difference (P>0.05) between ESM and CSM weekly measurements. Birth height was 75.5 and 75.4cm (P>0.05) respectively for the two different treatments which is in line with the birth height of 74.0cm found in a study conducted by Franklin *et al.,* 1998. However, at week 4 of age, calves receiving EMS in the current study's height were 78.3cm and 78.2cm for calves fed CSM while Franklin *et al.* (1998) found the average calf height 80cm. Heinrichs and Hargrove's (1987) also reported the average height at 4 weeks of age to be 80.1 ± 3.6 cm which is 2cm taller than the average height found in the current study. However, Heinrichs and Hargrove's (1987) data were collected from commercial Holstein dairies throughout Pennsylvania when calves received calf starter as well and age at measurement was calculated to the nearest whole month.

At 6 weeks of age calves' height in Franklin *et al.'s* (1998) study was 82.4 ± 0.4cm and 82.8 ± 0.4cm for the respective treatments while calves' height in the current study were 79.8 ± 0.5cm for both treatments. However, it must be noted that the calves in Franklin *et al.'s* (1998) study also received a calf starter (14.75% CP; 3.27%EE) with 4.6kg of pooled waste milk supplemented with vitamin A and calves included heifer and bull calves. This is most probably why those calves were taller than the calves in the current study. Franklin *et al.* (1998) also found that gender had an effect on body measurements at birth but that body weight, wither height, and body length increases were not affected (P>0.05) by gender or by supplementation of vitamin A to the full milk fed to the calves.

Calf length was 59.3cm, 65.8cm and 68.7cm at birth, 4 weeks and 6 weeks respectively in the Franklin *et al,* study. These values are lower than the 66.8cm (CSM) and 72.3cm (ESM) birth length and 70.5cm and 70.6cm at 4 weeks of age and 72.0cm and 72.3cm at 6 weeks of age for calves in the current study respectively. These differences could be due to differences in measuring procedures.

Recent studies (Bartlett, 2001; Blome *et al.,* 2003) have also shown clearly that body composition can be influenced by dietary composition in young dairy calves. Measurements of stature increase as the content of dietary crude protein is increased in isocaloric diets (i.e., as the dietary protein to energy ratio is increased indicating stimulation of skeletal growth (Bartlett, 2001; Blome *et al*., 2003).

The means of the change in body stature measurements (height, length, width, depth and heart girth) of calves receiving EMS or CSM between birth and 56 days of age, are shown in Table 4.6

Table 4.6: Effect of different milk replacers on the change in body stature[1] measurements between birth and 56 days of age

Item	Height[1] (cm)	Length[1] (cm)	Width[1] (cm)	Depth[1] (cm)	Heart[1] girth (cm)
ESM[2] (±SEM)[4]	6.0 (± 0.58)	6.7 (± 0.92)	2.3 (± 0.59)	3.3 (± 0.39)	7.2 (± 0.82)
CSM[3] (±SEM)[4]	5.3 (± 0.56)	7.2 (± 0.95)	2.3 (± 0.50)	3.4 (± 0.45)	8.8 (± 0.71)
P value	0.39	0.67	1.00	0.78	0.16
CV%	31.9	40.8	59.9	42.9	32.3

[1]Body stature: Shoulder height – Measured at the highest point of the calf's withers.
Body length – Measured straight from the shoulder joint to the hip joint.
Shoulder width – Measured at the widest part of the two shoulder joints.
Body depth – Measured from just behind the front legs to the calf's withers.
Heart girth – Measured snug but not too tight around the heart girth just behind the front legs and shoulder blade.
[2]ESM: experimental Surromel Calf, [3]CSM: commercial Surromel Calf, [4]SEM:standard error of the mean

No differences were observed between treatments (P>0.05) for any change in body stature measurements over the 56 day trial period.

It can therefore be concluded that there were no differences between treatments in any growth parameters including body weight and body stature measurements measured during phase 1 of the trial for calves receiving either ESM or CSM without starter. The calves grew slower than the norm for commercially raised dairy calves but because of the absence of a calf starter the DMI was much lower than that of commercially raised calves. Only winter and autumn calves where included and calves were not raised in environmentally controlled houses. Therefore the slow growth rate was not totally unexpected.

4.1.3 Fecal Score – Phase 1

According to Virtala *et al.* (1996) a variety of health conditions and diseases may have a severe impact on the growth rate of calves. They reported a decreased growth rate of 8, 18 and 29% respectively for calves with pneumonia, diarrhea or a combination of the two conditions. The study covered the period from 5 days to 70 days of age.

More than 50% of dairy calf mortality on US dairy farms is related to diarrhea which is in most cases caused by bovine coronavirus (Arthington et al, 2002). Fecal scoring can be used as an indicator of coronavirus challenge or the incidence of diarrhea which can be caused by feeding poor quality milk replacers to dairy calves.

The effects of feeding either ESM or CSM on the average amount of diarrhea days from birth to 56 days are shown in Table 4.7. Fecal consistency was subjectively scored once daily using a scale of 1 = firm, well-formed normal fecal consistency, 2 = soft, pudding like fecal consistency, 3 = runny, pancake batter and 4 = liquid splatters as adopted from the method of Larson *et al.* (1977). A fecal score 3 would indicate the beginning of diarrhea and a fecal score 4 would indicate severe diarrhea.

Only the total amount of days where calves scored 3 or 4 on fecal consistency over the 56 day trial period are included in Table 4.7 to indicate the occurrence of diarrhea during the trial period. The difference between ESM and CSM calves for days of diarrhea and days of severe diarrhea is of no statistical significance ($P>0.05$). Fecal scores generally peaked between day 7 - 14 and day 28 - 35 of age and declined thereafter, although scores remained somewhat elevated for week 4 as well.

