NUTRITIONAL FEEDING AND MANAGEMENT STRATEGIES TO OPTIMIZE GROWTH AND HEALTH IN DAIRY CALVES

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Introduction and Objectives

Young calves face numerous nutritional, environmental, and health challenges that make them the most highly rated morbidity and mortality group on dairy farms (National Animal Health Monitoring System, 2007). In a recent survey of heifer-rearing practices in the United States, the overall preweaning calf mortality rate is approximately 7.8% (National Animal Health Monitoring System, 2007). Consequently, calf mortality within the first three months of life is estimated to cost the U.S. dairy industry 200 million dollars annually (Roy, 1980), which is an unacceptable economic loss. In an effort to combat these losses, different feeding strategies to optimize calf growth and health must be explored. These feeding strategies include higher feeding rates, different planes of nutrition, and implementing growth promoting and disease altering additives.

The typical feeding program for dairy heifers being raised as herd replacements consists of a restricted liquid diet that is much lower than ad libitum consumption. Common recommendations for liquid feeding rates are 8 to 10% of body weight, which contrasts with reported ad libitum consumption rates for milk replacer of 16 to 24% of body weight (Mylrea, 1966; Lineweaver and Hafez, 1969). Restricted rates of liquid feeding results in considerably lower feed conversions for young dairy calves than for the young of other species. Lower feed conversions in calves are attributable to the limited supply of nutrients above maintenance, which allows for only small rates of gain. These lower rates of gain have generated considerable interest in feeding frequency and feeding rate in order to maximize calf growth and feed conversion.

The use of a computer controlled or automatic calf feeder has allowed producers to easily feed calves at different feeding frequencies throughout the day. Computer controlled calf feeders give calves a homogenous meal several times a day, which may aid in combating digestive problems. There are, however, major problems connected with computer controlled calf feeders including: hygiene, disease transmission, accuracy of milk allocation, and monitoring starter consumption. In contrast, manual feeding allows producers to monitor starter consumption and closely observe calves for health problems, while still delivering a homogenous meal several times a day.

Producers have also traditionally used antibiotics in the milk replacer and or starter to combat calf disease and infection. Traditionally, antibiotics were added to milk replacer to reduce calf morbidity and mortality and improve feed efficiency (Roy, 1980). Calf feeders and nutritionists have expressed concern over new 2010 FDA regulations (Feed Additive Compendium, 2011) changing the continuous use of 2:1 ratio of neomycin sulfate:oxytetracycline (NT) medicated milk replacers. Studies have been conducted using various feed additives such as essential oils, probiotic yeast cell wall extracts, soluble fiber and vitamin E in an effort to find an alternative to medicated milk replacer usage. These additives, however, have not been combined and explored as a new positive feed additive blend that could be used to increase calf health and growth.

Despite the economic importance of raising healthy dairy calves, little information exists concerning the strategy of increasing feeding frequency and plane of nutrition for milk replacer fed-calves. Moreover, the inclusion of essential oil additive

blends in milk replacer and starter in order to elicit a positive growth and health response in calves has been limited. Therefore, the main objectives of this thesis were:

1. To determine if the milk replacer program (standard 20% CP, 20% fat vs. modified 26% CP, 18% fat) and feeding frequency (2 vs. 4 times daily) alters starter intake, growth and health.
2. To determine the effects of a blend of essential oil (Maltigano), yeast cell wall extract, vitamin E, and digestible fiber in milk replacer (Essential Calf®) and starter (Essential Calf® starter) or both on calf performance and health.

Chapter 1

Review of Literature

A well-managed feeding program is critical to optimize calf performance and reducing calf morbidity and mortality. It provides the foundation needed for the rest of the calf's life. In order to achieve a smooth transition through the stages of development of the calf's digestive system and develop a healthy productive animal, it is essential that a consistent and well-managed feeding program is implemented during the nursery phase.

Colostrum

The first step in assuring that the immune system can start functioning and that the necessary nutrients for optimal growth and health are provided begins with the calf's very first feeding. Achieving timely and adequate intake of high-quality colostrum is the single most important management factor in determining calf health and survival. The dam begins producing colostrum 5 weeks prior to calving, but colostrum is defined as the first secretion produced by the mammary gland of cows after calving (Davis and Drackley, 1998). Colostrum is especially rich in immunoglobulins (Ig) or antibodies, which provide the calf with its immune protection. Moreover, colostrum contains twice as much dry matter and differs from normal milk in several ways (Davis and Drackley, 1998). Most distinctively, colostrum is higher in solids, fat, protein, fat soluble vitamins like vitamin A, Ig content, and lower in lactose (Davis and Drackley, 1998). The low levels of lactose in colostrum, specifically, help to reduce the incidence of neonatal diarrhea since calves have the inability to digest large amounts of lactose. An oversupply of lactose in the intestine is caused by both the rapid movement of milk out of the

abomasum and the slow breakdown of lactose in the intestine. However, the amount of solids and protein in lacteal secretions, especially the Ig content, declines rapidly after the first day. By the fourth milking, milk reaches normal composition and it no longer provides the calf with the ability to combat illness and acquire passive immunity.

The calf's immune system is immature at birth and incapable of producing sufficient Ig. It is, therefore, vital to provide high quality colostrum as soon as possible after birth in order to maximize dairy calf health. A successful colostrum management program will require producers to consistently provide calves with a sufficient volume of clean, high-quality colostrum within the first few hours of life (McGuirk and Collins, 2004). Colostrum quality is dictated by antibody concentration (primarily immunoglobulin G) and the presence or absence of bacteria. Bacterial contamination of colostrum can be detrimental to the calf through inoculation with pathogenic bacteria or interfering with intestinal Ig absorption, thereby increasing the risk for disease transmission or failure of passive transfer (Godden, 2008).

All mammals need maternal immunoglobulins for protection from disease following birth. Calves, in particular, obtain these immunoglobulins from the ingestion of colostrum (passive transfer of maternal IgG from colostrum after birth) and not *in utero* across the placenta like many other species. This absorption of IgG through the gut is termed passive immunity. Passive immunity protects the calf from disease until its own immune system becomes fully functional (Davis and Drackley, 1998).

The neonatal digestive system can absorb large molecules such as IgG intact for approximately 24 hours after birth by a process unique to the immature intestinal cells.

As these cells mature, they lose their ability to absorb large molecules, so early feeding of colostrum is essential (Davis and Drackley, 1998). Also during this time, normal digestive enzymes in the abomasum and small intestine do not function or function with limited activity, allowing IgG to reach the small intestine without being denatured. Enzyme inhibitors within the colostrum allow IgG to escape intestinal degradation, which is a crucial step for calves to obtain passive transfer from the dam (Davis and Drackley, 1998).

Evaluating passive transfer of immunity and the effectiveness of the colostrum management program is determined by measuring serum IgG levels or serum total protein in calves within the first week of life. Although there are several types of immunoglobulins (IgG, IgA, IgM), IgG is the predominant immunoglobulin passed to calves via colostrum (Butler, 1983). Passive transfer of immunity is considered successful if calves' serum IgG levels are 10 mg/mL (1,000 mg/dL) or greater at 24 to 48 hours of age (National Animal Health Monitoring System, 2007).

Serum total protein, on the other hand, can be measured as an estimate of serum IgG level. This is a critical measurement that allows producers to easily assess passive antibody transfer. Fortunately, total protein is relatively simple and inexpensive to measure. A serum total protein measurement greater than or equal to 5.2 g/dL is correlated with successful passive transfer of immunity in healthy calves that are not dehydrated (Tyler et al., 1996). The goal is to have at least 90 percent of calves with serum total protein values greater than 5.2 g/dL and 50 percent above 5.5 g/dL (National Animal Health Monitoring System, 2007) indicating that calves were fed colostrum.

Milk Replacer

In the short period of time from birth to weaning, calves undergo a remarkable physiological change. At birth, the abomasum accounts for 50 percent of the total weight of a calf's stomach (Warner and Flatt, 1965) allowing calves to digest proteins much like the stomach of a nonruminant. Calves younger than 3 weeks of age, however, have strict digestive limitations because they receive most of their energy by digesting milk or milk replacer in the abomasum and the small intestine (Davis and Drackley, 1998). Specifically, digestion of carbohydrates by the newborn calf is relatively poor since the intestine of the calf possesses limited carbohydrase activity except for lactase.

In order to properly receive and utilize milk or milk replacer, young calves possess a unique feature called the esophageal groove. The esophageal groove is a tube created by the contraction of muscles in the esophagus and reticulum. These muscles lie in a fold of tissue that extends from the base of the esophagus (cardia) to the reticulo-omasal orifice (Ørskov, 1972). The esophageal groove allows for 97% of the milk or milk replacer to bypass the reticulorumen and enter the abomasum, where it can be digested to provide nutrients for the calf (Tuolloc and Guilloteau, 1989).

Until the rumen can start supplying energy via fermentation and microbial protein sufficient for maintenance and growth, the calf must receive a high quality liquid milk or milk replacer diet. Milk replacers are fortified or contain beneficial additives to enhance growth and health such as added vitamins, minerals, or antimicrobials that are not contained in whole milk. Furthermore, milk replacers are often economical (second to waste milk) and, in many situations, are more easily adapted to the labor and facility

needs of calf-raising operations than either whole or waste milk (Fowler, 1992). Other advantages of milk replacer include disease control, consistency of product from day to day, and easy storage (Davis and Drackley, 1998).

Milk Replacer Composition. Milk replacers were first developed in the early 1950s and initial formulations were fed as "gruels" (Crane, 1991). Unless supplemented with milk, these so called "gruels" resulted in poor calf performance and health (Davis and Drackley, 1998). This spurred further interest to develop a more appropriate diet suitable for the physiological needs of the calf. From the late 1950s and into the early 1960s drastic changes were made in the milk replacer industry. Milk replacers were formulated for the underdeveloped digestive system of the young calf with the goal of delivering required nutrients for optimizing calf performance and health as an economical alternative to feeding saleable milk.

Milk replacers were formulated to contain dried skim milk, dried buttermilk, dried whey, and animal fat (Otterby and Linn, 1981) with skim milk being the primary source of protein and carbohydrates for these milk replacers. The use of skim milk increased at one point in time because of its low costs (Otterby and Linn, 1981). Prices of skim milk, however, increased in the late 1960s, and substitutes for dried skim milk were required (Schugel, 1974). At the time, casein and whey were available at moderate cost so the industry shifted to these products with little reduction in quality (Otterby and Linn, 1981). The majority of today's protein in milk replacer comes from whey.

Today, there are many commercial milk replacer options available. Most of the milk replacers generally contain between 18% and 28% crude protein (CP) with sources

classified into two groups: milk proteins or non milk proteins. Milk protein sources include whey protein concentrate, dried whey, dried whey product (delactosed whey), dried skim milk, casein, or sodium (or calcium) caseinate (Davis and Drackley, 1998). Non milk protein sources for milk replacers include mostly soy, wheat or animal plasma proteins.

In addition, further improvements in protein inclusion resulted from technologies that explored emulsification to help incorporate fat into milk replacer. Fat was added directly to milk products and batch mixed, a process that permits addition of up to 10% fat to the diet (Davis and Drackley, 1998). Methods for inclusion of fat were later improved by homogenization of the mixture before spray drying, and proportions of fat in milk replacers were increased to over 10% (Otterby and Linn, 1981). As a result, high quality replacers became available. Today, commercial milk replacers generally contain 10 to 22 percent fat.

Throughout the following years, both protein and fat substitutes were established. Fat source substitutions include animal fat, hydrogenated vegetable oil, and coconut fat (Raven, 1970). Both tallow and choice white pork grease have been used extensively, but recently milk fat, palm oil, sunflower oil, soybean oil, hydrogenated soybean oil, and partially hydrogenated fish oil have all been used successfully (Schugel, 1980).

Technological developments and processing improvements since the mid-1980s have resulted in dramatic changes in the ingredients available for use in milk replacer formulation (Davis and Drackley, 1998). Milk-derived ingredients from the dairy processing industry have dominated in the formulation of milk replacers because they are

readily digested by the young calf. These changes and the resulting variations in market prices are directly responsible for the ingredients currently used in modern milk replacers. Today, ultrafiltration and low-temperature concentration by evaporation are used to produce whey protein concentrates of high and uniform quality, with little denaturating of the proteins (Tomkins and Jaster, 1991). Furthermore, animal fat has become widely utilized due to its relatively low cost compared to other fat sources in today's market.

Milk Replacer Formulation. A wide variety of milk-replacer formulations are available commercially. These formulations vary widely in the amount and source of protein and fat. Milk replacers also vary in their content of metabolizable energy (ME), which is affected mostly by the content of fat (Davis and Drackley, 1998). Throughout the years, there has been much debate about the most efficient protein to fat ratio as well as how many times a day milk replacer should be fed. It is, however, crucial to understand that different milk replacer formulations and feeding strategies are not equally useful for all ages of calves, feeding systems, and management conditions. In addition, the intent of use should be the main driver of selecting an appropriate milk replacer rather than the price of the milk replacer.

According to the National Research Council (2001), milk replacers should contain at least 22% CP (DM basis). A more accurate determination of protein requirements considers the amount of protein that the calf needs to consume in order to support maintenance plus a given rate of growth. The rate of growth is regulated by the amount of feed that the calf consumes and the energy density of that feed (Davis and Drackley,

1998). For replacement calves, the standard recommendation found on commercial milk replacers is to feed 454 g/d (453.6 g/d) of milk replacer powder to large breed calves, regardless of body size, until weaning. This feeding rate however, only supports minimal body weight gains (Davis and Drackley, 1998). The amounts of CP required, assuming that the all milk protein is 90% digestible, range from 91 g/d for a 35 kg calf to 37 g/d for a 55 kg calf (Davis and Drackley, 1998). Larger calves require less protein than smaller calves, despite the larger body size, because the fixed energy intake limits growth potential.

Fat concentration, on the other hand, is usually 10% to 22% of the milk replacer (Tompkins and Jaster, 1991). This is lower than the concentration of fat in the DM of cow's milk, which averages about 28%, with a typical range of 26% to 34%. Fat deposition in the calf increases as the fat content in milk replacer increases within the range of 10% to 30% when milk replacer is fed in limited amounts (Roy, 1990). In addition, research by Radostits and Bell (1970) has shown that a milk replacer fat content of 10% appears to support adequate health and growth of replacement heifers. Radostitis (1970) also linked greater fat intakes to improved digestibility and retention of nitrogen due to the homogenization of fat.

Another advantage to increasing fat consumption is increasing the calf's fat deposition. Increased fat reserves can be beneficial for the calf to draw upon at weaning or in times of illness and as insulation in cold climates. Moreover, for colder climates, research has indicated that feeding a milk replacer higher in fat content increases growth because of the greater maintenance energy requirement of these calves (Schingoethe et

al., 1986). It is recommended that milk replacers contain about 20% fat during winter in cold climates, but there seems to be no distinct advantage of having fat contents of greater than 10%-15% during warmer weather.

Although research has indicated that fat intake may provide beneficial affects to dairy calves, it has also been known to cause diarrhea (Stobo, 1983) and decrease the intake of calf starter both before and after weaning (Kuehn et al., 1994). A study conducted by Waterman et al. (1997) showed that average daily gain (ADG) and calf starter intake were greatest when limit-fed milk replacer containing 18% CP (all from milk proteins) and 18% fat or less. Hill et al. (2006a), however, determined that a 27% CP, 17% fat MR powder fed at 0.66 kg DM/d was successful at improving ADG and not reducing starter intake compared with a 21% CP, 21% fat MR fed at 0.44 kg DM/d. This program, consequently, does not maximize ADG during the first month of life, but does maximize ADG during the second and third months of life (Hill et al., 2007b). A delicate balance must be made between the content of protein and fat in milk replacer.

Accelerated Versus Conventional Milk Replacer Feeding Programs.

Conventional calf-rearing systems place emphasis on restricting the amount of milk replacer fed during the first few weeks of life. Milk replacer is fed at a rate much lower than *ad libitum* consumption for dairy heifers being raised as herd replacements. Restricted liquid feeding is used in an effort to encourage starter intake and promote early weaning. A typical conventional milk replacer program consists of a 20% protein, 20% fat milk replacer offered at 0.45 kg (DM) per day until weaning. Using this method, calves receive sufficient nutrients to meet maintenance requirements and gain

approximately 0.30 to 0.40 kg per animal per day (Huber, 1984). This program, in a sense, forces growing calves to consume more dry feed in order to meet increasing nutrient needs. Successful use of this system has allowed calves to wean as early as 21 to 35 days of age due to the increase in dry feed intake at an early age.

Common recommendations for conventional liquid feeding rates are 8% to 10% of body weight (Davis and Drackley, 1998), which contrasts to reported *ad libitum* consumption rates for milk replacer of 16% to 24% of body weight (Lineweaver and Hafez, 1969). Conventionally fed dairy calves usually are not fed more than twice daily, which limits the total amount of liquid feed that the calf can consume daily (Wise and LaMaster, 1968). Over the last decade, research has shown that providing limited amounts of milk results in poor weight gains, (Hammon et al., 2002; Jasper and Weary, 2002), higher risk of disease (Godden et al., 2005; Khan et al., 2007a), and abnormal behaviors (Rushen and de Passillé et al., 1995; De Paula Vieira et al., 2008). These outcomes have developed an indication that this feeding method reduces calf welfare (von Keyserlingk et al., 2009). Although restricted rates of liquid feeding do not support maximal weight gains, such low rates of feeding encourage earlier intakes of feed (Hodgson, 1971), which in turn promotes rumen development (Kaiser, 1976).

This feeding pattern contrasts with the normal pattern of calves suckling their dams typically 6-8 times daily (Hafez and Lineweaver, 1968). In a recent study by de Passillé et al. (2008), Holstein calves that were allowed to suckle their dams consumed approximately 6 kg milk/d in week 1 and 12 kg milk/d in week 9. Ideally, calves fed milk replacer at a rate of 10% body weight, similar to 6-8 natural feedings, would be

expected to gain from 200 to 400 g/d. There is a direct relationship between increased milk replacer consumption and growth. Research has determined that calves fed more milk replacer, have increased growth rates (Jasper and Weary, 2002).

The remarkable improvements in growth and feed efficiency due to increased milk replacer consumption (Diaz et al., 2001 and Tikofsky et al., 2001) have stimulated renewed interest in early calf nutrition. Feeding increased quantities of milk replacer has been termed various names, including *accelerated early nutrition, accelerated growth, enhanced nutrition, intensified nutrition, and biologically appropriate growth*. Most milk replacers formulated for use in accelerated programs contain 26 to 30% protein and 15 to 20% fat. Although these formulations more closely resemble whole milk in protein concentrations, the fat content is still lower. The ratio of protein to fat is used to maximize lean gain and discourage the detrimental effects of over conditioning in young heifers. Increased lean gain has been observed with increased milk replacer protein content when energy was not limiting, and increased fat gain when protein was limiting (Blome et al. 2003 and Bartlett et al., 2006).

Furthermore, supplying a low fat milk replacer aids in increasing starter intake. Intake of calf starter is negatively correlated with energy intake from milk replacer. If calves consume more energy from milk replacer, they need less energy from calf starter. 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 long term growth (Weary et al., 2008).

Accelerated feeding recommendations differ by manufacturer, but all utilized amounts greater than the traditional one pound per day. Most programs limit liquid feeding during the first week of life to 1.5 to 2.0% of body weight in powder reconstituted to 12.5% solids. After the first week of life, milk is mixed to contain a higher percentage of solids (15 to 18%). Calves on accelerated feeding programs receive approximately twice as much milk powder compared to traditionally fed calves. To encourage weaning, milk replacer is dramatically decreased the week prior, often by half. These programs wean calves at an average of 56 days of age (Davis and Drackley, 1998).

The largest advantage of accelerated growth programs is the faster and more efficient rate of growth and future lactation performance. Calves on accelerated programs can gain up to 2 pounds per day in the second and third week of life. A study conducted at Michigan State University showed that gradually increasing milk from 4.1 to 7.0 kg during the first 2 weeks of treatment and feeding 7.6 kg per day thereafter until day 42 resulted in larger weight gains (Huber, 1984). In addition, the growth achieved is largely lean tissue with the use of high protein milk replacers. This increased rate of growth during early life may be able to decrease the time to target breeding age.

In regards to future performance, Rincker et al. (2006) reported that calves fed an intensive (30% CP, 16.1% fat) versus a moderate (21.5% CP, 21.5% fat) MR program calved 17 d earlier. Research by Foldager and Krohn (1994) showed that increased nutrient intake prior to 56 days of life produced 1,000 to 3,000 additional pounds of milk in first lactation compared to calves fed a restricted milk replacer program. Moreover, Ballard et al. (2005) reported that at 200 days in milk, calves fed two pounds of milk

replacer produced 1,543 lb milk more milk than calves that received one pound of milk replacer powder per day.

There are, however, several reservations to be considered when choosing an accelerated growth program over a conventional program. First, management of calves and facilities available must be considered. Calves on an accelerated program require a consistent source of water (Davis and Drackley, 1998) and a great deal of care when individually feeding. Calves must be managed more carefully when feeding for higher rates of gain as they may be more susceptible to nutritional scours, especially when milk replacer is fed at greater than 12.5 percent solids (Jones and Heinrichs, 2006). Second, inadequate colostrum ingestion, poor sanitation and inadequate ventilation will greatly limit the success of an accelerated program. Third, since calves fed at a higher rate of milk replacer consume less dry feed, rumen development is delayed. Consequently, at the time of weaning, solid feed intake usually is less for calves fed higher amounts of milk relative to restricted-fed calves, resulting in greater slumps in growth at weaning for calves receiving higher amounts of milk (Dalzell and Allen, 1970).

Lastly, the greatest consideration with accelerated programs is cost. Protein is the most expensive nutrient in any diet, making the feed costs greater for accelerated programs. These programs use milk replacer that is more costly, and the product is fed at a higher rate. The increased cost of high protein milk replacer and the extra cost to feed more dry matter must be offset by long-term improvements in growth or decreased overall heifer production costs.

Research has shown that accelerated and conventional feeding programs result in different responses and goals (Table 1.1). While interest in accelerated and conventional feeding systems has been increasing, a major limitation in adoption has been the unknown economic benefits of improved early nutrition. To develop a full economic model of the effect of such systems on dairy enterprise profitability, necessary inputs include effects on: growth rates and cost per unit height or weight increase, subsequent growth after weaning, health, and first lactation milk production. While data continue to accumulate in each of these areas, it is not yet possible to prepare a complete economic assessment due to insufficient study sites and animal numbers.

Feeding Frequency. With efforts concentrated on milk replacer feeding rates, much focus has been placed on decreasing labor requirements and increasing the feeding frequency for large numbers of calves. Interests revolve around being able to deliver a homogenous drink several times a day at a low cost. Feeding large numbers of calves is labor intensive; therefore, more interest in automatic feeding systems has developed. Computer controlled milk feeders have been advertised as a natural way of feeding calves milk because the calf can suck the milk and the daily milk allowance may be distributed over several small meals.

When computer controlled milk feeders are used, the calves are usually offered their daily rations in 8-12 meals (Jasper and Weary, 2002). If the calf skips a milk meal, it is often allowed a larger meal later on. Calves can ultimately take fewer and larger meals, as they grow older, similar to natural nursing. A comparison of conventional calf

feeding to free-access systems, including computer controlled milk feeders, is described in table 1.2.

A number of human epidemiological studies have been conducted to investigate the relationship between eating frequency and body weight. Some of these studies have detected a positive correlation (*i.e.* higher eating frequency is associated with higher weight) (Booth, 1988; Basdevant et al., 1993), some have failed to detect any significant relationship (Dreon et al., 1988; Edelstein et al., 1992), and others have detected an overall inverse relationship (*i.e.* higher eating frequency is associated with lower weight) (Metzner et al., 1977). The link between body weight and metabolism by providing calves with smaller more frequent meals, however, has not been extensively studied. A study showed that increasing meal frequency decreased insulin secretion with consequences on fuel utilization and therefore on energy and macronutrient intakes, blood lipids and particularly cholesterol synthesis in humans (Basdevant et al., 1993). On the other hand, in a study by Stanley et al. (2002), plasma glucose, NEFA, insulin and glucagon concentrations of calves were not affected by milk replacer frequency (once a day versus twice a day feeding period).

Restricted milk replacer feeding (conventional two times a day feeding) can also result in altered behavior. Thomas et al. (2001) demonstrated that calves fed restricted quantities of milk vocalized more than calves fed milk ad libitum. Calves fed restricted quantities of milk were also more active and more competitive than calves feed milk ad libitum (De Paula Vieira et al., 2008). In a study by Bøe and Havrevoll (1993) calves that received 0.5 L of milk every 2 h took the maximum number meals per day, 12. In

addition to the visits where they consumed milk, they visited the feeder up to 30 times per day where they did not get any milk because less than 2 h had passed since the last meal. An increase in competition and activity may have further implications on metabolic activity and stress levels.

Milk Replacer Additives. In general, milk replacers are supplemented or fortified to provide levels of vitamins and minerals similar to, or greater than, those found in whole milk (Davis and Drackley, 1998). There are few exceptions including the macro-minerals magnesium and calcium, which are increased to prevent excessive loss from formation of insoluble calcium soaps of long-chain fatty acids (Toullec et al., 1980). In addition, vitamin E needs to be included in a proper ratio to essential fatty acids (1.5-2.5 mg vitamin E per gram of linoleic acid) to prevent oxidation and rancidity problems (Stobo, 1983). Vitamin E supplementation has been a key component in milk replacer and has shown to increase ADG (Luhman et al., 1993) and decrease incidence of scouring (Luhman et al., 1993) with stimulatory effects on antibody formation (Quigley and Bernard, 1995).

The addition of medications in milk replacer is controlled by the Food and Drug Administration of the U.S. government and is used primarily to treat preweaning diarrheal and respiratory diseases. The use of antibiotic compounds such as oxytetracycline and neomycin are used for calves raised intensively in large numbers, for calves originating from different environments, and for calves subjected to transport stress before arrival at the growing facility (Tomkins and Jaster, 1991). Moreover, subtherapeutic levels of antimicrobials, such as tetracycline and neomycin added to milk

replacers, are used by producers for disease prophylaxis, feed efficiency, and growth promotion (McEwen and Fedorka-Cray, 2002).

Medicated milk replacers have been re-examined over the past few years because of the potential for developing resistance to bacteria, which may lead to a future inability to use some antimicrobials for human or animal disease. As the use of antibiotics in feed for livestock has come under criticism in recent years, interest has increased in other compounds with growth-promoting effects or abilities to alter gastrointestinal microbial populations. Such products include oligosaccharides, bacterial cultures (probiotics), and essential oils. These products promote natural host defense mechanisms and bind to viruses and bacteria to reduce pathogenicity.

Essential oils, specifically, have been of great interest. Aromatic plants and their extracts have received increased attention as potential alternatives to antibiotics. Essential oils are oily liquids composed of low molecular weight, hydrophobic (lipophilic) secondary metabolites extracted from plants (Benchaar, 2009) that are being considered as a way to improve or alter rumen fermentation. Like monensin, essential oils may also affect the cell membranes of gram negative bacteria or others can act within the cell of gram positive bacteria. It has been suggested that essential oils active against Gram-negative bacteria contain active secondary metabolites that are small enough to pass through porin proteins in the outer membrane and so are able to gain access to the plasma membrane (Nikaido, 1994; Dorman and Deans, 2000). In addition, essential oils are hydrophobic, which enables them to accumulate in the lipid bilayer of the microbial plasma membrane from where they organize their effects, which vary according to type

of secondary metabolite. Some alter membrane permeability, some interact with membrane proteins, and others may interact directly with cytoplasmic components from within the plasma membrane or by diffusing into the cytoplasm itself (Benchaar, 2009). Studies have determined that oregano oil inhibits the growth of several Gram-negative pathogens, including E. coli (Elgayyar et al., 2001; Marino et al., 2001). The implications of this research may help decrease calf mortality and increase calf productivity.

The incorporation of microbial additives such as yeast and yeast cell culture has also become a common practice in ruminant nutrition. In *vitro* and in *vivo* studies have shown that yeasts and yeast cell cultures stimulate growth of rumen cellulolytic bacteria (Callaway and Martin, 1997). In young calves, incorporating live yeast into the grain reduced the number of days with diarrhea (Galvão et al., 2005). Feeding yeast culture to calves reduced the incidence of elevated body temperature and antibiotic treatments from birth to 46 d of age (Seymour et al., 1995). Yeast stimulates the growth of rumen cellulolytic bacteria and improves carbohydrate digestion and rumen development (Callaway and Martin, 1997). In addition, soluble products present in yeast culture have been shown to inhibit microbial growth and activity (Jensen et al., 2008) and modulate the immune system (Jensen et al., 2007). Collectively, these results indicate potential benefits to animal health.

Starter

Rumen Development. Early consumption of dry feed is the most important factor in the transition of the young calf from a non ruminant to a ruminant. Calves at

birth and at weaning are physically and functionally two different types of animals with respect to their gastro-intestinal system. Neonatal calves do not have a functioning rumen. The development of the rumen generally occurs during the first 4 to 8 weeks of a calf's life (Davis and Drackley, 1998). The process of rumen development is driven primarily by consumption of dry feed and the establishment of anaerobic fermentation. If calves have feed, particularly calf starter, available from an early age, then the development of the rumen will begin within a couple weeks of birth.

Once the calf is weaned onto dry feed, there is a trend toward a reduction in disease problems, especially diarrhea (Morrill, 1992) and more consistent fecal matter. Calves, however, start to depend on establishment of microbes to help develop the rumen. The majority of these microbes depend on substrates provided by the dry feed. When the calf is first born, the rumen is sterile. By one day of age, however, a large concentration of aerobic bacteria can be found. The number and type of bacteria changes as dry feed intake and substrate available for fermentation changes (Davis and Drackley, 1998).

The change in bacterial numbers and types is almost always a function of intake of substrate (Davis and Drackley, 1998). Prior to consumption of dry feeds, bacteria in the rumen exist by fermenting ingested hair, bedding, and milk that flows from the abomasum into the rumen. The substrate ingested, such as the difference between hay and grain fed calves versus milk fed calves only, will also affect the types of ruminal bacteria that flourish in the young rumen.

The presence of rapidly fermentable material in the reticulo-rumen, in particular, stimulates growth of the mucosal tissue, especially the papillae that cover the inner

surfaces of the reticulo-rumen epithelium (Brownlee, 1956). The changes in tissue growth and morphology provide the much needed surface area for absorption of the end products of microbial digestion that occurs in the forestomach as dry-feed intake increases (Davis and Drackley, 1998). The end products of fermentation that are responsible for the growth and development of ruminal tissues are the volatile fatty acids (VFA): acetic, propionic, and butyric acid. Butyric and proprionic acid, in particular, are the principle VFAs involved in accelerating forestomach development (Sander et al., 1959) by directly affecting the proliferation and differentiation of gastrointestinal epithelial cells (McGillard et al., 1965). In addition, butyric and propionic acid also provide energy for the growing stomach tissue (McGillard et al., 1965).

Starter Formulation. Until the early 1950s, it was generally believed that roughages were necessary for growth of ruminal tissues. It was thought that roughages increased the size of the ruminal compartment, as well as stimulated growth and development of the papillae (Brownlee, 1956). Over time, however, Brownlee (1956) determined that concentrates were superior to roughages in stimulating rumen development due to the less fibrous nature of concentrates. Cereal grains were thus selected on the basis of digestibility and for overall metabolizable energy.

In most regions of the United States, corn is the cereal grain of choice. Aside from being the most economical, corn is an excellent feedstuff to include in starter feed because of its palatability. Moreover, corn is highly digestible throughout the gastrointestinal tract. When corn is not available, however, barley is the next most widely used cereal grain in calf starter feeds (Davis and Drackley, 1998). In addition, oat

grains are widely used in starter feeds for young calves because it adds bulk, is very palatable, and is a good source of fiber (Davis and Drackley, 1998). Ground or chopped hay (legume or legume-grass mixture), on the other hand, is the most widely used fiber source in starter feeds with soybean meal being the most commonly used protein source.

Some commercial calf starters include some B-vitamin supplementation to provide calves with a source of B vitamins before the rumen begins to produce them on its own. Also, many commercial calf starters contain a coccidiostat that provide protection against coccidiosis. Coccidiostats added to starters have been reported to increase live-weight gain by calves, even when there is no diagnosis of clinical coccidiosis (Davis and Drackley, 1998).

Starter feed for young calves is determined by its chemical contents of crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF). Most research supports a 16% to 18% CP content in the starter feed on an as-fed basis for the calf from birth to 8-10 weeks of age (Roy, 1980). This CP level appears to be adequate for the very young calf, provided that it is also receiving milk or milk replacer up to 4-6 weeks of age.

Fiber content, on the other hand, is determined by the ADF value. Research has determined that starters with an ADF value below 6% or higher than 20% should be avoided (Kang and Leibholz, 1973; Thomas and Hinks, 1983). The lower level is indicative of a high-concentrate feed, which could lead to digestive problems such as rumen acidosis and bloat. An ADF concentration above 20% suggests a lower-energy feed than desirable. The content of NDF, however, depends on several factors, but

acceptable levels generally fall between 15% and 25%. The source of NDF is a major factor influencing the amount that can be used satisfactorily because this fiber fraction in various feedstuffs is broken down at different rates in the reticulo-rumen (Davis and Drackley, 1998).