Table 4.7: Effect of feeding different milk replacers on the amount of diarrhea days from birth to 56 days by means of fecal scores

	Group average of total amount of days over the 56 day trial period where calves showed beginning of diarrhea or severe diarrhea	
	Fecal score 3[1]	**Fecal score 4[1]**
ESM[2](±SEM)[4]	10.4 (± 1.72)	3.7 (± 1.15)
CSM[3](±SEM)[4]	15.3 (± 1.72)	4.5 (± 1.15)
P value	0.07	0.62
CV%[5]	46.4	97.5

[1]Group average of the total amount of days over the 56 day trial period where calves scored a fecal score 3 or 4 respectively. Fecal score 3: runny, pancake batter (beginning of diarrhea) and Fecal score 4: liquid splatters(severe diarrhea)
[2]ESM: experimental Surromel Calf, [3]CSM: commercial Surromel Calf, [4]SEM: standard error of the mean, [5]CV%: coefficient of variance.

It must also be mentioned that the incidence and severity of diarrhea in this study was consistent with infections by *Cryptosporidium* sp. Although this organism was not specifically isolated in this study, the farm had a history of *Cryptosporidium* infection in preweaned calves. It is also reported by Harp *et al.* (1989) that high titers of colostral antibody specific for *Cryptosporidium parvum* were ineffective in protecting calves against challenges of *C. parvum,* although Lopez *et al*. (1988) indicated a positive relationship between shedding of *Cryptosporidium* and concentrations of Ig in serum.

Timmerman *et al.* (2005) conducted a study with Holstein-Friesian bull veal calves where a calf starter and milk replacer (22.5% CP; 16.5% fat) with or without multispecies probiotic or calf-specific probiotic was fed from day 10 of age at 1.5l twice daily, with an increase in volume to 6l twice daily after 8 weeks. Diarrheic days per animal were estimated from day 0 to day 14 in the trial (from day 10 of age onwards). Percentage of animals with diarrhea differed between 19.4% and 70.8% between the different experimental treatments. The highest incidence of diarrheic days was 25% for the 2 week period whereas calves in the current study also showed 25% diarrheic days for calves fed experimental Surromel Calf and 35% diarrheic days for calves fed commercial Surromel Calf®. However, this was over a

56 day period and these percentages include not only severe diarrhea but also border line diarrhea.

The diarrhea days over the 56 day trial are relatively high if compared with diarrhea days for calves in phase 2 that received starter as well (see Table 4.7). The lower nutrient intake of calves not receiving starter probably contributed to the higher incidence of diarrhea since nutritional stress contributes greatly to immunosuppression in calves. This can also be one of the reasons for the calves' slower growth rate.

4.2. Phase 2: Growth study comparing milk and milk replacer with calf starter *ad lib*

Heifers should be raised in an inexpensive way to be healthy and fast growing replacements that will reach age at first calving at the earliest time possible without sacrificing lifetime milk yield (Engsrtom, 2005), so that they are prepared to express their genetic potential for milk production when they calve (Quigley, 2005). An early weaning will reduce the cost of feed and labor and lower the risk of nutritional diarrhea. The transition from preruminant to ruminant is not instantaneous (Engstrom, 2005). When calves consume both starter and water at an early age, maturation of the rumen occurs at an earlier age compared with liquid-feeding alone (Franklin *et al.,* 2003). The trend towards early weaning, rapid growth, and early breeding, therefore stresses the importance of a well balanced calf starter ration (Clapp, 1981).

4.2.1 Body weight, starter intake and average daily gain

Calves were fed either 2l of full milk (25-26% CP; 29-30% fat DM) or 2l experimental Surromel Calf (20%CP;12% fat DM) twice daily for the full duration of the trial after receiving colostrum for 3 days. Additionally the calves had *ad lib* access to a commercial calf starter (Meadow Complete Calf® - Tiger milling & feeds LTD, Reg. No. V 12012). The chemical composition of the milk replacer and calf starter is shown in Table 3.1 and Table 4.8. respectively. All calves readily consumed the total volume of full milk (FM) or experimental Surromel Calf (ESM) during each feeding; the experimental milk replacer therefore did not cause any palatability problems.

The amount of starter offered was recorded daily, and orts were weighed and recorded weekly. Any fouled starter was removed, weighed, dried in an oven and on a dry matter basis replaced with fresh starter. The calf starter fed was obtained from the same source throughout the trial and no variation in calf starter composition was observed throughout the trial.

Table 4.8: Nutrient composition of the commercial calf-starter[1]

Nutrients:	g/kg
Protein(Min)	180
Fat (Min)	25
Fibre (Max)	150
Moisture (Min)	120
Calcium (Max)	8.0
Phosphorus (Min)	3.5
Medication:	
Albac[2]	15ppm/100g/t
Romensin[3]	15ppm/75g/t

[1]Tiger milling & feeds LTD, Reg. No. V 12012, [2]Zinc Bacitracin (Insta Vet - 11 Vervoer Rd, Kya Sand, Randburg, Gauteng, South Africa), [3]Monensin, monosodium salt (Elanco Animal Health - 34 Director Rd, Spartan Ext 2, Kempton Park, Gauteng, South Africa)

The weekly mean body weight and weekly mean starter intake for the two experimental groups are shown in Table 4.9

Table 4.9: Weekly mean body weight and starter intake for calves receiving full milk plus starter or experimental milk replacer plus starter

	Body weight(kg)			**Starter intake(kg)**		
Day	**FMS[1] (±SEM)[3]**	**EMSS[2] (±SEM)[3]**	**P value**	**FMS[1] (±SEM)[3]**	**EMSS[2] (±SEM)[3]**	**P value**
0	39.4(±0.11)	39.6(±0.11)	0.31	-	-	
7	37.0(±0.43)	38.2(±0.43)	0.07	0.2(±0.02)	0.2(±0.02)	0.91
14	37.3(±0.59)	38.0(±0.59)	0.44	0.3(±0.05)	0.3(±0.05)	0.31
21	39.5(±0.78)	39.3(±0.78)	0.80	1.2(±0.23)	1.0(±0.23)	0.64
28	41.7(±0.77)	41.8(±0.77)	0.91	2.1(±0.30)	2.4(±0.30)	0.46
35	45.8(±0.89)	45.5(±0.89)	0.82	3.1(±0.35)	3.8(±0.35)	0.20
42	50.0(±1.00)	50.0(±1.00)	1.00	5.4(±0.49)	6.0(±0.49)	0.42
49	55.4(±1.21)	54.4(±1.21)	0.59	6.9(±0.57)	7.2(±0.57)	0.69
56	60.3(±1.19)	60.2(±1.19)	0.94	7.7(±0.58)	7.7(±0.58)	0.99