Starter Quality. The quality of calf starter is important in ensuring good rumen development and allowing for early weaning. More specifically, the physical form (the particle size of the feed) plays a crucial role in starter quality control. Calf starters may come in the form of meals (unpelleted), pelleted, or textured type feeds. It is the ingredients used in calf starters, however, that generally reflect the type of starter used. Textured feeds, for example, generally contain grains, such as rolled oats and corn, and a pellet, which contains protein, carbohydrate sources plus vitamins and minerals.

It is important to stay away from finely ground feeds. Finely ground feeds not only result in decreased feed intake but also are much more likely to cause rumen parakeratosis because they become impacted between the papillae (Davis and Drackley, 1998). Franklin et al. (2003) concluded that a texturized starter resulted in better performance than a pelleted or a ground starter (with no differences between the last two). Palatability may be the most important factor in choosing a calf starter. If calves like the starter, and begin to eat it readily from a young age, calves can be ready to be weaned at an earlier age, which can have a positive economic impact. Palatability is generally highest with textured feeds, followed by complete pellets (Quigly, 1996). Calves generally do not like mash feeds and palatability and intake are usually lower than with other types of feeds. Many commercial feed companies have developed unique

manufacturing technologies designed to improve starter palatability. Molasses, in particular, is often used as a palatability agent (at 4 to 5% of the formula) to increase intake and palatability and control dust (Davis and Drackley, 1998).

Efficiency and Growth

Nutrient Requirements. Calf growth is affected by many factors, but daily intake of protein and energy are most important. Protein and energy requirements of calves fed milk replacer and starter is affected by weight of the animal and growth rate of the animal. Protein provides amino acids used to build body tissues and energy is used to support body functions and allow dietary protein to be used in building body tissue. The amounts of protein and energy required by a calf are divided into two categories based on their use for maintenance and growth.

Maintenance describes the amount of energy and protein needed to support normal bodily functions, including maintaining body temperature. Maintenance requirements are related to body size; bigger animals have higher maintenance needs. Environmental conditions also affect maintenance requirements. Extremely hot or cold weather increases energy needs. Growth requirements on the other hand, account for the nutrients required to build body tissues. Nutrients consumed are first used to support maintenance and then growth.

Most often, energy intake is the first limiting factor for growth. If a calf consumes more energy than needed for maintenance, the energy not utilized can be used to convert dietary protein into body tissue accretion. Feeding too little of either energy or protein, or feeding the wrong ratio of energy to protein, will limit growth (Jones and

Heinrichs, 2006). Nutrients are provided by liquid feed and starter grain consumption, and composition of these feeds affect growth potential.

The metabolizable energy (ME) requirement for young calves fed milk replacer and starter from the Nutritional Research Council (2001) publication assumes that a calf at about 2 weeks of age consumes on the average a diet containing 60 percent of DM intake derived from milk replacer (ME at 4.74 Mcal/kg of DM) and 40 percent from starter (ME at 3.28 Mcal/kg of DM). In this diet, milk replacer supplies 68% of the total ME, and starter supplies 32 percent. The overall efficiencies for use of ME in the combined diet (milk replacer plus starter) are 82.5 and 65.2 percent for maintenance and gain, respectively, calculated as the weighted average (weighed by contribution to the total ME Supply) of the individual efficiencies (Nutritional Research Council, 2001).

The total protein requirement for maintenance plus gain of the young calf is primarily a function of the rate of body weight gain. Based on a standard 20 percent CP milk replacer fed at 0.56 kg per calf per day will support daily gains of 0.34 kg in calves weighing 45.4 kg. Usually, this rate of gain is sufficient, and increases to over 0.45 kg per day as the calf begins to consume dry feed.

Calf Health

Environment. Environmental conditions play a large role in the health and nutrient intake in preweaned calves. In the northern United States calves that are born in the late winter and early spring often experience sustained periods of cold during the first weeks of life that affect their health. Results from a study by Godden et al. (2005) support this assertion. Of the 438 calves evaluated, the morbidity rate of calves born in

the winter was 52% compared with 13% for calves born in the summer. Similarly, calf mortality was 21% in the winter and 3% in the summer. Martin et al., (1975) concluded that the majority of calf losses in winter are associated with cold, wet, and windy weather, whereas losses in the summer are closely associated with hot, dry weather. Ensuring nutritional sufficiency during periods of cold stress is important but often difficult in the preruminant calf because of the increased maintenance requirements for thermoregulation (Drackley, 2005).

The thermoneutral zone of the young calf ranges from 15 to 25° C and varies with calf age, weight, environmental temperature, and other stressors (Schrama et al., 1993). In a thermoneutral environment, the calf is not required to elicit specific heat-conserving or heat-dissipating mechanisms to maintain core body temperature (Nutrition Research Council, 2001). When the lower critical temperature (LCT), defined as the effective ambient temperature dependent on wind velocity, humidity, and tissue insulation is reached, a calf must produce more heat to maintain body temperature (Nonnecke et al., 2009). In addition, when temperatures fall below the LCT, the energy needed to maintain core body temperature is supplied either by increased energy intake or from the metabolism of mobilized adipose tissue (VanAmburgh, 2003).

Conversely, when the temperature rises above the upper critical temperature, a calf must expend energy to dissipate heat from its body causing a decrease in intake (Davis and Drackley, 1998). Decreasing intake aids in lowering heat production generated by digestion and absorption of nutrients. Nutritional insufficiency is problematic for immune function during cold or heat stress. Without nutrients obtained

from the milk replacer or starter, calves cannot maintain optimal growth performance and elicit as effective of an immune response to pathogens.

Enteric Disease (Scours). Calf disease, particularly diarrhea and respiratory disease, has significant effect on the profitability of every calf raising enterprise. Calf mortality and treatment costs represent a huge economic loss to the dairy industry, estimated to exceed $250 million annually (Simmons and Bywater, 1991). Specifically, neonatal diarrhea, or scours, is a common problem among young dairy calves and accounts for 56.5% of calf mortalities (National Animal Health Monitoring System, 2007). Scours is defined as the clinical appearance of hypersecretion of fluids into the alimentary tract in response to an irritant (Radostits, 1975). Some of the common causes of diarrhea in newborn calves include enteropathogenic E. *coli* (Fey, 1972) and *Salmonellae spp.* (Robinson, 1966), reo-like viruses (Mebus et al., 1971), milk replacers containing heat denatured whey protein (Roy, 1970), overfeeding and other faulty feeding practices. Diarrhea may also occur due to large quantities of glucose and lactose in the diet (Blaxter, 1953). Common diarrhea causing pathogens are described in table 1.4.

Liquids are normally secreted from the blood into the intestine and are reabsorbed from the intestine into the blood. When the absorption of these fluids (and dietary fluids) is impaired, or the secretion of liquid into the intestine increases, then hyperfluidity of feces occurs (Davis and Drackley, 1998). In calves where immune response is poor, both rotavirus and coronavirus lead to a sloughing of epithelial cells on the tips of the villi and this reduces reabsorption of fluid from the intestine (Blowey, 2005). Infectious agents

such as Coccidia and *Cryptosporidium* also have the ability to cause inflammation and or trauma increasing intestinal permeability.

Hypersecretion, on the other hand, causes diarrhea when the intestine is induced to produce large amounts of fluid. The most prevalent pathogen that causes this form of diarrhea is *Escherichia coli* (Roy, 1970). *Escherichia coli* produce endotoxin that stimulates the crypt epithelium to secrete fluid beyond the absorptive capacity of the intestine. The epithelium in this case retains it functionality and is not destroyed during the infection.

Osmotic diarrhea, also known as nutritional scours, is the most commonly occurring type of diarrhea (Roy, 1970). It occurs when solutes collect in the gut, which causes water to be retained in the intestine. This may be caused by malabsorption or maldigestion due to dietary imbalances in liquids (excess lactose or protein) or rapid changes in the diet (Roy, 1970). Malabsorption, in particular, digestion failure, usually caused by physical destruction of epithelial cells by invading pathogens (Davis and Drackley, 1998) such as rotavirus and coronavirus. Maldigestion, on the other hand, can be caused by poor quality ingredients, allergens in feed ingredients, the presence of trypsin inhibitors, or disorders of the intestinal tract (Roy, 1970). Maldigestion usually leads to not only malabsorption but increased osmotic pressure and scours.

Respiratory Disease. Respiratory disorders, on the other hand, are a greater problem than enteric diseases in calves 6 to 8 weeks of age (Roy, 1990). According to the National Animal Health Monitoring System (2007) respiratory disease accounted for 22.5% of mortalities in preweaned heifer calves. Pneumonia, in particular, remains a key

problem in calf rearing and is something that continues to be difficult to control. It is even more problematic for animals purchased and taken to the rearing unit (Roy, 1990). The disease may vary from a subclinical pneumonia to an acute fatal disease and appears to be the result of the interaction of one or more microorganisms with several predisposing causes, such as the stress of being moved long distances, or being run through sale barns. In a survey conducted by Webster et al. (1985) the proportion of farmers treating calves for reparatory disease was 5 to 6 times greater for bought-in than for home-bred calves.

Respiratory problems have been associated with the level of milk feeding. In contrast to an early weaning regimen, very high growth rates (1.57 kg/d) and associated high body fat deposition resulting from feeding milk substitute diets at high concentration also appear to increase susceptibility to respiratory infections (Stobo and Roy, 1979). Moreover, in ad libitum milk feeding the large output of urine may result in wet bedding and a high humidity at calf level (Bee, 1984).

Often overlooked, the function of the esophageal groove plays a key role in the development of pneumonia. As discussed earlier, the function of the esophageal groove is to transport milk directly from the esophagus into the abomasum bypassing the rumen. If the esophageal groove is not properly closed, milk can enter the rumen and ferment, leading to colic, bloat, scours and poor growth (Blowey, 2005). Affected calves have a comprised immune system and are more susceptible to a range of other enteric and pneumonic conditions (Blowey, 2005). Achieving good groove closure in calves is vital. Calves need to know that they are to be fed, so the sound, sight and smell of food

preparation are important. Calves that are fed at irregular intervals, fed inconsistent or unpalatable milk replacer, fail to achieve good groove closure. Failure of the groove to close further results in digestive upsets and other infections disorders (Blowey, 2005).

Conclusion

A consistent and high quality milk replacer and starter program for calves is essential for optimizing calf performance and health. Limited research exists on the implications of feeding frequency and feeding rate as well as adding essential oils blends into calf feed. With efforts concentrated on keeping preweaning morbidity and mortality low, producers are in great need of nutritional feeding programs designed to maintain calf health.

Research is warranted to determine the optimal feeding frequency and milk replacer program for both summer and winter months. Determining the relationship between the milk replacer program and cold stress and heat stress is crucial for understanding optimal nutrient intake and growth as well as combating seasonal diseases. Moreover, research is needed to explore potential benefits of milk replacer and starter additive blends. In particular, use of essential oils needs to be investigated to determine both potential benefits and optimum feeding rate for calves. Lastly, for calves comingled and transported prior to weaning, receiving procedures and feeding programs need to be developed in order to minimize mortality and morbidity. These procedures and feeding programs will not only reduce illness, but may also reduce stress and increase overall calf welfare.

Table 1.1. Effects of feeding higher than conventional volumes[1] of liquid feed to Holstein calves on production and health.
Adapted from Khan et al., 2011.

Parameter	Effect[2]	Reference
Preweaning performance		Diaz et al., 2001; Jasper and Weary, 2002;
Starter intake	—	Bartlett et al., 2006; Cowles et al., 2009; Hill et
BW gain	+	al., 2009.
Structural growth[3]	+	
Feed efficiency	+	
Postweaning performance		Jasper and Weary, 2002; Khan et al., 2007a;
Daily starter intake	—/+*	Raeth-Knight et al., 2009; Hill et al., 2009.
BW gain	—/+*	
Structural growth	+*	
Feed efficiency	—/+*	
Long-term performance		Shamay et al., 2005; Raeth-Knight et al., 2009;
Mammary development[4]	+	Brown et al., 2005b; Meyer et al., 2006;
First breeding age	+	Moallem et al., 2010.
First lactation yield	+	
Health		Diaz et al., 2001; Godden et al., 2005; Bartlett
Fecal score[5]	—/+	et al., 2006; Quigley et al., 2006.
Mortality	—	

[1]Supply of milk (whole milk, waste milk, and pasteurized milk) or milk replacers of varying composition to calves (individual and group housed) more than conventional amounts (10% of calf BW for 4 to 8 wk of age using nipples, buckets, and automatic feeders.
[2]Effects: + = increased in calves fed higher volumes of liquid feed than conventional amounts; — = decreased in calves fed higher volumes of liquid feed than conventional amount; *(+ or —) = response with gradual weaning in calves fed higher volumes of liquid feed.
[3]Structural growth = increased in hip or wither height, heart girth, and hip width.
[4]Mammary development is measured as mammary cell proliferation and (or) increase in mammary DNA mass.
[5]Different studies use different methods of fecal scoring.

Table 1.2. A comparison of conventional calf feeding to free-access systems from d 1 to 42.

Parameter	1x Feeding	Conventional Feeding (2x-3x)	Ad Libitum
% Body Weight	10	10-15	20-25
Liters	4-6	4-6	8-10
Meals	1x	2-3x	≥ 4x
Nursing minutes	–	6-8	48
Interval, h	–	4	10-14
ADG, kg	0.29	0.28-0.53	0.36
Starter intake, kg/d	0.79	0.75	0.67
Reference	Galton and Brakel, 1975 Stanely et al., 2002	Stanley et al., 2002 Jasper and Weary, 2002	Jasper and Weary, 2002

Table 1.3. Effects of milk replacer and starter feed additives, mechanism of action and reported effect. Adapted from Litherland, 2010.

Feed additive/Strategy	Pathogen Affected	Mechanism of Action and Reported Effect	Reference
Probiotics (DFM) (live individual organisms or combinations of organisms)	—	Produce enzymes and vitamins to prevent pathogen colonization; Re-inoculate the GI tract	Timmerman et al., 2005; Jenney et al., 1991
Live yeast culture (*S. Cerevisiae*)	*E. Coli*	Prevents adherence of pathogens to the intestinal wall; promotes growth of beneficial bacteria	Magalhães et al., 2008
Fructooligosaccharides (FOS) family of oligosaccharides consisting of several β-(1,2) or β-(1-6) linked fructose residues	*Clostridium Difficile*	Non-digestible polysaccharide, selectively stimulates the growth and activity of beneficial bacteria in the intestine	Donovan et al., 2002; May et al., 1994, Webb et al, 1992
Mannanoligosaccharide (MOS) from yeast cell (*S. Cerevisiae*) walls	*E. Coli* and *Salmonella*	Reduce the adhesion of bacteria to the intestinal epithelium and promote growth of beneficial intestinal bacteria	Heinrichs et al., 2003
Essential Oils	*E. Coli* and *Salmonella*	Antimicrobial properties, alter membrane permeability	Calsmaiglia, 2007; Ultee et al., 1999; Benchaar, 2009
Vitamin E	—	Maintenance of cell membrane stability and immune system potential	Reddy et al., 1986

Table 1.4. Main intestinal pathogens found in calves, mode of action and prevention strategy. Adapted from Jones and Heinrichs, 2006.

Intestinal Pathogen	Occurrence	Organism	Mode of Action	Effect on Calves	Prevention/Treatment Strategy
E. Coli	1-5 d	Bacteria	Attaches to intestinal wall and produces toxins or destroys intestinal cells	Diarrhea, navel infection, septicemia	Oral rehydration therapy; vaccinate bred heifers and dry cows 6 and 3 weeks before calving
Salmonella	14-28 d	Bacteria	Attaches to the intestine via mannose-specific lectins (proteins or glycoproteins)	Respiratory disease, diarrhea	Strict sanitation and isolation of sick animals
Clostridium perfringens B & C	5-10 d	Bacteria	Produces a systemic toxin that damages tissue	Diarrhea, tissue damage	Antitoxin and oral antibiotics
Rotavirus/ Coronavirus	5-15 d	Virus	Damage intestinal cells	Diarrhea	Vaccines available for cows or calves
Cryptosporidia	14-21 d	Protozoa	*C. parvum* damages cells lining the intestine	Diarrhea	Keep calves warm, dry, and well fed; oral rehydration; strict hygiene
Coccidia	21 d to 2 yr	Protozoa	Parasite causes acute and subclinical infections and damages cells lining the intestine	Dehydration and death	Add approved feed additives to milk replacer, water or starter (decoquinate, lasalocid, and monensin)

Chapter 2

Effects of a modified intensive milk replacer program fed two or four times daily on nutrient intake, calf growth and health

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CHAPTER SUMMARY

The objective of this study was to determine if milk replacer (MR) program and feeding frequency altered calf performance. Forty-eight Holstein and cross-bred heifer and bull calves were balanced across treatments according to body weight (BW), breed, sex, and total serum protein and assigned to one of four treatments (n=12): 1) 20:20 MR fed at 1.5% BW 2x/d (STD2); 2) 20:20 MR fed at 1.5% BW 4x/d (STD4); 3) 26:18 MR fed at 2.0% BW 2x/d (MOD2); or 4) 26:18 MR fed at 2.0% BW 4x/d (MOD4). All calves were fed at 0600 and 1700 h and STD4 and MOD4 were fed additionally at 1100 and 1400 h. Treatments were fed from 1 to 42 d of age and all MR feeding rates were adjusted weekly to maintain powder intakes at 1.5% or 2.0% of BW reconstituted at 15% DM. Milk replacer feeding frequency was reduced by 50% on d 36 and calves were weaned on d 42. Calves were housed in hutches bedded with straw and offered water and a texturized 18% CP starter *ad libitum*. Calf growth was measured weekly and starter intake and fecal scores recorded daily. Data were analyzed using Proc Mixed in SAS as a completely randomized design with repeated measures and the least significant difference test was used for mean separations when main effects were significant ($P < 0.05$). Birth BW averaged 41.8 kg. Average daily gain (ADG) d 1-42 was similar ($P = 0.39$) and averaged

0.59, 0.63, 0.69, and 0.70 kg/day for STD2, STD4, MOD2 and MOD4 (SEM = 0.05). Average daily gain from d 1 to 56 was also similar among treatments (P = 0.18) and averaged 0.62, 0.72, 0.78 and 0.75 kg/d for STD2, STD4, MOD2, and MOD4 (SEM = 0.06). Starter intake on d 42 was different between treatments and averaged 0.96 for STD2, 1.26 for STD4, 0.79 for MOD2, and 0.78 kg/d for MOD4. STD4 had the greatest starter intake on week six and seven (P < 0.05; treatment × week). BW of calves was greater for MOD2 than STD2 on week 8 (P < 0.05; treatment × week). BW gain from d 1 to 42 were similar (P = 0.4) and averaged 24.9 and 26.4 kg for STD2 and STD4, while MOD2 and MOD4 calves gained 28.8 and 29.8 kg. BW gain from d 1 to 56 was not different (P = 0.2) and averaged 34.9, 40.1, 43.9, and 42.2 kg for STD2, STD4, MOD2 and MOD4. Fecal scores did not differ. Feeding a 20:20 MR four times daily resulted in greater starter intake yielding 5.2 kg additional gain through d 56.

Key Words: Calf, Milk Replacer, Feeding Frequency

INTRODUCTION

Conventional calf rearing systems historically have restricted the amount and frequency of milk replacer (**MR**) fed during the first few weeks of life in an effort to encourage solid feed intake, early weaning, and to develop a functional rumen (Bush and Nicholson, 1986). Generally, increased intake of nutrients consumed in liquid reduces starter and forage intake (Jasper and Weary, 2002). Over the last several years, however, research has shown remarkable improvements in growth and feed efficiency obtained by feeding greater quantities of milk (Flower and Weary, 2001; Jasper and Weary, 2002; Brown et al., 2005; and Diaz et al., 2001).

In addition to nutrient intake and quantities of milk or milk replacer offered, distribution of nutrient availability within a day also can be altered. One common practice is to provide calves with milk or milk replacer twice a day, for a total intake of approximately 10% of the calf's BW (Jasper and Weary, 2002). Thus, a 40 kg calf would receive two meals each of approximately 2 kg. In contrast, a calf left with its dam will suckle on average 7 to 10 times a day and consume substantially larger quantities of milk (Albright and Arave, 1997). Furthermore, in colder climates, increasing the number of feedings from two to three times per day and increasing the amount of dry matter fed has improved weight gain and calf health (Schingoethe et. al., 1986).

Nutrition of the calf during the milk feeding period is crucial for efficient growth of young dairy calves and profitability of the dairy enterprise. Dairy producers are seeking strategies to improve calf performance and health before weaning while reducing

labor costs. Labor for care and individual feeding of calves before weaning is the major cost of calf production and involves extensive management practices.

Due to the labor demands of traditional calf rearing, computer controlled calf feeders have been of great interest recently. The objective of computer controlled calf feeders is to save labor and to avoid digestive problems by giving calves a homogenous drink several times a day. There are, however, major problems connected with computer controlled calf feeders including: hygiene, disease transmission, accuracy of milk allocation, and monitoring starter consumption. In contrast, manual feeding allows producers to monitor starter consumption and closely observe calves for health problems, while still delivering a homogenous meal several times a day.

Feeding equal amounts of milk replacer in four meals verses two meals may improve health and growth efficiency of dairy calves when fed manually compared with the current industry standard of feeding twice daily or using a computer controlled calf feeder. By feeding calves in individual hutches manually, health and starter consumption can be stringently monitored. We hypothesized that increased feeding frequency may result in increased starter intake when calves are fed on a high plane of nutrition. The objectives of this study were to determine if, the milk replacer (**MR**) program (standard 20% CP, 20% fat fed at 1.5% body weight (**BW**) vs. modified 26% CP, 18% fat fed at 2.0% BW) and feeding frequency (2 versus 4 times daily) alters calf starter intake, growth and health of manually-fed calves.

MATERIALS AND METHODS

Animals

The experimental protocol was reviewed and approved by the University of Minnesota Institutional Animal Care and Use Committee. Forty eight (n = 12) Holstein and cross bred male and female calves averaging 41.8 kg of BW at birth were used to determine the effects of a modified intensive milk replacer program fed two or four times daily on nutrient intake, growth and health. Calves were born at the University of Minnesota Dairy Research and Teaching Facility in St. Paul, Minnesota, between October, 2009 and April, 2010.

At birth, calves were removed from their dams and weighed. Each calf was identified and placed in individual calf hutches (Calf-tel, Hampel Corp., Germantown, WI and PolyDome, Litchfield, MN) bedded with straw within 24 h of birth. Calves received 1.9 L of colostrum within 24 h of birth at each of the first two feedings and were trained to drink milk from buckets during the first 3 d of life. Refused colostrum was fed via esophageal feeding tube. A blood sample was collected via jugular venipuncture into evacuated serum collection tubes (SST; Beckton Dickenson Vacutainer Systems, NJ) 24 h after birth and centrifuged at 2,000 × *g* for 20 min. Serum was separated and analyzed for total serum protein concentration using a refractometer (Reichert Rhino VET360, Reichert, Depew, NY).

Assignments to Treatments and Feeding

Calves were balanced across treatments by BW, gender, breed, and total serum protein and were assigned randomly to 1 of 4 experimental treatments (n=12 per

treatment) on d 3. Total serum protein status was based on plasma IgG concentration on arrival and is correlated with IgG status (adequate = plasma IgG > 10.0 g/L; marginal = 5.0 to 10 g/L; and deficient = < 4.0 g/L) (Bovine Alliance on Management and Nutrition, 1995). Of the 48 calves assigned to treatment, three calves were replaced during the trial. Two calves assigned to STD2 were replaced; one was replaced at 35 d of age due to extremely poor performance and an abscess on its lower jaw and the second calf was replaced at 14 d of age after it died. A third calf on STD4 was replaced at 28 d of age due to a leg injury. All other calves completed the trial in good health.

Each calf was offered 1 of 4 medicated 2:1 neomycin sulfate:oxytetracyline (NT) milk replacer (Milk Products Inc., Chilton, WI) treatments. The treatment diets were as follows: control (**STD2**) standard 20% CP, 20% fat MR fed at 1.5% of birth BW twice daily; standard 20% CP, 20% fat MR fed at 1.5% of birth BW four times daily (**STD4**); modified 26% CP, 18% fat MR fed at 2.0% of birth BW twice daily (**MOD2**); and modified 26% CP, 18% fat MR fed at 2.0% of birth BW four times daily (**MOD4**).

All MR were prepared by Milk Products Inc. were medicated, contained whey protein as the protein source and animal tallow as the fat source. Proportions of whey and animal tallow were varied to achieve the desired protein and fat concentrations. All MR were reconstituted to 15% solids and offered to calves in buckets. Treatments were fed from 1 to 42 d and all MR feeding rates were adjusted weekly to maintain 1.5% or 2.0% of BW. STD4 and MOD4 fed calves were fed four times daily at 0600, 1100, 1400, and 1700 h and twice daily at 0600 and 1700 h from d 37 to 42. STD2 and MOD2 fed calves were fed twice daily at 0600 and 1700 h from d 1 to 36 and once daily at 0600 h

from d 36 to 42. MOD2 and MOD4 fed calves were fed at 1.5% BW from d 1 to 10 and MR was adjusted to 2.0% BW from d 11 to 42.

All calves were fed the same mixture of grains to meet or exceed nutrient requirements for a preweaned and early-weaned Holstein calf to achieve adequate growth as suggested by the NRC (2001) and others (Davis and Drackley, 1998). Textruized starter grain (Table 2.1) was fed once daily in the afternoon for *ad libitum* intake during the first 60 d of age. Starter refusals were recorded daily in the afternoon feeding and refusals of MR were recorded at each feeding. Warm fresh water was available to calves for *ad libitum* consumption after each feeding.

Feed Analysis

Samples of MR and complete calf starter were collected weekly and composited monthly. Samples were stored frozen (-20^{o}C) prior to analysis for DM, CP, ether extract, ash, Ca, P, K, and Mg (AOAC, 1990). Analysis was conducted by Dairyland Labs, Inc. in Arcadia, WI. Starter samples were analyzed in duplicate for moisture (AOAC, 1990). Crude protein (AOAC, 2000) was analyzed using a Leco FP-528 Nitrogen Combustion analyzer (Leco, St. Joseph, MI).

Body Growth and Health Monitoring

Body weight (**BW**), body length (**BL**) (Dairy Calf Weigh Tape, Nasco, WI), hip width (**HW**), and hip height (**HH)** (Measuring Stick, Nasco, WI) were measured weekly immediately after the 0600 h feeding. Calves were observed at least twice daily from 1 to 56 days of age for general health, including appearance (alertness) and appetite (ability to consume feed). Body temperatures were recorded if calves were ill. Fecal and

respiratory scores were also recorded daily from 1 to 56 days of age. Indices of calf health were monitored and recorded once daily, under the following guidelines: fecal scores (**FS**): 1 = normal, firm and well formed, 2 = semi-formed, pasty, 3 = loose, but stays on top of bedding, and 4 = watery, shifts through bedding (Larson, 1977). Scours were defined as FS $\geq$ 3. Scours were treated primarily with oral electrolytes (Bounce Back, Manna Pro, Chesterfield, MO) and continued milk replacer feeding.

Respiratory scores were scored in the following manner: 1 = normal, 2 = induced single cough, 3 = heavy breathing, induced repeated coughs or occasional spontaneous cough, and 4 = repeated spontaneous coughs (Larson, 1977). Calves were treated with Excenel (Pfizer Animal health) subcutaneously in the neck if a calf had a respiratory score of $\geq$ 3. Other health disorders were diagnosed and treated according to veterinary instructions.

Sample Collection and Preparation

Blood Collection and Processing. Jugular blood (10 mL total) was collected into evacuated tubes containing sodium heparin (Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ) on d 14, 21, 35, and 42 before the morning feeding (after a 12-h fast). Plasma samples were kept on ice after collection and were transported to the laboratory within 1 h. Immediately after arrival at the laboratory, the samples were centrifuged at 2,000 × *g* at 4^{o} C for 20 min. After centrifugation, plasma was decanted into individually labeled 12 x 75-mm polypropylene tubes (Becton Dickenson, Franklin Lakes, NJ), and stored in a -20^{o} C freezer until analyzed for non-esterified fatty acids (**NEFA**) concentrations. Using commercial spectrophotometric kits, serum was analyzed

for NEFA concentrations (NEFA-C Kit, ACS-ACOD Method; Wako Chemicals, USA, Richmond, VA).

Muscle Biopsy and Total lipid assay. Muscle samples were collected from each animal on d 21 and 42. Calves were aseptically biopsied from the left semitendinosus muscle on d 21 and from the right semitendinosus muscle on d 42. A local anesthetic (4 mL 2% lidocaine hydrochloride) was injected both inter muscularly and subcutaneously distal to the tuber ischia, then a 2-cm incision was made using a sterile scalpel blade. Approximately 50 mg of muscle tissue was removed using a biopsy needle. Muscle tissue was snap frozen in liquid nitrogen and stored frozen (-20^{o} C) until analyzed for total lipids (Hara and Radin, 1978).

Experimental Design and Statistical Analysis

Statistical analyses were conducted utilizing the Mixed procedure of SAS (version 9.2; SAS Institute Inc., Cary, NC). Data were analyzed as a completely randomized design. Calf within treatment was designated as a random effect, whereas effects of dietary treatment, week and the interaction of treatment and week were included in the model as fixed effects. For variables with repeated measures, the model also contained calf (as a random effect) and the fixed effects of time (as a repeated factor) and treatment × time interactions. Covariance structure considered were compound symmetry, autoregressive order 1, and unstructured; the autoregressive order 1 structure was found to be the most appropriate for all variables based on Alkaike's Information Criteria. PDIFF was used for means separation and significant differences were declared at $P <$

0.05, and trends toward significant effects were noted at $P < 0.10$. Least square means and standard errors are reported.

RESULTS AND DISSCUSSION

Diet Composition

Nutrient composition of MR and starter are listed in Table 2.2. Diets were isocaloric on a GE basis by design. Analyzed contents of CP and fat DM were slightly greater than target values for both the 20% CP, 20% fat and 26% CP, 18% fat milk replacers.

Body Growth Data

Least square means of BW and total serum protein on day of birth were not different among treatments (Table 2.3), but Holstein calves were heavier ($P < 0.05$) than Cross bred calves (Table 2.4). BW was greater ($P < 0.05$; treatment × time) for MOD2 versus STD2 on week 8 (Figure 2.1). BW gain from d 1 to 42 were not different ($P = 0.71$) among treatments and averaged 26.5 and 26.4 kg for STD2 and STD4 respectively, while MOD2 and MOD4 calves gained 28.8 and 28.7 kg respectively (Table 2.6). Similarly, BW gain from d 1 to 56 was not significantly different among treatments ($P = 0.36$) and averaged 37.2, 40.1, 43.9, and 41.2 kg for STD2, STD4, MOD2 and MOD4 respectively (Table 2.6). Contrary to results in this study, stimulation of growth by increasing dietary CP has been reported previously in calves (Donnelly and Hutton, 1976a, b; Gerrits et al., 1996). Brown et al. (2005) reported increased BW (12.1 kg) and calf height (2.4 cm) at d 56 for calves fed an intensive (30.3% CP, 15.9% fat) as

compared with a conventional (21.3% CP, 21.3% fat) MR feeding program. However, they used a higher CP and lower fat MR for the intensive treatment. Statistical treatment differences for BW gain were not detected due to the insufficient number of animals assigned to treatment.

Average daily gain (ADG) during d 1 to 42 was not significantly different among treatments (P = 0.39) and averaged 0.63, 0.63, 0.69, and 0.76 kg/day (SEM = 0.05) for STD2, STD4, MOD2 and MOD4 respectively (Figure 2.2; Table 2.6). ADG from d 1 to 56 was not different among treatments (P = 0.23) and averaged 0.66, 0.72, 0.78 and 0.79 kg/d for STD2, STD4, MOD2 and MOD4 respectively (Figure 2.2; Table 2.6). Contrary to results, Blome et al. (2003) demonstrated that increasing the amount of CP in isocaloric milk replacers fed at 1.5% of BW daily (DM basis) linearly increased ADG.

There was no significant treatment or treatment × week interaction for measures of BL, HW, or HH gain (Table 2.5). There was a tendency (P = 0.08) for a treatment × week interaction of WH as accelerated fed calves tended to be taller at the withers. There was a significant treatment effect on HG ($P < 0.05$). MOD4 calves had a larger HG than calves on STD2, STD4 and MOD2. In a similar study, Cowles et al. (2006) reported increased ADG during the preweaning period, increased HH the week of weaning and increased HG over-all for calves fed an intensive as compared with a conventional MR.

Starter Intake

There was a significant treatment × week interaction (P < 0.05) for starter intake as calves on STD4 consumed more starter on weeks six and seven than all other treatments (Figure 2.3; Table 2.7). Least square means of starter intake (kg/d) on d 42

were 0.96 for STD2, 1.26 for STD4, 0.79 for MOD2, and 0.78 for MOD4. Feed efficiency was not different between treatments from d 1 to 42 or d 1 to 56 (Table 2.6) and dry matter intakes were similar for all diets (Table 2.7). The time span used in this trial (October through April) subjected a maximum number of calves to cold or variable temperatures. Average daytime high and low temperatures in the St. Paul area range from - 6 and -14^{o} C in January to a high of 19 and a low of 7^{o} C in April for the months evaluated (Weather Underground, St. Paul, MN). This fluctuation in temperature may have affected the consumption of starter feed.