[1]FMS: full milk plus starter, [2]EMSS: experimental Surromel Calf plus starter, [3]SEM: standard error of the mean

Starter consumption was negligible for the first three weeks of the trial, averaging less than 0.2kg/d from 15 - 21 days of age. This data is comparable with a study conducted by Akayezu *et al.* (1994) where a starter intake of less than 0.20kg/d at 18 days of age was recorded. In the current study starter intake was 0.30kg/d and

0.34kg/d respectively at 35 days of age and 1.11kg/d for FMS calves and 1.10kg/d for EMSS calves at 56 days at the end of the trial (P>0.05).

The starter used in the current study was in a pelleted form. Although Franklin *et al.* (2003) found higher intakes and better growth rates on calves fed a textured feed (containing pellets plus whole or processed grains) rather than a pelleted starter, pelleted feeds are doing well in the industry. Either of these two forms is preferred over meal feeds because calves generally do not find meal very palatable due to their dusty nature (Quigley, 1998a).

Mean birth weight at the onset of the trial was 39.4 kg and 39.6kg respectively and was not different among the two treatment groups FMS and EMSS (P>0.05). This trend continued throughout the trial and no differences were observed in weekly body weight change between the treatments (P>0.05). The average body weight during week 8 was 60.3 and 60.2kg for the FMS and EMSS group respectively.

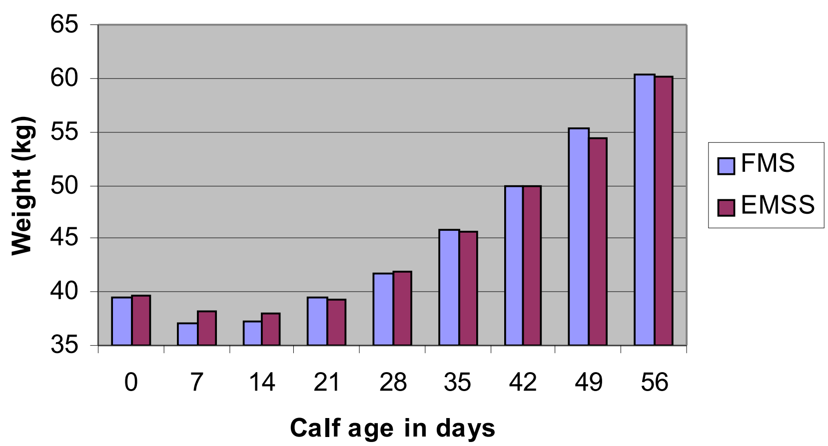

Figure 1. Weekly body weight change (kg) of calves fed either full milk and starter (FMS) or experimental milk replacer and starter (EMSS)

An increase in body weight as age increased is illustrated in Fig 1. Body weight increased from week two onwards as age increased. The decrease in body weight from birth up to week two can be expected because of stress, and sensitivity towards cold temperatures and diarrhea that is more common within the first two weeks of life. This is consistent with other studies such as a study conducted by Kühne *et al.* (2000) where calves' body weight also decreased during the first week of life.

When the average daily consumption of starter is calculated over the first 6 weeks it amounts to 291g/d (FMS) and 326g/d (EMSS) respectively. This is approximately 100g/d lower than the intake of 408g/day for calves reported by Lammers *et al.* (1998) where mean *ad lib* starter intake (21% CP) was monitored from birth up to 6 weeks of age with an overall ADG of 469g/d. These researchers also found that ADG was highly correlated with total starter intake ($r^2 = 0.72$).

The mean difference between birth and weaning weight and mean ADG is shown in Table 4.10. The growth and ADG did not differ between the two treatments (P>0.05).

Table 4.10: Body weight gain and average daily gain of calves fed either full milk plus starter or experimental milk replacer plus starter

Item	FMS[1] (±SEM)[3]	EMSS[2] (±SEM)[3]	P value	CV%[4]
Change in body weight (kg)	20.9 (± 1.65)	20.6 ± (1.66)	0.86	19.4
Average daily gain (kg)	0.4 (± 0.03)	0.4 ± (0.03)	0.84	19.6

[1]FMS: full milk plus starter, [2]EMSS: experimental Surromel Calf plus starter, [3]SEM: standard error of the mean, [4]coefficient of variance

The ADG for this 56-day growth study were 370g/day for both FMS and EMSS (P>0.05). This gain was somewhat lower than the ADG of 408g/d found by VandeHaar (2004) for calves fed a commercial milk replacer (21.3%CP and 21.3% fat) at 1.2% of body weight and calf starter(20.5%CP) at restricted intake.

Morril et al, (1995) reported an ADG of 302g/day and 319g/day for calves fed milk replacer containing bovine and porcine plasma respectively, for 43 days. Calves in Morrill *et al's* (1995) study were fed 454g of milk replacer per day until weaning at approximately 35 days and weighed approximately 54 kg at 6 weeks of the study (7 weeks of age). This is lower than the mean of 55.38kg and 54.42kg for FMS and EMSS calves in the current study.

As expected, the calves receiving milk or experimental milk replacer plus starter gained more body weight and had higher ADG compared to the calves receiving only liquid feed in Phase 1 of the trial. Average daily gain of calves receiving FMS and EMSS were similar to other studies (Tomkins, et al., 1994; Heinrichs et al., 2003) where milk replacer contained milk and plant proteins. Intake increased as age and body weight increased. By week 8, calves of both FMS and EMSS consumed 1.1 kg starter per day. Quigley and Bernard (1996) also reported a starter intake of 1.1kg/day by week 8. The average daily gain in the latter study averaged 473g/day, however milk replacer intake increased as age and body weight increased, therefore the total nutrient intake was higher than in this study and therefore not fully comparable. By week 8, the calves consumed 700g of DM of the milk replacer per day while the calves in the current study received only 500g of DM of the milk replacer or 4l full milk. Differences between intake of calf starter in this study and those from other reports (Quigley *et al*, 1994; Quigley *et al* 1992) were probably due to differences in amount of milk replacer fed and type of calf starter offered. It is therefore imperative that when ADG from different studies is compared it should be done on the basis of nutrient intake and nutrient content from either starter or liquid feed to ensure a fair comparison.