Lower environmental temperatures and wind chill factors result in cold stress. Energy to generate body heat comes from food or stored body fat. During cold temperature days, calves may burn body fat and lose weight. Calves fed the MOD2 and MOD4 treatments received a relatively low fat MR. These calves may have used their body fat stores and may not have efficiently utilized the high protein content of the MR, reducing any potential to see difference between treatments in ADG and feed efficiency.

Health and Fecal Measurements

Calves generally were healthy throughout the study. Incidence of disease was minimal and unrelated to treatment. Diarrhea often is associated with higher intakes of milk (Butterworth, 1972; Grieve. 1972). In this experiment, FS did not differ among treatments (Figure 2.4). There was a significant treatment × week interaction (P = 0.04) for fecal scores as calves on MOD4 had higher fecal scores than calves receiving other treatment during weeks three and four. Least square means of fecal scores from d 1 to 42 were 1.22 for STD2, 1.24 for STD4, 1.27 for MOD4 and 1.23 for MOD2 (Table 2.8).

Typically, increased MR feeding has been linked to higher fecal scores, but do not affect calf health (Diaz et al., 2001). Quality sanitary and management conditions probably played a more important role than the amount of milk consumed in incidence of diarrhea in young calves. Through 56 d, fecal scores and days scouring (fecal scores≥ 3) were not different across treatments.

Metabolite and Total Lipid Data

Least squares means for plasma NEFA concentrations are reported in Table 2.9. Plasma NEFA concentrations were affected ($P < 0.003$) by milk replacer feeding frequency and composition. Calves on MOD4 had a higher NEFA concentration than calves on STD2, STD4, or MOD2. Chilliard (1993) postulated that circulating NEFA become elevated because of incomplete removal of free fatty acids by adipocytes following the action of lipoprotein lipase on chylomicrons and lipoproteins. The milk replacer used in this study contained 18% fat (DM basis) for MOD2 and MOD4 treatments, which fed at 2.0% of BW, resulted in higher fat intake by calves on these treatments than calves fed MR containing 20% fat at 1.5% BW. Increased concentrations of NEFA indicated breakdown of fat, which occurs in response to increased energy demand. Plasma NEFA declined linearly with increasing age across all treatments. At the beginning of life, calves are more dependent on MR as their main dietary energy source and therefore mobilized NEFA before the morning feeding. As calves begin to rely on calf starter as their primary nutrient source, NEFA concentrations declined. This indicates a transition at weaning as calves began to rely on ruminal fermentation to supply a significant amount of energy and protein for maintenance and growth. There

was no difference among treatments for total lipid composition in the muscle (Table 2.10).

Feed Costs

Feed costs are presented in Table 2.11. Milk replacer cost was determined using a price of $2.89/kg of DM for STD2 and STD4 and $3.24/kg DM for MOD2 and MOD4. Calf starter costs were $0.33/kg of DM for all treatments. A labor cost of $10/h was calculated into the costs with each feeding time calculated to be 3 min per calf per feeding. Calf rearing costs for STD2 was $255.28, $305.12 for STD4, $322.43 for MOD2 and $377.01 for MOD4.

CONCLUSIONS

Feeding four times daily resulted in higher starter intake when calves were fed a 20% CP, 20% fat milk replacer. This higher starter intake resulted in 5.2 kg additional body weight gain for calves fed four times daily through day 56. As expected, calves fed the modified accelerated program showed some growth enhancements over the conventional milk replacer program. Due to the fluctuating temperatures and cold stress, protein intake for calves on MOD2 and MOD4 and starter intake for all calves may not have been optimal. Overall, calves performed well. BW for calves fed STD2 and STD4 treatments nearly doubled between birth and 56 d of age and BW of calves on the MOD2 and MOD4 treatments doubled between birth and 56 d of age. There was a low incidence of scours throughout the study. Further research should confirm these results with more

calves per treatment and with the use of labor saving technology such as an automated calf feeder and automated monitored starter intake.

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The authors thank the staff at the University of Minnesota Dairy Research and Teaching Facility for animal care and Milk Products, Inc for partial milk replacer donation.

Table 2.1. Starter composition for calves fed either a 20:20 or 26:18 MR two or four times daily.

Item	Starter
Ingredient, % of diet	
Soybean meal	51.0
Sunflower meal (32% CP)	20.0
Wheat middlings	11.3
Linseed meal	5.0
Limestone	4.2
Alfalfa meal	2.5
Molasses w/fat blend	2.0
Salt	1.1

Table 2.2. Nutrient composition[1] of experimental milk replacer and starter (DM basis).

Item, % DM	20:20 Milk replacer	26:18 Milk replacer	Starter
Dry matter	97.2[a]	96.8[a]	84.8
CP	20.8[a]	27.7[b]	23.0
Fat	21.2[a]	19.0[b]	4.3
Ash	—	—	7.9
Ca	—	—	1.25
P	—	—	0.62
Mg	—	—	0.32
K	—	—	1.61

[a-b]Means within a row without common superscripts are different at $P < 0.05$.
[1] Determined by Dairyland Laboratories, Inc. (Arcadia, WI).

Table 2.3. Least square means for initial body weight and total serum protein of calves fed either a 20:20 or 26:18 MR two or four times daily.

	Treatment[1]					
Item	STD2	STD4	MOD2	MOD4	SEM	P-Value
Initial BW, kg	42.3	40.6	41.1	41.3	3.55	0.91
Total serum protein, mg/dL	5.7	5.7	5.7	5.8	0.24	0.97

[1] Treatments: STD2 = conventional milk replacer (20% CP, 20% fat) fed twice daily at 1.5% BW; STD4 = conventional milk replacer (20% CP, 20% fat) fed four times daily at 1.5% BW; MOD2 = modified milk replacer (26% CP, 18% fat) fed twice daily at 2.0% BW; MOD4 = modified milk replacer (26% CP, 18% fat) fed four times daily at 2.0% BW]. Calves on all treatments were weaned at 42 d. An 18% CP starter and water were offered free choice.

Table 2.4. Least square means for initial body weight and total serum protein of Holstein and crossbred calves fed either a 20:20 or 26:18 MR two or four times daily.

	Holstein	Crossbred	SEM	P-Value
Initial BW, kg	43.7	39.9	2.90	0.03
Total protein, mg/dL	6.0	5.6	0.19	0.11

Table 2.5. Least square means for body growth measurement gains from d 1-56 or calves fed a 20:20 MR twice or four times daily and calves fed a 26:18 MR fed either twice or four times daily.

	Treatment[1]					
	STD2	STD4	MOD2	MOD4	SEM	P-Value
Body measurements, cm						
Hip Height	10.8	10.5	10.1	12.4	0.76	0.16
Hip Width	3.8	5.0	4.4	5.2	0.50	0.22
Wither Height	9.1	10.2	10.2	11.6	0.91	0.27
Hearth Girth	16.3	19.3	19.3	21.4	0.82	< 0.05
Body Length	12.4	11.2	19.5	14.3	3.10	0.25

[1]Treatments: STD2 = conventional milk replacer (20% CP, 20% fat) fed twice daily at 1.5% BW; STD4 = conventional milk replacer (20% CP, 20% fat) fed four times daily at 1.5% BW; MOD2 = modified milk replacer (26% CP, 18% fat) fed twice daily at 2.0% BW; MOD4 = modified milk replacer (26% CP, 18% fat) fed four times daily at 2.0% BW. Calves on all treatments were weaned at 42 d. An 18% CP starter and water were offered free choice.
[2]Gain divided by milk replacer plus starter.

Table 2.6. Least squares means for BW, ADG, and feed efficiency of calves fed either a 20:20 or 26:18 MR two or four times daily.

	Treatment[1]					
	STD2	STD4	MOD2	MOD4	SEM	P-Value
BW, kg						
Initial, d 0	42.3	40.7	41.1	41.3	1.61	0.91
Final, d 56	79.5	80.7	85.0	82.5	3.50	0.70
Total gain, d 42	26.5	26.4	28.8	28.7	1.97	0.71
Total gain, d 56	37.2	40.1	43.9	41.2	2.67	0.36
ADG, kg/d						
d 1 to 42	0.63	0.63	0.69	0.76	0.05	0.25
d 1 to 56	0.66	0.72	0.78	0.79	0.05	0.23
Efficiency, kg gain/kg DM)[2]						
0 to 42 d	0.57	0.57	0.60	0.59	0.03	0.91
0 to 56 d	0.48	0.49	0.54	0.51	0.03	0.43

[1]Treatments: STD2 = conventional milk replacer (20% CP, 20% fat) fed twice daily at 1.5% BW; STD4 = conventional milk replacer (20% CP, 20% fat) fed four times daily at 1.5% BW; MOD2 = modified milk replacer (26% CP, 18% fat) fed twice daily at 2.0% BW; MOD4 = modified milk replacer (26% CP, 18% fat) fed four times daily at 2.0% BW. Calves on all treatments were weaned at 42 d. An 18% CP starter and water were offered free choice.
[2]Gain divided by milk replacer plus starter.

Table 2.7. Least square means for starter intake, total DM intake, and total MR intake of calves fed either a 20:20 or 26:18 MR fed two or four times daily.

	Treatment[1]					
	CON	STD4	MOD2	MOD4	SEM	P-Value
Starter Intake, kg/d						
d 7	0.03	0.01	0.02	0.02	0.01	0.30
d 14	0.17	0.12	0.08	0.12	0.03	0.27
d 21	0.30[a]	0.28[a]	0.20[ab]	0.14[b]	0.05	0.07
d 28	0.49[a]	0.51[a]	0.24[bc]	0.24[c]	0.06	<0.05
d 35	0.64[a]	0.72[a]	0.41[b]	0.28[b]	0.07	<0.05
d 42	0.96[abc]	1.26[a]	0.79[b]	0.78[bc]	0.11	0.01
d 49	2.03	2.38	1.88	1.90	0.14	0.06
d 56	2.44	2.85	2.82	2.52	0.18	0.27
Total MR Intake, kg						
d 1 to 42	29.1[a]	27.0[a]	36.8[b]	36.7[b]	1.22	<0.05
Total Starter Intake, kg						
d 1 to 42	18.3[a]	20.6[a]	12.3[b]	11.3[b]	1.90	<0.05
d 1 to 56	47.1[abc]	57.2[a]	44.9[b]	39.7[bc]	3.71	0.01
Total DM Intake, kg						
d 1 to 42	46.8	47.8	48.3	47.3	2.37	0.98
d 1 to 56	77.9	84.2	81.6	78.9	4.13	0.69

[a-c]Within a row, means with different subscripts differ ($P < 0.05$).

[1]Treatments: STD2 = conventional milk replacer (20% CP, 20% fat) fed twice daily at 1.5% BW; STD4 = conventional milk replacer (20% CP, 20% fat) fed four times daily at 1.5% BW; MOD2 = modified milk replacer (26% CP, 18% fat) fed twice daily at 2.0% BW; MOD4 = modified milk replacer (26% CP, 18% fat) fed four times daily at 2.0% BW. Calves on all treatments were weaned at 42 d. An 18% CP starter and water were offered free choice.

Table 2.8. Least square means for fecal scores of calves fed either a 20:20 or 26:18 MR two or four times daily.

	Treatment[1]					
	STD2	STD4	MOD2	MOD4	SEM	P-Value
Fecal Score[2]						
d 1 to 42	1.2	1.2	1.3	1.2	0.07	0.95
d 1 to 56	1.2	1.2	1.2	1.2	0.09	0.91
Scouring days[3]						
d 1 to 42	2.7	3.4	3.2	3.8	0.83	0.80
d 43 to 56	0.1	0.0	0.3	0.1	0.14	0.63
Days fecal score of 4						
d 1 to 42	0.2	0.1	0.0	0.3	0.16	0.52

[a-c]Within a row, means with different subscripts differ ($P < 0.05$).

[1]Treatments: STD2 = conventional milk replacer (20% CP, 20% fat) fed twice daily at 1.5% BW; STD4 = conventional milk replacer (20% CP, 20% fat) fed four times daily at 1.5% BW; MOD2 = modified milk replacer (26% CP, 18% fat) fed twice daily at 2.0% BW; MOD4 = modified milk replacer (26% CP, 18% fat) fed four times daily at 2.0% BW. Calves on all treatments were weaned at 42 d. An 18% CP starter and water were offered free choice.

[2]Fecal score system: 1 = normal; 2 = semi-formed, pasty; 3 = loose, but stays on top of bedding; 4 = watery, shifts through bedding. Abnormal fecal scores were d with scores ≥ 3.

[3]Scouring day = any day with a fecal score ≥ 3.

Table 2.9. Concentration of plasma NEFA in calves from 2 to 6 wk of age.

	Treatment[1] NEFA (mM)					
	STD2	STD4	MOD2	MOD4	SEM	P-Value
Week						
2	0.22[a]	0.25[a]	0.23[a]	0.31[b]	0.02	0.03
3	0.17[a]	0.26[b]	0.29[b]	0.31[b]	0.02	<0.05
4	0.17[a]	0.18[a]	0.20[a]	0.33[b]	0.02	<0.05
5	0.19[a]	0.16[a]	0.21[a]	0.31[b]	0.02	<0.05
6	0.14[a]	0.14[a]	0.18[b]	0.15[a]	0.02	0.04

[a-c]Within a row, means with different subscripts differ ($P < 0.05$).

[1]Treatments: STD2 = conventional milk replacer (20% CP, 20% fat) fed twice daily at 1.5% BW; STD4 = conventional milk replacer (20% CP, 20% fat) fed four times daily at 1.5% BW; MOD2 = modified milk replacer (26% CP, 18% fat) fed twice daily at 2.0% BW; MOD4 = modified milk replacer (26% CP, 18% fat) fed four times daily at 2.0% BW. Calves on all treatments were weaned at 42 d. An 18% CP starter and water were offered free choice.

Table 2.10. Concentration of plasma NEFA and total lipids in calves by treatment.

	Treatment[1]					
	STD2	STD4	MOD2	MOD4	SEM	P-Value
NEFA, mM	0.18[a]	0.20[a]	0.22[a]	0.28[b]	0.02	<0.05
Total lipid, mg/dL	1.33	1.28	1.61	1.67	0.14	0.12

[a-c]Within a row, means with different subscripts differ ($P < 0.05$).

[1]Treatments: STD2 = conventional milk replacer (20% CP, 20% fat) fed twice daily at 1.5% BW; STD4 = conventional milk replacer (20% CP, 20% fat) fed four times daily at 1.5% BW; MOD2 = modified milk replacer (26% CP, 18% fat) fed twice daily at 2.0% BW; MOD4 = modified milk replacer (26% CP, 18% fat) fed four times daily at 2.0% BW. Calves on all treatments were weaned at 42 d. An 18% CP starter and water were offered free choice.

Table 2.11. Cost of DMI and gain with and without labor during the 56-d preweaning period.

	Treatment[1]					
Item	STD2	STD4	MOD2	MOD4	SEM	P-Value
Preweaning and early postweaning period (d 0 to 56)						
Calves, n	12	12	12	12	—	—
MR, [2]$	83.81[a]	77.95[a]	119.07[b]	120.31[b]	2.43	<0.05
Starter, [3]$	14.99[abc]	17.11[a]	13.55[b]	12.99[bc]	1.04	0.04
Total, $	98.84[a]	95.12[a]	132.71[b]	131.91[b]	4.22	<0.05
Cost ($) / gain (kg)	1.25[a]	1.17[a]	1.59[b]	1.61[b]	0.04	<0.05
Labor, $/h	10.00	10.00	10.00	10.00	—	—
Feeding time per calf, [4]min	8.0	16.0	8.0	16.0	—	—
Feeding cost with labor[5]	255.28[a]	305.12[b]	322.43[b]	377.01[c]	8.72	<0.05

[a-c]Within a row, means with different subscripts differ ($P < 0.05$).

[1]Treatments: STD2 = conventional milk replacer (20% CP, 20% fat) fed twice daily at 1.5% BW; STD4 = conventional milk replacer (20% CP, 20% fat) fed four times daily at 1.5% BW; MOD2 = modified milk replacer (26% CP, 18% fat) fed twice daily at 2.0% BW; MOD4 = modified milk replacer (26% CP, 18% fat) fed four times daily at 2.0% BW. Calves on all treatments were weaned at 42 d. An 18% CP starter and water were offered free choice.

[2]Milk replacer cost: STD2 and STD4 = $2.89/kg of DM; MOD2 and MOD4 = $3.24/kg of DM.

[3]Starter cost: STD2, STD4, MOD2 and MOD4 = $0.33/kg of DM.

[4]Feeding time per calf was observed to be 4 minutes per calf per feeding.

[5]Feeding cost with labor = (($0.17/min*4 min/feeding*[2 or 4 feedings/d])*56 d) + ($ total of each diet).