Average daily gain was unaffected by treatment (P>0.05) indicating that the nutrients provided from the milk replacer were utilized with the same efficiency as these provided by full milk.

Mean body weight at 56 days of age were slightly lower than the guidelines suggested by Linn *et al.* (1989) and the growth standards of herd replacements published by Heinrichs and Hargrove (1987) and by Hoffman *et al.* (1992) for dairy calves of similar ages. Reasons for this result include possible differences in feeding management, experimental procedures, and genetic bases of the populations studied. Nevertheless, if 350kg is considered to be the optimal bodyweight of heifers at breeding (Moss, 1998), and if this body weight is to be attained by 14 months of age, then two months old calves with mean body weight similar to calves receiving the experimental Surromel Calf plus starter and full milk plus starter must grow at rates of 0.79kg/d to attain the target weight of 340kg at 14 months of age. These rates of gain are achievable under good management practices. However, various feeding and management factors, such as group size, feed bunk management, dry matter intake, roughage quality, crude protein and energy content of diets, source and degradability of protein, and feeding management (restricted vs. *ad libitum*), may affect calf response and growth rate (Akayezu, 1994).

The lack of treatment effects on ADG (Table 4.10) indicates that the experimental milk replacer sustained growth in a similar way as full milk. Based on literature studies where a similar milk replacer as used in our study was compared to full milk, one would have expected calves receiving full milk to have a higher ADG than the calves receiving milk replacer. However, it must be remembered that these calves were housed in a relatively cold environment with very little shelter and *Cryptosporiduim* spp. were isolated in some of the calves. This could have compromised the full milk with starter group more, leading to a lower growth rate and the similar growth in the end.

4.2.2 Body stature measurements

Body stature measurements are used primarily to monitor calf growth and to estimate contemporary growth as part of the growth monitoring process (Wilson *et al*., 1997). Size is an indicator of body volume. The larger the body volume is at calving the less the risk of problems during the first lactation (Murphy, 2004). The different production systems on different farms can cause differential growth rates and body dimension changes compared with different management strategies and feeding regimes on different farms (Wilson et al., 1997). Diaz *et al.* (2001) also concluded that nutrient supply can alter the body composition and growth of neonatal calves. It is also important that growth consists of skeletal and muscle growth rather than fat and to grow tall heifers rather than fat heifers (Hutjens, 2004).

4.2.2.1 Body stature measurements – Phase 2

The weekly means of changes in body stature (height, length, width, depth and chest diameter) are shown in Table 4.10.

Birth heights for FMS and EMSS were 75.8cm and 75.0cm respectively. These heights compare well with birth height measured in a study by Franklin, *et al.,* 1998. Calves in the latter study, which included bulls and heifers, also received a calf starter (14.8% protein;3.3% EE) with 4.6kg of pooled waste milk supplemented with vitamin A. Franklin *et al.* (1998) found that gender had an effect on body measurements at birth but that body weight, wither height, and body length increases were not affected ($P>0.05$) by gender or by supplementation of vitamin A to the full milk fed to the calves. At 4 weeks of age Franklin *et al.,* 1998 found an average height of 79.7±0.4 and 80.2±0.5 whereas calves' heights in the current study were 77.8±0.42 (FMS) and 78.2±0.42 (EMSS) respectively ($P>0.05$). Calves in our study were taller when compared to Franklin *et al.* (1998) calves. This is most probably due to differences in methodology utilized when measuring body stature over the period from birth to 42 days.

Table 4.11: Effect of feeding full milk plus starter or experimental Surromel Calf plus starter on body stature measurements[1] (cm) of calves from birth to 56 days

Day	Width (±SEM)[4]		Depth(±SEM)[4]		Heart girth(±SEM)[4]		Height(±SEM)[4]		Length(±SEM)[4]	
	FMS[2]	EMSS[3]	FMS[2]	EMSS[3]	FMS[2]	EMSS[3]	FMS[2]	EMSS[3]	FMS[2]	EMSS[3]
0	19.1(±0.42)	19.6(±0.42)	27.8(±0.32)	28.6(±0.32)	77.7(±0.74)	78.9(±0.74)	75.8(±0.47)	75.0(±0.47)	67.0(±0.70)	67.6(±0.70)
7	19.3(±0.39)	20.0(±0.39)	28.4(±0.24)	28.6(±0.24)	78.3(±0.57)	78.8(±0.57)	76.0(±0.40)	75.4(±0.40)	68.1(±0.57)	68.8(±0.57)
14	19.3(±0.37)	20.0(±0.37)	28.8(±0.29)	28.9(±0.29)	78.8(±0.53)	79.3(±0.53)	76.3(±0.44)	76.7(±0.44)	68.8(±0.58)	69.0(±0.58)
21	19.9(±0.34)	20.3(±0.34)	29.3(±0.19)	29.3(±0.19)	80.3(±0.56)	80.6(±0.56)	76.9(±0.37)	77.4(±0.37)	70.0(±0.58)	69.6(±0.58)
28	20.4(±0.32)	20.6(±0.32)	30.0(±0.32)	29.9(±0.32)	81.7(±0.68)	81.6(±0.68)	77.8(±0.42)	78.2(±0.42)	70.5(±0.65)	70.6(±0.65)
35	20.8(±0.25)	20.9(±0.25)	30.9(±0.29)	30.9(±0.29)	83.6(±0.75)	83.7(±0.75)	79.0(±0.47)	79.0(±0.47)	71.5(±0.59)	72.0(±0.59)
42	21.3(±0.30)	21.3(±0.30)	31.9(±0.33)	31.8(±0.33)	85.8(±0.76)	86.3(±0.76)	80.3(±0.40)	80.8(±0.40)	73.3(±0.64)	73.2(±0.64)
49	21.8(±0.31)	21.7(±0.31)	33.2(±0.28)	32.6(±0.28)	89.7(±0.76)	88.6(±0.76)	81.9(±0.54)	82.1(±0.54)	75.5(±0.50)	74.6(±0.50)
56	22.0(±0.32)	21.9(±0.32)	33.9(±0.42)	33.9(±0.42)	90.8(±0.99)	91.8(±0.99)	82.8(±0.50)	83.5(±0.50)	77.0(±0.50)	77.1(±0.50)