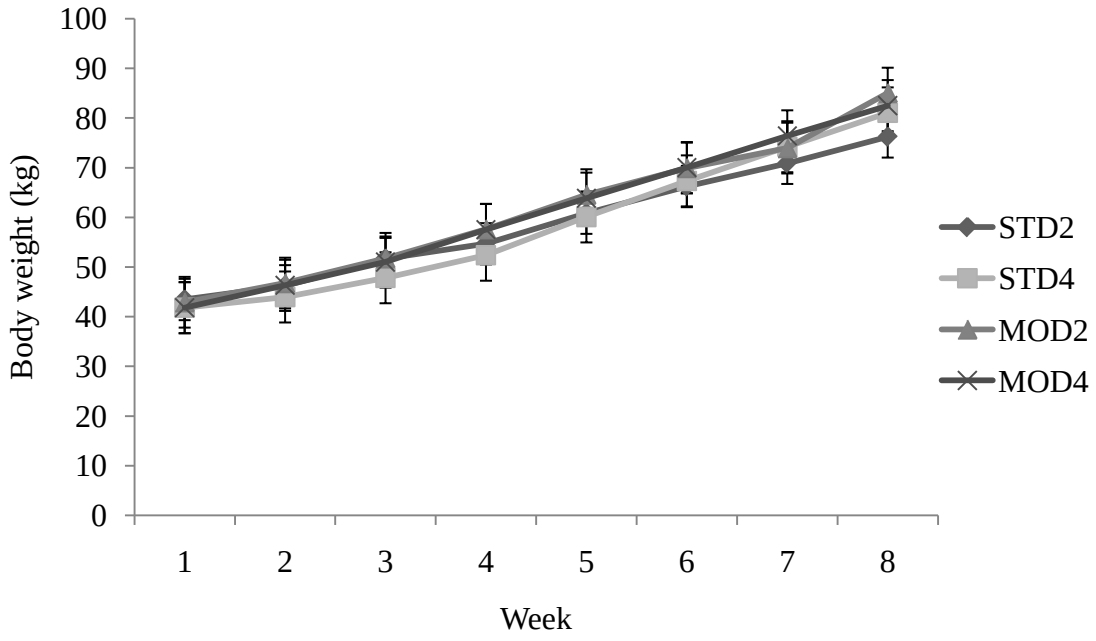

Figure 2.1. LS means of BW gain of calves fed 1 of 4 treatments [STD2 = conventional milk replacer (20% CP, 20% fat) fed twice daily at 1.5% BW; STD4 = conventional milk replacer (20% CP, 20% fat) fed four times daily at 1.5% BW; MOD2 = modified milk replacer (26% CP, 18% fat) fed twice daily at 2.0% BW; MOD4 = modified milk replacer (26% CP, 18% fat) fed four times daily at 2.0% BW]. Calves on all treatments were weaned at 42 d. An 18% CP starter and water were offered free choice. BW was greater ($P < 0.05$; treatment × week) for MOD2 versus STD2 on week 8.

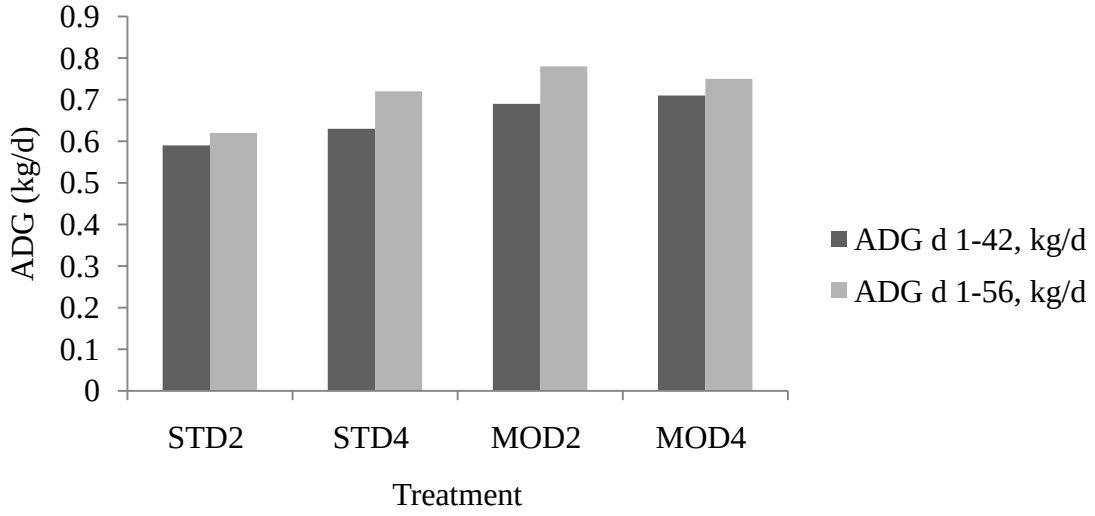

Figure 2.2. ADG (kg/d) of calves from d 1-42 and d 1-56 of calves fed 1 of 4 treatments [STD2 = conventional milk replacer (20% CP, 20% fat) fed twice daily at 1.5% BW; STD4 = conventional milk replacer (20% CP, 20% fat) fed four times daily at 1.5% BW; MOD2 = modified milk replacer (26% CP, 18% fat) fed twice daily at 2.0% BW; MOD4 = modified milk replacer (26% CP, 18% fat) fed four times daily at 2.0% BW]. Calves on all treatments were weaned at 42 d. An 18% CP starter and water were offered free choice. Average daily gain (ADG) during d 1 to 42 was not significantly different among treatments (P = 0.39). ADG from d 1 to 56 was not different among treatments (P = 0.23).

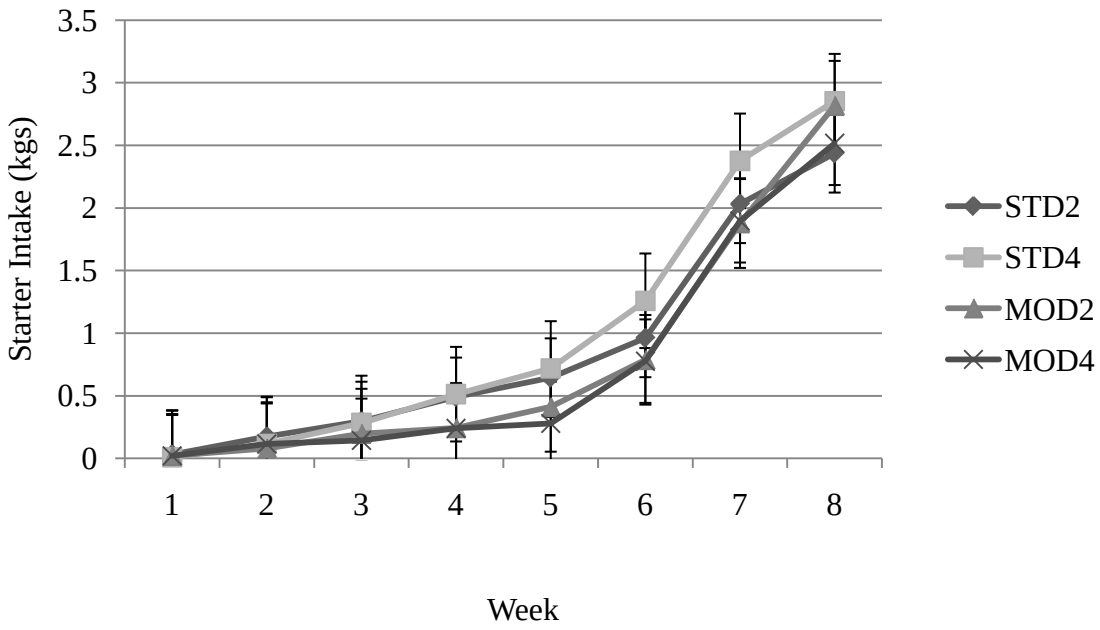

Figure 2.3. Starter intake (kg) of calves fed 1 of 4 treatments [STD2 = conventional milk replacer (20% CP, 20% fat) fed twice daily at 1.5% BW; STD4 = conventional milk replacer (20% CP, 20% fat) fed four times daily at 1.5% BW; MOD2 = modified milk replacer (26% CP, 18% fat) fed twice daily at 2.0% BW; MOD4 = modified milk replacer (26% CP, 18% fat) fed four times daily at 2.0% BW]. Calves on all treatments were weaned at 42 d. An 18% CP starter and water were offered free choice. There was a significant treatment × week interaction ($P < 0.05$) for starter intake.

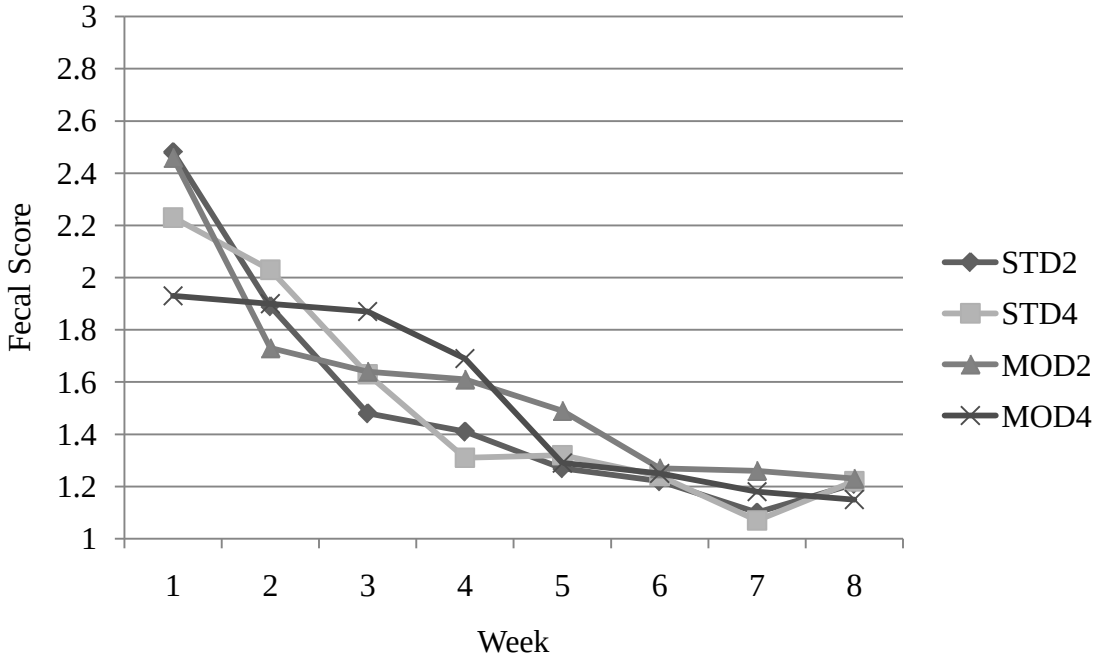

Figure 2.4. Fecal score of calves fed 1 of 4 treatments [STD2 = conventional milk replacer (20% CP, 20% fat) fed twice daily at 1.5% BW; STD4 = conventional milk replacer (20% CP, 20% fat) fed four times daily at 1.5% BW; MOD2 = modified milk replacer (26% CP, 18% fat) fed twice daily at 2.0% BW; MOD4 = modified milk replacer (26% CP, 18% fat) fed four times daily at 2.0% BW]. Calves on all treatments were weaned at 42 d. An 18% CP starter and water were offered free choice. Fecal scores did not differ among treatments ($P > 0.05$).

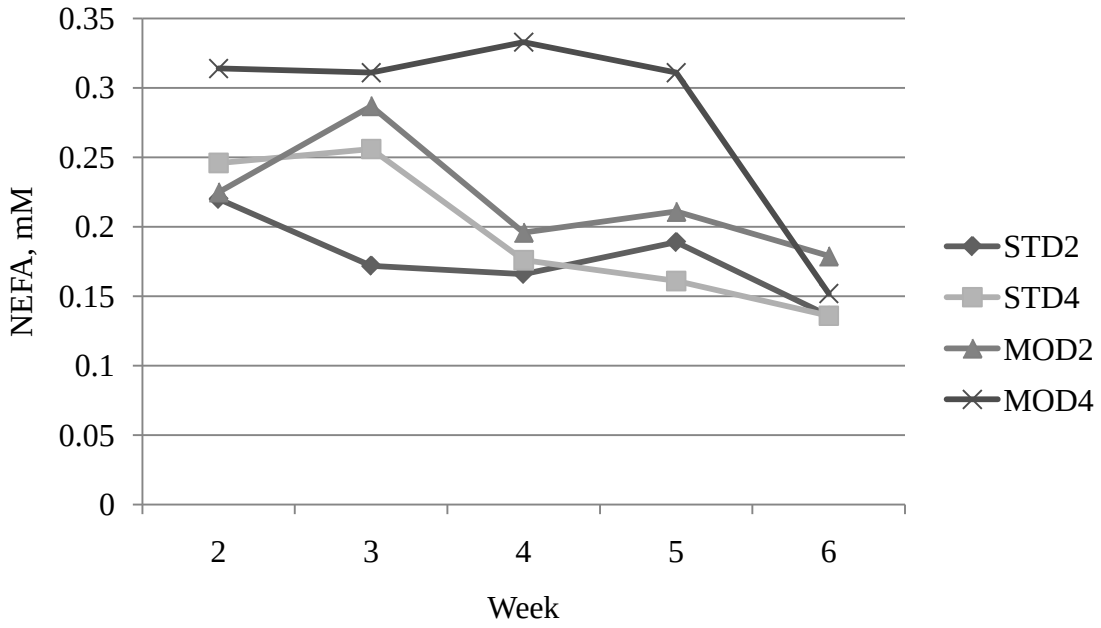

Figure 2.5. Concentration of plasma NEFA for calves fed 1 of 4 treatments [STD2 = conventional milk replacer (20% CP, 20% fat) fed twice daily at 1.5% BW; STD4 = conventional milk replacer (20% CP, 20% fat) fed four times daily at 1.5% BW; MOD2 = modified milk replacer (26% CP, 18% fat) fed twice daily at 2.0% BW; MOD4 = modified milk replacer (26% CP, 18% fat) fed four times daily at 2.0% BW] in calves from 2 to 6 wk of the study. Calves on all treatments were weaned at 42 d. An 18% CP starter and water were offered free choice.

Chapter 3

Effects of a milk replacer and starter additive blend on dairy calf health and performance

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CHAPTER SUMMARY

The objective of this study was to determine the effects of including Essential Calf® additive blend in the milk replacer (**MR**), starter feed, or both on calf performance and health. Sixty male (n = 15) Holstein calves < 7 d of age were randomly assigned to 1 of 4 treatments and balanced by initial body weight (BW). The treatments were as follows: 1) 20% CP, 20% fat MR and 18% CP texturized starter **(CON)**; 2) 20% CP, 20% fat MR with 10 g/d Essential Calf® and18% CP starter (**MRO**); 3) 20% CP, 20% fat MR and Essential Calf® starter additive blend (SO); 4) 20% CP, 20% fat MR with 10 g/d Essential Calf® and Essential Calf® starter additive blend (**MRS**). Essential Calf® consists of an essential oil blend, yeast cell wall extract, *B. subtilis*, and a source of digestible fiber. Essential Calf® starter consists of digestible fiber, yeast cell wall extract, an essential oil blend, niacin and an enzyme premix. MR were non medicated, reconstituted to 12.5% solids and fed at 1.5% of arrival BW. Calves were weaned at 42 d of age. Water and starter were provided *ad libitum* from day 1 of arrival to d 56. Weekly weight and structural measurements and daily starter intake and fecal scores (**FS**) were recorded. Data were analyzed using Proc Mixed in SAS as a completely randomized

design with repeated measures. Starter and total DM intakes were not different among treatments. Least square means of starter intake (kg/d) from d 1 to 56 were 0.62 for CON, 0.59 for MRO, 0.53 for SO, and 0.49 for MRS. There was a tendency (P = 0.08) for an increase in starter intake by week. BW gain from d 1 to 42 was not affected by treatment (P = 0.41) and averaged 15.4 and 14.0 kg for CON and MRO and 13.0 and 10.7 kg for SO and MRS. BW gain from d 1 to 56 was not different among treatments (P = 0.47) and averaged 24.9, 20.1, 19.2, and 20.3 kg for CON, MRO, SO, and MRS. Average daily gain (**ADG**) during d 1-42 was not different (P = 0.45) and averaged 0.37, 0.33, 0.31, and 0.26 kg/d for CON, MRO, SO, and MRS. ADG from d 1-56 was not different (P = 0.47) and averaged 0.43, 0.36, 0.34 and 0.36 kg/d for CON, MRO, SO, and MRS. There was no significant treatment or treatment × week interaction for hip width, hip height, wither height or heart girth. FS were not different (P = 0.99) between treatments and averaged 2.2. Inclusion of Essential Calf® in both MR and calf starter may may reduce nutrient intake.

Key Words: Calf, Milk Replacer Additives, Essential Oils

INTRODUCTION

Despite many years of research and improvements in calf nutrition too many producers struggle with calf health. According to the 2007 USDA-NAHMS survey, mortality rates in unweaned heifers were 7.8 percent. Scours (56.5%) and respiratory illness (22.5%) were the most frequently cited mortality causes. Implementing new feed additives that show benefits in human (Isolauri, 2001 and Miguel, 2010) and other livestock neonates (Hernandez et al., 2004 and Petit et al. 1993) may be useful nutritional strategies to improve dairy calf health.

During the nursery phase, dairy calves are susceptible to many pathogens that cause preweaning diseases. Calves are especially susceptible to gastroenteric diseases during the first weeks of life that can cause scouring. Scours are characterized clinically by profuse watery diarrhea, progressive dehydration, and death within a few days of its onset with *Escherichia* coli being a common causative pathogenic agent (Blood et al.,1992). Neomycin sulfate, which acts mainly in the lumen of gastrointestinal tract when administered orally (Aschbacher and Feil, 1994), is one of the most commonly used antibiotics in commercial milk replacers or calf starters to treat diarrhea in calves (Zwald et al., 2004). Traditionally, antibiotics were added to milk replacer to control calf mortality, reduce the incidence of scours, and improve feed efficiency (Roy, 1980). Thus, many calf feeders and nutritionists have expressed concern over new FDA regulations (Feed Additive Compendium, 2011) changing the continuous use of 2:1 ratio of neomycin sulfate:oxytetracycline (**NT**) medicated milk replacers. Previous NT approved use in medicated milk replacers was for concentrations of 200-400 g/ton

neomycin and 100-200 g/ton oxytetrocycline. Within this system of antibiotic use, calves were fed on a continuous basis of 2:1 ratio of NT therapy throughout the milk replacer feeding period for the treatment of bacterial enteritis (scours). As of April 1, 2010, 2:1 NT milk replacers are no longer allowed to be manufactured.

Furthermore, under the newly approved regulation, there are two weight based options for the medication of milk replacer feeding programs. The first option is continuous feeding of a 1:1 ratio of NT at a feeding rate of 0.05 to 0.10 mg/lb of body weight. The lower dose concentration will be 8-16 g/ton of each antibiotic versus the previously approved 100-200 g/ton neomycin and 200-400 g/ton oxytetracycline. The FDA guideline for this low rate of feeding protocol is labeled for increased rate of weight gain and improved feed efficiency.

The second option, under the new milk replacer medication standards, permits manufacturers to market products for the treatment of clinical bacterial enteritis (scours) caused by *E. Coli* and/or bacterial pneumonia caused by *P. multocida*. Administered on the basis of calf weight, this treatment will deliver five to ten times more antibiotic therapy than the previous 2:1 NT program. This higher concentration antibiotic program is labeled to be fed continuously for 7 to 14 days. During this therapeutic treatment period, medication will be added to the non-medicated milk replacer so that 1:1 NT treatment (10 mg/lb of body weight) will be consumed daily. Assuming a 100 lb calf consuming 1 to 1.25 lb of milk replacer powder daily, this equates to 16 to 20 g of NT per ton of milk replacer. Producers will need to either handle two separate milk replacers (low and high antibiotic) or use an add-pack to add NT 1:1 for calves needing treatment.

It will be increasingly important for producers, nutritionist, and veterinarians to work together to ensure that calves are being treated correctly to minimize mortality.

The widespread and prolonged use of antibiotics, such as NT, as therapeutic agents and growth stimulants, has resulted in growing concerns regarding the development of resistant bacteria populations that complicate subsequent antibiotic therapy (Fuller, 1999). New alternative feed additives must be explored to maintain calf health and growth rate. Many naturally occurring and synthetic feed additives have been identified as potentially providing intestinal health benefits that may be of greater importance with new NT regulations. Some of these additives include essential oils (Calsamiglia, 2007), yeast cell wall extracts (Callaway and Martin, 1997), and digestible fiber (NRC, 2001). Each of these feed additives has been evaluated in calf, swine, poultry, and other neonatal models; however, changes in performance have been inconsistent.

Essential oils, specifically, have been of great interest. Essential oils are blends of secondary metabolites obtained from the plant volatile fraction by steam distillation (Calsmaiglia, 2007). The purported main mode of action of essential oils is as an antimicrobial with its effects on bacterial cell membranes. It is believed that most essential oils exert their antimicrobial activities by interacting with bacterial cell membrane processes, including electron transport, ion gradients, protein translocation, phosphorylation, and other enzyme-dependent reactions (Ultee et al., 1999; Dorman and Deans, 2000).

Essential oils with antimicrobial activity include garlic (Ross et al., 2001), dill (Deans and Ritchie, 1987), paprika (Deans and Ritchie, 1987), oregano (Dorman and Deans, 2000), and thyme (Juven et al., 1994). The majority of research with essential oils has been conducted in vitro with limited published research available in calves. Published research (Bampidis et al., 2006 and Olson et al., 1998) does not strongly support the use of essential oils as alternatives to antibiotics, but does show some interesting potential benefits.

Essential oils are primarily being considered as a way to improve or alter rumen fermentation and gut intestinal heath with naturally occurring compounds rather than synthetic additives or antibiotics. Altering rumen fermentation by increasing propionate and butyrate production and decreasing methane production results in more efficient growth (Calsamiglia, 2007). In addition, like monensin, essential oils may affect either the cell membranes of gram negative bacteria or can act within the cell of gram positive bacteria. This mechanism may reduce scour causing bacteria in the intestine by inhibiting growth of gram-negative bacteria by disrupting the outer cell membrane and reducing microbial growth efficiency.

Yeast cell cultures, on the other hand, are fed to increase DMI, alter rumen pH, and increase nutrient digestibility (Callaway and Martin, 1997; Kumar et al., 1997; Dann et al., 2000). In vitro and in vivo studies have shown that yeasts and yeast cultures stimulate growth of rumen cellulolytic bacteria (Callaway and Martin, 1997), which is critical for carbohydrate digestion and rumen development in newborn calves. Feeding yeast culture to calves reduced the incidence of elevated body temperature and antibiotic

treatments from birth to 46 days of age (Seymour et al., 1995). In addition, soluble products present in yeast culture have been shown to inhibit microbial growth and activity (Jensen et al., 2008) and modulate the immune system (Jensen et al., 2007). Collectively, these results indicate potential benefits to animal health, which are not necessarily accompanied by improvements in growth performance.

Many feed additives for milk replacer and calf starter as well as management strategies have been employed to improve calf performance and health. It is plausible that combinations of feed additives may provide an additive response to promote calf health and growth. There is a need to identify affordable and effective combinations of these compounds and determine their effectiveness within diverse nutrition and management scenarios. Drackley (2008) suggested that the effectiveness of additives may be enhanced if tested in calves fed biologically normal amounts of milk or milk replacer verses restricted amounts of milk replacer. Applications of feed additive technology for milk fed dairy calves will likely become more important as group feeding with automated calf feeders becomes more common. Controlling enteric disease challenges in group housed calves will likely continue to be an important consideration for calf welfare.

Significant changes in FDA regulations regarding the use of antibiotics in milk replacer offer an opportunity to reexamine nursery calf nutrition. The goal should be to continue to discover feeding and management strategies to optimize the efficiency of calf growth while continuing to improve health and welfare. Discovering new feed additives or feed additive combinations will offer more tools to accomplish this goal. Research

should continue to test additives in university trials to understand mode of action and also in on-farm studies to determine animal response with greater calf numbers and subsequent economic impact.

Data demonstrating the effects of an affordable blend of additives (oregano, yeast, B-vitamins, probiotics, vitamin E and soluble fiber) in milk replacer in addition to additives in calf starter on calf health and growth will be useful in determining strategies to reach calf performance similar to that achieved with feeding NT. The objectives of this study was to determine the effects of an additive blend consisting of essential oils (Maltigano), yeast cell wall extract (Levucell SC, Lallemand, Milwaukee, WI), and a source of digestible fiber in milk replacer (Essential Calf® MR) along with a digestible fiber, yeast cell wall extract, an essential oil blend, niacin and enzyme premix additive blend to starter (Essential Calf® starter) on calf performance and health. We hypothesize that combining both milk replacer additive blend and starter additive blend will result in increased calf growth, increased growth efficiency, and reduce days scouring when compared to no additive or either milk replacer or starter additive blend alone.

MATERIALS AND METHODS

Animals and Facilities

The experimental protocol was reviewed and approved by the University of Minnesota Institutional Animal Care and Use Committee. Sixty Holstein bull calves were acquired from a commercial dealer within 3 d of birth averaging 46.0 kg ± 0.64 kg of body weight (**BW**) on arrival. The inclusion criteria for these animals were as follows:

Holstein bull calves only, initial BW between 41.0 to 47.0 kg, no clinical sickness and no birth defects. Calves arrived in one shipment on July 1, 2010. Upon arrival at the University of Minnesota Dairy Research and Teaching Facility in St. Paul, MN, each calf was weighed and received an ear tag. Each calf was placed in an individual calf hutch (Poly Square Calf Nursery, Polydome, Litchfield, MN) bedded with straw within 2 h of arrival. A blood sample was collected via jugular venipuncture into evacuated serum collection tubes (SST; Beckton Dickenson Vacutainer Systems, NJ) 24 h after arrival and centrifuged at 1171 × *g* for 20 min. Serum was separated and analyzed for total serum protein concentration using a refractometer (Reichert Rhino VET360, Reichert, Depew, NY). Calves were offered electrolytes in warm water for the first feeding and milk replacer was offered at the second feeding and all feedings thereafter.

A premise fly spray (Tempo, Bayer Health Care, Shawnee Mission, KS) was sprayed weekly to control for flies. Calves were castrated with elastrator rings (Nasco, Fort Atkinson, WI) at 30 d of age.

Assignments to Treatments and Feeding

Calves were assigned randomly to 1 of 4 experimental treatments (n=15 per treatment). Calves were balanced within each treatment by arrival BW and serum total protein. Total serum protein status was used to estimate IgG status and successful transfer of passive immunity (adequate = plasma IgG > 10.0 g/L; marginal = 5.0 to 10 g/L; and deficient = < 4.0 g/L) (Bovine Alliance on Management and Nutrition, 1995).

Calves received milk replacer twice daily from d 1 to 35 at 0600 and 1600 h and once daily at 0600 h from d 36 to 42 from individual buckets. Calves were weaned at 42

d of age. All milk replacer (**MR**) was prepared by Milk Products Inc. (Milk Products Inc., Chilton, WI) and was all milk protein and non-medicated. All MR were reconstituted to 12.5% solids and fed at 1.5% of arrival BW. The MR was formulated to contain 20% CP and 20% fat (Table 3.1). An 18% CP (as fed) texturized starter was provided ad *libitum* from day 1 of arrival to d 56. The treatment diets were as follows: 1) control (**CON**) 20% CP, 20% fat MR and conventional starter; 2) 20% CP, 20% fat MR with the inclusion of 10 g/d Essential Calf® (Ralco Nutrition, Inc., Marshall, MN) and conventional starter (**MRO**); 3) 20% CP, 20% fat MR and Essential Calf® starter (**SO**); 4) 20% CP, 20% fat with the inclusion of 10 g/d Essential Calf® and Essential Calf® starter (**MRS**).

Amount of MR fed each day was fixed within each treatment. MR was batch mixed daily for each treatment. MR and hot water (43.3^{o} C) were weighed out according to treatment group and the MR was mixed into the water using a battery operated drill fitted with a painter mixer. For calves receiving Essential Calf® in MR, MR was reconstituted and 5 g of Essential Calf® was added to each bucket at each feeding using a level calibrated measuring spoon. Essential Calf® premix in the starter was added to the base pellet diet during manufacturing. Calves were offered cold water ad *libitum* twice daily after each feeding. All MR and starter refusals were weighed back and recorded after each feeding.

Laboratory Analysis

Samples of MR, Essential Calf® MR additive blend, control and treated calf starter were collected weekly and composited monthly. Samples were stored (-20^{o}C)

prior to analysis for DM, CP, ether extract, ash, Ca, P, K, and Mg (AOAC, 1990). Monthly feed analysis was conducted by Dairyland Labs, Inc., Arcadia, WI. Starter samples were analyzed in duplicate for moisture (AOAC, 1990). The nitrogen content of samples was analyzed using a nitrogen analyzer (FP-528 Nitrogen Determinator, Leco Corporation, St. Joseph, MI), and CP was calculated by multiplying the nitrogen content by 6.25 (AOAC 1996). Mineral content was analyzed using an inductively coupled plasma mass spectrometer (Thermo Jarrell- Ash, Franklin, MA). Mold and yeast counts were analyzed by extracting a known volume of contaminated sample and pipetting amount into dilution flask using a sterile Potato Dextrose Agar plate using the spread plate technique and then incubating at room temperature for 56 h (Molds and Mycotoxins in Food, 2009).

Health Monitoring

Calves were observed daily for general health, including appearance (alertness), appetite (ability to consume feed), and fecal scores. Fecal scores (**FS**) were recorded daily using the following guidelines: 1 = normal; 2 = semi-formed, pasty; 3 = loose, but stays on top of bedding; 4 = watery, shifts through bedding (Larson, 1977). Scours were defined as FS $\geq$ 3. Calves were given electrolytes (Bounce Back, Manna Pro, Chesterfield, MO) and or antibiotics as treatment for abnormal health scores.

Individual health costs per calf were calculated using: $0.71/mL for treatment of Baytril (Bayer Health Care, Shawnee Mission, KS); $0.52/mL for treatment of Nuflor (Intervet Schering-Plough, Netherlands); $0.74/mL for treatment of Excenel (Pfizer, Inc., New York, NY); and $0.04/mL for treatment of Penicillin (U.S. Vet MicroSuspension II

Sterile Penicillin G Procaine, G.C. Hanford Mfg. Co., Syracuse, NY). Clinical health signs (respiratory problems) indicated the need for blanket treatment of all calves. All medical treatments were recorded.

Body Growth and Behavioral Measurements

Calves were weighed weekly after the morning feeding on the same day each week. Measures of body weight (**BW**), body length (**BL**) (Dairy Calf Weigh Tape, Nasco, Fort Atkinson, WI), hip width (**HW**), and hip height (**HH)** (Measuring Stick, Nasco, WI) were recorded.

Rumination and eating behaviors were recorded using direct visual instantaneous sampling of individual calves every 10 min (Hötzel et. al, 2010). Rumination was defined as the time a calf was seen ruminating during the 10 min scan and eating bouts were determined when a calf was seen eating out of the bucket. Data were recorded 22 times/day, from 0800 h to 1200 h. Recordings were performed on day 21, 28, 35, 42, 49, and d 56.

Statistical Analysis

Statistical analyses were conducted utilizing the Mixed procedure of SAS (version 9.2; SAS Institute Inc., Cary, NC). Data were analyzed as a completely randomized design. Calf within treatment was designated as a random effect, whereas effects of dietary treatment, week and the interaction of treatment and week were included in the model as fixed effects. For variables with repeated measures, the model also contained calf (as a random effect) and the fixed effects of time (as a repeated factor) and treatment × time interactions. Covariance structure considered were compound symmetry,

autoregressive order 1, and unstructured; the autoregressive order 1 structure was found to be the most appropriate for all variables based on Alkaike's Information Criteria. Data prior to any calf death was used and after death, calves that had died were analyzed as missing data. PDIFF was used for means separation and significant differences were declared at $P < 0.05$, and trends toward significant effects were noted at $P < 0.10$. Least square means and standard errors are reported.

RESULTS AND DISCUSSION

Diet Composition

Nutrient composition of MR, Essential Calf® additive blend, control starter, and Essential Calf® additive blend starter are described in Table 3.1. The CP of the starter was lower than expected. The control starter was 16 % CP and the treated starter was 17.2 % CP. Higher amounts of MR were offered than what is traditionally fed. MR was offered at 1.5 % instead of 1.25 % of birth BW to provide a closer to biological normal amount of MR.

DM Intake, MR Refusal, and Starter Intake

Total DM intake at d 42 ($P = 0.32$) and d 56 ($P = 0.35$) was not different among treatment groups (Table 3.4). There were no treatment effects on starter intake on d 14, 28, 42 or 56 (Table 3.2). Starter intake was low for all calves at d 14 and remained low throughout the study. Low starter intake early in this stage may be an indication of compromised calf health or low palatability of the starter grain. There was, however, a

tendency (P = 0.08) for an increase in starter intake by week as calves tended to eat more starter as they got older (Figure 3.1).