[1]Body stature: Shoulder height – Measured at the highest point of the calf's withers.
Body length – Measured straight from the shoulder joint to the hip joint.
Shoulder width – Measured at the widest part of the two shoulder joints.
Body depth – Measured from just behind the front legs to the calf's withers.
Heart girth – Measured snug but not too tight around the heart girth just behind the front legs and shoulder blade.

[2]FMS: Full milk plus starter, [3]EMSS: experimental Surromel Calf plus starter
[4]SEM: standard error of the mean

Calves in the current study's average increase in height over the period from birth to 42 days of age were 0.11cm/d for FMS and 0.14cm/day for EMSS. This compares well to results from Lammers *et al.* (1998) where the average growth in height at 42 days was between 0.13 and 0.16cm/day. The heights found at 42 days by Franklin *et al.,* 1998 were 82.4 and 82.8cm while heights at 42 days in the current study were 80.3±0.4cm (FMS) and 80.8 ± 0.4cm (EMSS) (P < 0.05).

Initial chest diameter differed between 80.1cm and 82.6cm and growth in chest diameter over the 6 week period differed between 0.22 and 0.24cm/day whereas initial chest diameter for FMS was 77.67cm and 78.92cm for EMSS and growth for FMS was 0.19 and 0.17 for EMSS.

The error associated with these measurements, along with the small degree of skeletal growth during this period, makes it difficult to detect possible differences. With calves on accelerated growth programs where average daily gains of up to 0.9kg/day can be achieved, differences would probably be more profound (Lammers, *et al.,* 1998).

Table 4.12: Effect of full milk plus starter or experimental Milk Replacer plus starter on the change in body stature[1] measurements between birth and 56 days of age ± Standard error of the mean (± SEM)

	Height[1] (cm)	**Length[1] (cm)**	**Width[1] (cm)**	**Depth[1] (cm)**	**Heart girth[1] (cm)**	**Weight (kg)**	**ADG (kg)**
FMS[2] (± SEM)[4]	7.0 (± 0.68)	10.0 (± 0.78)	2.9 (± 0.33)	6.1 (± 0.42)	13.2 (± 0.82)	20.9 (± 1.65)	0.4 (± 0.03)
EMSS[3](± SEM)[4]	8.5 (± 0.67)	9.5 (± 0.64)	2.3 (± 0.33)	5.3 (± 0.55)	12.9 (± 0.72)	20.6 (± 1.65)	0.4 (± 0.03)
P value	P = 0.17	P = 0.47	P = 0.29	P =0.23	P = 0.85	P = 0.86	P = 0.85
CV%[5]	31.3	16.8	49.4	25.4	23.5	19.4	19.6

[1]Body stature: Shoulder height – Measured at the highest point of the calf's withers.
Body length – Measured straight from the shoulder joint to the hip joint.
Shoulder width – Measured at the widest part of the two shoulder joints.
Body depth – Measured from just behind the front legs to the calf's withers.
Heart girth – Measured snug but not too tight around the heart girth just behind the front legs and shoulder blade.
[2]FMS: Full milk plus starter, [3]EMSS: experimental Surromel Calf plus starter, [4]SEM: standard error of the mean, [5]CV%: coefficient of variance

The calves receiving the treatments with starter grew more in terms of stature, when compared to the calves that only received milk replacer. For example the average growth in length over the 8 week period of the liquid fed only calves averaged 6.67cm and 7.17cm respectively compared to 7cm and 8.46cm of the combined liquid plus starter fed calves. The increase in height averaged 6cm and 5.33cm for the liquid fed calves and 7cm and 8.46cm for the combined liquid plus starter fed calves respectively. The stature measurements were numerically higher for the liquid plus starter fed calves compared to liquid fed only calves. This was to be expected because of the high dry matter and nutrient intake of the liquid plus starter fed calves.

4.2.3. Fecal score – Phase 2

The effects of feeding either FMS or EMSS on the average number of diarrhea days from birth to 56 days are shown in Table 4.13. Fecal consistency was subjectively scored once daily using a scale of 1 = firm, well-formed normal fecal consistency, 2 = soft, pudding like fecal consistency, 3 = runny, pancake batter and 4 = liquid splatters as adopted from the method of Larson *et al.* (1977). A fecal score 3 would indicate the beginning of diarrhea and a fecal score 4 would indicate severe diarrhea. Only the total amount of days where calves scored 3 or 4 on fecal consistency over the 56 day trial period are included in Table 4.13 to indicate the occurrence of diarrhea during the trial period.

Table 4.13: Effect of feeding full milk plus starter or experimental Surromel Calf plus starter on the amount of diarrhea days from birth to 56 days by means of fecal scores

	Group average of total amount of days over the 56 day trial period where calves showed beginning of diarrhea or severe diarrhea	
	Fecal score 3[1]	**Fecal score 4[1]**
FMS[2] (±SEM)[4]	5.1 (± 1.18)	3.3 (± 0.85)
EMSS[3](±SEM)[4]	6.8 (± 1.18)	6.1 (± 1.4)
P value	0.02	0.22
CV%[5]	26.4	110.4

[1]Group average of total amount of days over the 56 day trial period where calves scored a fecal score 3 or 4 respectively. Fecal score 3: runny, pancake batter (beginning of diarrhea) and Fecal score 4: liquid splatters (severe diarrhea)

[2]FMS: full milk plus starter, [3]EMSS: experimental Surromel Calf plus starter, [4]SEM: standard error of the mean, [5]CV%: coefficient of variance

The group average of total number of days during the 56 day trial where calves showed beginning of diarrhea as shown in Table 4.13 were 5 days for FMS and 7 days for EMSS calves. The total number of days where severe diarrhea was observed were 3 days for FMS calves and 6 days for EMSS calves during the 56 day trial period.

Fecal scores generally peaked at week 2 and declined thereafter, although scores remained somewhat higher in week 4 and 5 for EMSS calves compared to FMS calves. Franklin *et al.* (1998) reported mean weekly fecal scores highest during week 2 and week 3 which is in agreement with the current study. Fecal scores were found to be numerically lower over the 56 day trial period for Phase 2 calves than Phase 1 calves. This is most probably due to the fact that calves in Phase 2 had a higher dry matter and nutrient intake with the starter fed *ad lib.*

CHAPTER 5

NRC VALIDATION / GROWTH STANDARDS

With the release of the 2001 National Research Council Nutrient Requirements of Dairy Cattle (NRC, 2001), a more useful approach to feeding calves has been developed. The new Dairy NRC employs a more mechanistic approach to calf growth and development than previously utilized, and with adoption of the system the industry will be encouraged to re-evaluate the one-size fits all approach to calf feeding that currently exists (Van Amburgh, 2003). It provides reasonable estimates of the animal's nutrient requirements and is consistent with the remainder of the publication regarding tabular values and estimates of nutrient requirements. The estimates of energy requirements for young calves are more consistent with existing literature and can provide nutritionists and other dairy professionals with legitimate means to model dairy animal growth and select management strategies to optimize profitability. The latest edition of the NRC uses metabolizable energy for calves. This system is the most commonly used method of calculating an animal's energy requirement and the energy content of feeds. However many South African producers are reluctant to use the calf and heifer growth recommendations since these have not been validated under South African conditions.

The growth prediction was only compared with the growth of calves in Phase 2 of the trial where a commercial calf starter was fed *ad lib,* the reason being that this is the most commonly used feeding system on dairy farms in South Africa.

The estimated growth as predicted by the NRC at different temperatures with the same intake as calves in the current study receiving full milk and starter are shown in Table 5.1.

Table 5.1: Average daily gain(kg) of calves fed full milk and starter compared with NRC (2001) estimation of ADG with the same nutrient intake at different temperatures

	NRC (2001) ADG growth prediction at different temperatures								Actual starter intake and ADG	
Day	**NRC est. 5°C**		**NRC est. 10°C**		**NRC est. 15°C**		**NRC est. 20°C**		**Daily Starter Intake (kg)**	**Actual ADG**
	Energy Allowable ADG	ADP Allowable Gain	Energy Allowable ADG	ADP Allowable Gain	Energy Allowable ADG	ADP Allowable Gain	Energy Allowable ADG	ADP Allowable Gain		
7	0.23	0.40	0.30	0.40	0.37	0.40	0.44	0.40	0.02	-0.35
14	0.28	0.41	0.42	0.41	0.42	0.41	0.48	0.41	0.03	0.05
21	0.38	0.47	0.44	0.47	0.51	0.47	0.57	0.47	0.17	0.32
28	0.44	0.53	0.50	0.53	0.57	0.53	0.63	0.53	0.30	0.31
35	0.51	0.59	0.57	0.59	0.64	0.59	0.70	0.59	0.45	0.59
42	0.66	0.74	0.72	0.74	0.78	0.74	0.84	0.74	0.77	0.60
49	0.72	0.83	0.78	0.83	0.85	0.83	0.91	0.83	0.98	0.77
56	0.72	0.88	0.78	0.88	0.85	0.88	0.92	0.88	1.11	0.71

Using phase 2 of the trail where calves received 4l of milk and starter - the new NRC 2001 guidelines where used to calculate daily gain on a weekly basis at different temperatures over the 8 week trial period. The specifications of starter used for the prediction was the Meadow Feeds calf starter which was used in the current study.

A 39.4kg calf fed full milk at 4l/day would be predicted to gain between 0.23 and 0.40kg per day. However calves lost weight during the first week of the trial. This weight loss can be due to a lot of stress factors. During the second week of the trial calves were predicted to grow at a rate of 0.28 – 0.41kg per day but the actual growth was 0.03kg per day.

From week three onwards the NRC 2001 guidelines were in agreement with the growth of calves in the current study. The starter intake was negligible during the first two weeks of life and from week 3 onwards intake started to increase. At week 3 of age the NRC estimated an energy allowable ADG of 0.38kg/day at 5°C and the calves in the current study grew at a rate of 0.32kg/day. That constitute to a difference of 60g growth per day and therefore the real growth and NRC prediction is very much comparable. From week 5 onwards the NRC guidelines were comparable with the current study with less than 100g difference between the current study's real weights. The results from this study suggest that the NRC program predicts growth more accurately during the latter stage (4-8weeks) of the calf growth phase compared to the initial growth phase (1-3weeks). This is most probably related to the effect of housing which is very much different between the US and South Africa

The estimated growth as predicted by the NRC at different temperatures with the same intake as calves in the current study receiving experimental Surromel Calf and starter are shown in Table 5.2.

Table 5.2: Average daily gain (kg) of calves fed experimental Surromel Calf and starter compared with NRC estimation of ADG with the same nutrient intake at different temperatures

	NRC ADG growth prediction at different temperatures								**Actual starter intake and ADG**	
Day	**NRC est. 5°C**		**NRC est. 10°C**		**NRC est. 15°C**		**NRC est. 20°C**		**Daily Starter Intake (kg)**	**Actual ADG**
	Energy Allowable ADG	ADP Allowable Gain	Energy Allowable ADG	ADP Allowable Gain	Energy Allowable ADG	ADP Allowable Gain	Energy Allowable ADG	ADP Allowable Gain		
7	Weight loss	Weight loss	0.10	0.29	0.18	0.29	0.26	0.29	0.02	-0.20
14	0.06	0.31	0.15	0.31	0.23	0.31	0.30	0.31	0.05	-0.03
21	0.16	0.36	0.24	0.36	0.31	0.36	0.38	0.36	0.15	0.18
28	0.30	0.44	0.37	0.44	0.44	0.44	0.50	0.44	0.34	0.37
35	0.41	0.53	0.47	0.53	0.54	0.53	0.60	0.53	0.54	0.53
42	0.57	0.67	0.63	0.67	0.70	0.67	0.76	0.67	0.86	0.64
49	0.61	0.74	0.67	0.74	0.74	0.74	0.80	0.74	1.03	0.63
56	0.59	0.77	0.66	0.77	0.73	0.77	0.79	0.77	1.10	0.83

At 7 days of age the calves lost 0.20kg per day and the NRC predicted weight loss at 5°C. In the second week of life the calves in the current study lost 0.03kg per day and the program estimated an energy allowable gain of 0.16kg per day which comes to a difference of 0.19kg growth per day between the growth found and the NRC estimated growth.

From week three onwards the NRC 2001 guidelines were in agreement with the growth of calves receiving experimental Surromel Calf and starter. The starter intake was negligible during the first two weeks of life and from week 3 onwards intake started to increase which is also in agreement with calves receiving full milk and starter (Table 5.1). At week 3 of age the NRC estimated an energy allowable ADG of 0.30kg/day and 0.37kg/day at 5°C and 10°C respectively and the calves in the current study grew at a rate of 0.37kg/day. It seems as if energy was the limiting factor concerning the growth of the calves. From week 5 onwards the NRC guidelines were in line with the current study's results.

From the above results it is clear that the NRC growth predictions are in agreement with the current study's growth results in particular from 3 weeks onwards and can be used with confidence by South African producers.

CHAPTER 6

CONCLUSION

The milk replacer industry is intimately involved with the economy of the primary milk production industry and therefore changes in the producer price of milk have a profound effect on milk replacer sales. If a benefit of at least 40c/l over full milk is not realized, then most dairy producers would rather feed full milk to heifer calves. Because of the high cost of producing milk replacer of a good quality, and the availability of new technology, Clover SA decided to investigate a different manufacturing process of Surromel Calf®.

The major difference between the existing and the new manufacturing processes lies in the mixing of the replacer ingredients. The traditional Surromel Calf® is mixed in dry form where all the ingredients are mixed dry in a tumbler and thereafter it is packaged in dry form. The experimental Surromel Calf (ESM) is produced by separately dissolving all the dry ingredients into liquid and all the different liquid ingredients are then mixed. Thereafter the complete product is spray-dried in a spray-dry tower and the dry product is packaged. With the new manufacturing process of experimental Surromel Calf the imported raw material is reduced by 15% resulting in a 10%-12% financial benefit for the dairy farmer.

The implementation of a new manufacturing process however, also necessitates evaluation of the end product. The first objective of this study, therefore, was to evaluate in a calf growth study, the experimental Surromel Calf against the traditional Surromel Calf®.

If a price-competitive milk replacer could guarantee similar growth results as full milk and is readily available commercially, then dairy producers would have confidence in using these replacers instead of full milk. Very little research on milk replacers has been conducted in South Africa over the past decade and it is important that the latest milk replacers with different feed ingredients and where new technology has been implemented has to be evaluated. This leads to the second objective of the study in which growth data is evaluated when feeding experimental acidified milk replacer plus calf starter in comparison with feeding full milk plus calf starter. The purpose of feeding liquids with starter is to evaluate growth in a feeding system used commonly on commercial dairy farms.

An important development in the feeding and management of dairy cattle has been the release of the NRC Dairy 2001. Growth standards for dairy calves with body weight less than 100kg have been included for the first time. Many producers are reluctant to use the calf and heifer growth recommendations since these have not been validated under South African conditions. Therefore the third objective was to validate the NRC Dairy 2001 calf model under South African conditions.

During phase 1 of the project, 24 Holstein heifer calves received either commercial Surromel Calf® (CSM) or experimental Surromel Calf (ESM) for 56 days without a calf starter. Milk replacer was offered at 10% of birth weight (500g DM/day) for the first two weeks, 12.5% (625g DM/day) of birth weight for week 3 to week 6 and 15% (750g DM/day) of birth weight for week 6 to week 8 when the trial ended. Although there was a difference in ingredients and in the manufacturing process, the composition for both the ESM and CSM were the same. Nutrient intake and dry matter intake, therefore, were the same for both groups. Water was available *ad lib* except for 30 minutes before and after milk replacer feedings.

Body weight and skeletal development (body length, shoulder height, shoulder width and chest diameter) were measured weekly. The fecal consistency was subjectively scored every morning before feeding in order to assist in the evaluation of the health status of the calf as well as the treatment of diarrhea.

Because the calves received only restricted amounts of milk replacer and no starter, it resulted in a lower growth rate than commercially raised calves, where a calf starter is usually fed *ad libitum*, or in accelerated growth systems where milk intake is not restricted and dry matter intake is higher. Average body weight decreased (P>0.05) during the first two weeks when compared to birth weight, but it did not differ significantly between CSM and ESM. During the first week average body weight decreased by 1.15kg and 1.34kg (P>0.05) respectively for calves receiving either ESM or CSM when compared to birth weight.

Although the body stature changes increased in a positive fashion over time, there were no significant differences (P>0.05) between ESM and CSM weekly measurements.

The final body weight gains for calves fed either ESM or CSM were 9.5kg ± 2.5 and 9.9kg ± 2.0 respectively over the eight week period. Mean ADG were 170g/day and 176g/day for calves receiving either ESM or CSM respectively and did not differ between treatments (P>0.05). According to the NRC (2001) prediction, the calves were predicted to grow at a rate of 234g/day at 20ºC. Winter temperatures well below 20ºC could have contributed to the lower growth rate.

The calves grew slower than the NRC 2001 predicted norm for commercially raised dairy calves but because of the absence of a calf starter the DMI was much lower than that of commercially raised calves. It is also important to note that calves in the current study were not housed in an environmentally friendly environment as in most of the other published studies, and only autumn and winter calves that were housed in open pens, were included. The colder months of the year could be a possible cause for the lower growth rate found in the first phase of this trial. The calves also received only milk replacer and no starter which most probably has resulted in a slower growth rate than commercially raised calves, where a calf starter is usually fed *ad lib*, or where milk intake is not restricted and dry matter intake is higher. The ANOVA comparison excluded any seasonal differences (P = 0.345) for ADG of calves raised in autumn or winter.

The difference between ESM and CSM calves for days of diarrhea and days of severe diarrhea is of no statistical significance (P>0.05). Fecal scores which give a good indication of diarrhea generally peaked between day 7 - 14 and day 28 - 35 of age and declined thereafter. The diarrhea days over the 56 day trial are relatively high if compared with diarrhea days for calves in phase 2 that received starter. The lower nutrient intake of calves not receiving starter probably contributed to the higher incidence of diarrhea since nutritional stress contributes greatly to immunosuppression in calves. Therefore the slow growth rate was not totally unexpected.

It is important to notice that the incidence and severity of diarrhea in this study was consistent with infections by *Cryptosporidium* sp. Although this organism was not specifically isolated in this study, the farm had a history of *Cryptosporidium* infection in preweaned calves.

During the second phase of this trial the calves were fed either 2l of full milk (25-26% CP; 29-30% fat DM) or 2l experimental Surromel Calf (20%CP;12% fat DM) twice daily for the full duration of the trial. Additionally the calves had *ad lib* access to a commercial calf starter. The amount of starter offered was recorded daily, and orts were weighed and recorded weekly. The rest of the management and data collection was similar to phase 1.

Starter consumption was negligible for the first three weeks of the trial, averaging less than 0.2kg/d from day 15 - 21. Starter intake was 0.30kg/d and 0.34kg/d respectively at 42 days of age and 1.11kg/d for FMS fed calves and 1.10kg/d for EMSS fed calves at 56 days at the end of the trial (P>0.05).

Body weight decreased from birth up to week two after birth. This decrease has been anticipated because of stress, and sensitivity towards cold temperatures and diarrhea that is more common within the first two weeks of life. Body weight increased from week two onwards as age increased. This is consistent with other studies such as a study conducted by Kühne *et al.* (2000) where calves' body weight also decreased during the first week after calving.

The ADG for the 56-day experiment were 370g/day for both FMS and EMSS (P>0.05). Average daily gain was unaffected by treatment (P>0.05) indicating that the nutrients provided from the milk replacer were utilized with the same efficiency as these provided by full milk and sustained growth in a similar way as full milk. Based on literature studies where a similar milk replacer as used in our study was compared to full milk, one would have expected calves receiving full milk to have a higher ADG than the calves receiving milk replacer. However, it must be remembered that this calves were housed in a relatively cold environment with very little shelter and *Cryptosporiduim* spp. were isolated in some of the calves. This could have disadvantaged the full milk with starter treatment more, leading to a lower growth rate and the similar growth in the end.

As expected, the calves receiving milk or experimental milk replacer plus starter gained more body weight and had higher ADG compared to the calves receiving only liquid feed in Phase 1 of the trial.

The calves receiving the treatments with starter performed better in terms of stature, when compared to the calves that only received milk replacer. For example the average growth in height over the 8 week period of the liquid fed only calves averaged 6cm and 5.33cm respectively compared to 7cm and 8.46cm of the combined liquid plus starter fed calves. Although the body stature changes increased over time, there were no significant differences (P>0.05) between the FMS and EMSS weekly measurements. The stature measurements were numerically higher for the liquid plus starter fed calves compared to liquid fed only calves. This was to be expected because of the higher dry matter and nutrient intake of the liquid plus starter fed calves. It is also important to notice there is most probably an error associated with these skeletal measurements due to measuring procedures, along with the small degree of skeletal growth during this 56 day period, which makes it very difficult to detect possible differences. With calves on accelerated growth programs where average daily gains of up to 0.9kg/day can be achieved, differences would probably be more profound.

The difference between ESM and CSM calves for days of diarrhea and days of severe diarrhea was of no statistical significance (P>0.05). Fecal scores generally peaked at week 2 and declined thereafter, although scores remained somewhat higher in week 4 and 5 for EMSS calves compared to FMS calves. Fecal scores were found to be lower over the 56 day trial period for Phase 2 calves than Phase 1 calves which indicate a lower tendency towards diarrhea. This is most probably due to the fact that calves in Phase 2 had a higher dry matter and nutrient intake.

The third and last objective was to evaluate the growth of the calves against the growth estimation of the NRC computer program.

The growth prediction was only compared with the growth of calves in Phase 2 where a commercial calf starter was fed *ad lib,* the reason being that this is the most commonly used feeding system on dairy farms in South Africa.

The new NRC 2001 guidelines where used to calculate daily gain on a weekly basis at different temperatures over the 8 week trial period. The starter used for the prediction was the Meadow Feeds calf starter, Complete Calf®, which was used in the current study. The NRC predicted a slightly higher growth than obtained in the current study up to week 4. Thereafter the predictions were in line with the growth obtained in the current study and can be used with confidence by South African producers.

In conclusion, results from study 1 support the conclusion that the new experimental Surromel Calf can be successfully introduced commercially since growth results were comparable to the well researched commercial Surromel Calf®. Results, however were poorer compared to other literature results due to differences in milk replacer nutrient composition, volume of milk replacer fed, and harsh environmental conditions. Results from study 2 suggest that the experimental Surromel Calf yielded similar growth results when compared to full milk and can therefore be successfully utilized by dairy producers. The NRC Dairy (2001) calf model compared well with the growth obtained in the current study. Prediction was lower during the first few weeks but compared favorably from week 4 onwards. The NRC Dairy could be used with confidence when predicting the growth of calves from week 4 onwards and more data is needed to evaluate the model during the early calf feeding phase.

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