Least square means of starter intake (kg/d) at d 42 were 0.91, 0.77, 0.67, and 0.60 for CON, MRO, SO, and MRS (P = 0.28) respectively (Table 3.2). Least square means of starter intake (kg/d) at d 56 were 1.83 for CON, 1.68 for MRO, 1.65 for SO, and 1.66 for MRS (Table 3.2). Calves on our previous study using similar feeding methods (Kmicikewycz, MS thesis chapter 2) ate 0.96 kg/d of an 18% CP texturized calf starter at d 42 and 2.44 kg/d on d 56. From this previous study, there is a 0.61 kg/d difference in starter intake at d 56 compared to the CON treated calves. Difference in starter intake between these two studies are likely due to: calf health, starter palatability, season of year (summer vs. winter), and calf origin (co-mingled calves from multiple dairies vs. single source dairy). Lower calf starter intake by MRS calves resulted in 7.0 kg less total DMI through d 56 compared with CON.

Throughout the study, MR refusals of calves that did not consume all MR were weighed 30 min after feeding. Least square means for MR refusal on a DM basis from d 1 to 42 were 0.31, 0.71, 0.46 and 0.89 kg (P = 0.10) for CON, MRO, S, and MRS respectively (Table 3.3). Calves on the MRS treatment refused more milk replacer than calves on the CON treatment (P = 0.02). Research has shown that some essential oils must be fed within a very small concentration range to be effective and consistent (Calsamiglia et al., 2007). Furthermore, not only is the concentration of essential oils important for obtaining a response, but also consistency with which the active ingredients are delivered to the gastrointestinal tract (Calsamiglia et al., 2007). Feeding 10 g/d of

Essential Calf® in the MR may have increased concentrations of essential oils beyond the range of being effective in calf health and performance.

A number of environmental factors could have attributed to the overall low starter and MR intake. The study was conducted in the summer months (July through September) where temperatures were above the calves' thermal neutral zone and calves were subjected to a maximum number of hot and humid temperatures. The average daytime high temperature in the St. Paul area was 29.7^{o} C in August with a heat index of 27^{o} C for the months evaluated (Weather Underground, St. Paul, MN). This high temperature and humidity may have affected the consumption of starter feed. Hot environments are detrimental to the productivity of animals. The upper limit of the zone of thermoneutrality for young calves is at an effective environmental thermal neutral zone of about 26^{o} C (Hahn, 1981). As the environmental temperature increases beyond this point, termed the point of hyperthermal rise or upper critical temperature, the animal must expend energy to dissipate heat from its body. In addition, warm and humid conditions likely contributed to an increase in the fly population near the calves' hutches, which likely accounted for an increase in environmental stress.

Starter intake may have also been influenced by the quality of the Essential Calf® starter blend. A monthly composite of the control starter revealed a 400,000 col/gm mold count while the Essential Calf® blend treated starter was determined to contain 10,000 col/gm of mold (Table 3.1). Both starter and MR were stored on palates above ground level in order to keep the feed dry. The trial, however, was conducted during the summer months in Minnesota and due to a lack of a cooler storage facility, feed was subjected to

higher than normal temperatures which may have instigated mold growth. The mold content in the starter is likely to have reduced the starter palatability, thus decreasing starter intake.

Furthermore, starter intake of supplemented calves, SO and MRS, was lower than that of CON and MRO fed calves and may have been due to the palatability of the additive blend in the starter. The Essential Calf® blend emitted a strong odor that may have reduced palatability of the starter. An increase in respiratory problems and disease may also have been a substantial contributing factor to the decrease in starter intake.

BW Gain

Least square means of BW on day of arrival were not different among treatments (Table 3.4). Low initial BW SEM indicates uniformity of the group of calves. Body weight gain from d 1 to 42 were not different ($P = 0.40$) among treatments and averaged 15.4 and 14.0 kg for CON and MRO respectively, while SO and MRS calves gained 13.0 and 10.7 kg respectively (Table 3.4). Similarly, body weight gain from d 1 to 56 was not significantly different among treatments ($P = 0.47$) and averaged 24.2, 20.1, 19.2, and 20.3 kg for CON, MRO, SO and MRS respectively (Table 3.4). Previous studies have indicated BW gain from d 1 to 42 averaged 26.5 kg and 37.2 kg by d 56 for conventional 20% CP, 20% fat MR fed calves (Kmicikewycz, MS thesis chapter 2). The CON calves on this study have significantly lower growth rates compared to the control calves on the previous study. These low BW gains are not typical of conventionally fed calves.

Average daily gain (ADG) during d 1 to 42 was not significantly different among treatments ($P = 0.45$) and averaged 0.37, 0.33, 0.31, and 0.26 kg/d for CON, MRO, SO

and MRS respectively. ADG from d 1 to 56 was not different among treatments (P = 0.47) and averaged 0.43, 0.36, 0.34 and 0.37 kg/d for CON, MRO, SO, and MRS respectively (Table 3.4). Cowles et al. (2006) reported 0.48 kg/d ADG for conventionally fed calves at d 42, which is 0.11 kg/d more compared to the CON calves on this study. There was no difference in feed efficiency (P = 0.46) among treatments for d 1 to 42 or d 1 to56 (P = 0.50) (Table 3.4).

Initial HW, HH, WH, HG, and BL were similar among all calves. There was no significant treatment or treatment × week interaction for measures of HW, HH, WH or HG gain (Table 3.5). There was a tendency (P = 0.06) for a treatment × week interaction of BL as CON fed calves tended to be longer than calves on the MRO, SO and MRS treatments.

Behavioral Measurements

Treatment had no effect on calf rumination bouts. Observed rumination bouts increased with calf age ($P < 0.05$) as expected (Figure 3.2). Research has shown that by 6 wk of age, the rumen contents of calves show evidence of rumination (Kesler *et al.* 1951). Eating bouts were similar among treatments (Figure 3.3). Like rumination, eating bouts significantly increased ($P < 0.05$) with calf age. There was a difference in week ($P < 0.05$) for eating bouts. CON calves were observed to have a greater number of eating bouts/ h compared with MRS calves on week 4.

Health and Fecal Measurements

Serum protein concentrations of calves at the time of arrival at the University of Minnesota Dairy Research and Teaching Facility were similar across treatments with an

average of 5.4 g/dL (Table 3.6). Fecal scores from d 1 to 42 were not different among treatments and averaged 2.3, 2.3, 2.2, and 2.2 for treatments CON, MRO, SO, and MRS respectively (Table 3.6). Fecal scores were lower from d 1 to 56 than from d 1 to 42 averaging 1.7, 1.6, 1.6, and 1.5 for CON, MRO, SO, and MRS respectively.

Throughout 56 d, fecal scores were not different across treatments. The overall incidence of scours, evaluated as the number of days during the trial with fecal scores $\geq$ 3, were high, averaging 14.9, 16.1, 16.5, and 16.4 d for CON, MRO, SO, and MRS respectively from d 1 to 42. Compared to NT and antibiotic fed calves, these scores are much higher. Donovan et al. 2002 reported that on average calves from d 1 to 42 had a total of 6.2 d of fecal scores $\geq$ 3 for calves being fed a 138 mg/kg oxytetracycline and 276 mg/kg neomycin antibiotic. There were no differences in the number of d calves scoured the last week of the study and in general the incidence and severity of diarrhea during this study were high.

Treatment costs, which reflect the cost of administering medication to calves, from d 1 to 56 were not significantly different across treatment ($P = 0.18$), averaging \$4.07/calf (Table 3.6). This is, however, much higher than reported treatment costs by Raeth-Knight et al. of \$1.54 for conventionally fed calves from d 1 to 56. The Essential Calf® blend in the MR or starter did not result in any difference in average fecal score, scouring days, or treatment cost. One of the proposed benefits of plant extracts is their antimicrobial properties aid in decreasing scouring (Bampidis et al., 2006). In the trial reported here, however, no reductions in abnormal fecal score days or treatment days were observed.

Ten calves (16.7%) died during the study. Calves on MRS had a numerically higher mortality rate (60%) than calves on CON (20%), MRO (10%) and SO (10%). Necropsies were conducted on eight of the ten calves that died (Veterinary Diagnostic Laboratory, University of Minnesota). Clinical signs and necropsy results were consistent with pneumonia, enteric infections, and the pathogen *Salmonella Dublin* (*S. dublin*) which were identified as sources of mortality (Table 3.7). *S. dublin*, in particular, is a cattle host-adapted strain that usually presents as a respiratory illness, primarily in young stock less than 2 months of age (range 1 week to 6 months), although any age animal can be infected (Cornell University Animal Health Diagnostics Center, 2006). Clinical signs of infection include scouring, calf dehydration causing collapsing and death, and pneumonia (NADIS, 2007). Stress resulting from coinfections with other pathogens, poor hygiene, transportation, or dietary inadequacies can result in clinical signs in infected carrier animals or recrudescence of shedding in latently infected animals.

Since calves were of varying sources prior to arrival at the research facility, it is possible that previous pathogenic exposure contributed to morbidity. Neonatal calves exposed to transportation stress followed by exposure to environmental pathogens are more susceptible to illness and mortality.

CONCLUSIONS

Under the conditions of this study, feeding calves Essential Calf® in either the MR or calf starter did not result in improved calf performance compared to the CON fed

calves. Feeding Essential Calf® resulted in moderate fecal scores from d 1-42 and high treatment costs. There was no difference between groups in general appearance or in response to treatment for diarrhea. Compared with control fed calves, the addition of Essential Calf® in the MR, starter or MR and starter did not improve BW, ADG, or calf health as we had hypothesized. Furthermore, the incidence of *S. dublin* throughout the herd during this trial was a key factor leading to decreased starter intake and retarded growth.

Bull calves from commercial dairies fed an adequate plane of nutrition did not respond to a combination of feed additives. The concentration of the essential oil in this blend should be fed within a smaller range in order to be effective and consistent. Further research is needed to determine the appropriate amount of Essential Calf® in MR and starter.

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Table 3.1. Nutrient composition[1] and mold and yeast count[1] of experimental milk replacer and starter (DM basis) with and without Essential Calf®.

Item	Milk replacer	Essential Calf®	Control starter	Essential Calf® starter
Ingredient, % DM	97.1	93.1	87.6	89.9
CP, % of DM	21.3	6.4	16.0	17.2
Fat, % of DM	20.4	11.2	4.4	4.3
Ash, % of DM	9.5	11.4	5.8	5.7
Ca, % of DM	—	0.42	0.66	0.85
P, % of DM	—	0.10	0.46	0.44
Mg, % of DM	—	0.02	0.70	0.64
K, % of DM	—	4.7	1.1	1.1
Mold, col/gm	—	—	400,000	10,000
Yeast, col/gm	—	—	< 1,000	< 1,000

[1]Determined by Dairyland Laboratories, Inc. (Arcadia, WI). All values are expressed on a dry matter basis.

Table 3.2. Least square means for starter intake of calves fed milk replacer and starter with or without Essential Calf®.

	Treatment[1]					
	CON	MRO	SO	MRS	SEM	P-Value
Starter Intake, kg/d						
d 1 to 42	0.35	0.32	0.24	0.23	0.05	0.56
d 1 to 56	0.62	0.59	0.52	0.49	0.07	0.70
Starter Intake, kg/d						
d 14	0.11	0.09	0.08	0.07	0.03	0.80
d 28	0.38	0.36	0.25	0.27	0.07	0.50
d 42	0.91	0.77	0.67	0.60	0.12	0.28
d 56	1.83	1.68	1.65	1.66	0.15	0.77

[1]Treatments: CON = 20:20 MR and control starter; MRO = 20:20 MR with 10 g/d Essential Calf® and control starter; SO = 20:20 MR and Essential Calf® starter; MRS = 20:20 MR with 10 g/d Essential Calf® and Essential Calf® starter.

Table 3.3. Least square means of MR DM refusals of calves fed milk replacer and starter with or without Essential Calf®.

	Treatment[1]					
	CON	MRO	SO	MRS	SEM	P-Value
Total MR DM refused, kg						
d 1 to 42	0.31	0.71	0.46	0.89	0.18	0.10

[1]Treatments: CON = 20:20 MR and control starter; MRO = 20:20 MR with 10 g/d Essential Calf® and control starter; SO = 20:20 MR and Essential Calf® starter; MRS = 20:20 MR with 10 g/d Essential Calf® and Essential Calf® starter.

Table 3.4. Least square means for growth and feed efficiency (kg of gain/kg of DMI) of calves fed milk replacers and starters with and without Essential Calf®.

	Treatment[1]					
	CON	MRO	SO	MRS	SEM	P-Value
BW, kg						
Initial	46.0	46.0	46.1	46.2	0.64	0.99
d 42	61.1	60.3	59.1	57.2	2.04	0.55
d 56	70.0	66.5	65.3	66.7	2.78	0.58
Total gain, kg						
d 1 to 42	15.4	14.0	13.0	10.7	2.00	0.41
d 1 to 56	24.9	20.1	19.2	20.3	2.67	0.47
ADG, kg/d						
d 1 to 42	0.37	0.33	0.31	0.26	0.05	0.45
d 1 to 56	0.43	0.36	0.34	0.37	0.05	0.47
Total DMI, kg						
d 1 to 42	35.6	36.2	31.8	31.0	2.49	0.32
d 1 to 56	60.0	55.1	52.1	50.5	4.10	0.35
Efficiency[2]						
1 to 42 d	0.40	0.38	0.39	0.31	0.04	0.46
1 to 56 d	0.40	0.36	0.36	0.36	0.02	0.50

[1]Treatments: CON = 20:20 MR and control starter; MRO = 20:20 MR with 10 g/d Essential Calf® and control starter; SO = 20:20 MR and Essential Calf® starter; MRS = 20:20 MR with 10 g/d Essential Calf® and Essential Calf® starter.
[2]Gain divided by milk replacer plus starter.

Table 3.5. Least square means for body growth measurement gains from d 1-56 of calves fed milk replacers and starters with and without Essential Calf®.

	Treatment[1]					
	CON	MRO	SO	MRS	SEM	P-Value
Body measurements, cm						
Hip Height	4.8	4.5	3.5	3.4	0.80	0.42
Hip Width	2.5	2.6	2.1	2.3	0.34	0.64
Wither Height	4.7	4.1	3.6	3.9	0.62	0.56
Heart Girth	12.8	10.7	11.3	10.9	1.87	0.83
Body Length	10.7	10.0	9.5	8.3	0.92	0.29

[1]Treatments: CON = 20:20 MR and control starter; MRO = 20:20 MR with 10 g/d Essential Calf® and control starter; SO = 20:20 MR and Essential Calf® starter; MRS = 20:20 MR with 10 g/d Essential Calf® and Essential Calf® starter.

Table 3.6. Least square means for fecal scores and medical days of calves fed milk replacers and starters with and without Essential Calf®.

	Treatment[1]					
	CON	MRO	SO	MRS	SEM	P-Value
Total Serum Protein, g/dL	5.4	5.4	5.4	5.4	0.11	0.99
Fecal Score[2]						
d 1 to 42	2.3	2.3	2.2	2.2	0.12	0.91
d 1 to 56	1.7	1.6	1.6	1.5	0.10	0.80
Scouring days[3]						
d 1 to 42	14.9	16.1	16.5	16.4	1.05	0.65
d 43 to 56	3.8	3.6	3.4	2.7	0.67	0.71
Days fecal score of 4						
d 1 to 42	2.1	3.2	2.6	2.7	0.55	0.56
Treatment cost[4], $						
d 1 to 42	0.53	0.95	0.59	2.09	0.47	0.08
d 43 to 56	3.41	2.75	2.96	3.00	0.36	0.64
d 1 to 56	3.94	3.71	3.54	5.09	0.54	0.18

[1]Treatments: CON = 20:20 MR and control starter; MRO = 20:20 MR with 10 g/d Essential Calf® and control starter; SO = 20:20 MR and Essential Calf® starter; MRS = 20:20 MR with 10 g/d Essential Calf® and Essential Calf® starter.

[2]Fecal score system: 1 = normal; 2 = semi-formed, pasty; 3 = loose, but stays on top of bedding; 4 = watery, shifts through bedding. Abnormal fecal scores were d with scores ≥ 3.

[3]Scouring day = any day with a fecal score ≥ 3.

[4]Treatment cost: Baytril = $0.71/mL; Nuflor = $ 0.52/mL; Excenel = $0.74/mL; and Penicillin = $0.04/mL.

Table 3.7. Calf death summary of calves fed milk replacers and starters with and without Essential Calf®.

Treatment[1]	Day	Cause of death
MRS	9	Enterocolitis
CON	22	Perforated abomasum
MRO	25	Ventricular septal defect
MRS	38	*S. dublin* septicemia
MRS	44	*S. dublin* septicemia
MRS	44	*S. dublin* septicemia
MRS	46	*S. dublin* septicemia
MRS	51	*S. dublin* septicemia
SO	52	*S. dublin* septicemia
CON	52	*S. dublin* septicemia

[1]Treatments: CON = 20:20 MR and control starter; MRO = 20:20 MR with 10 g/d Essential Calf® and control starter; SO = 20:20 MR and Essential Calf® starter; MRS = 20:20 MR with 10 g/d Essential Calf® and Essential Calf® starter.

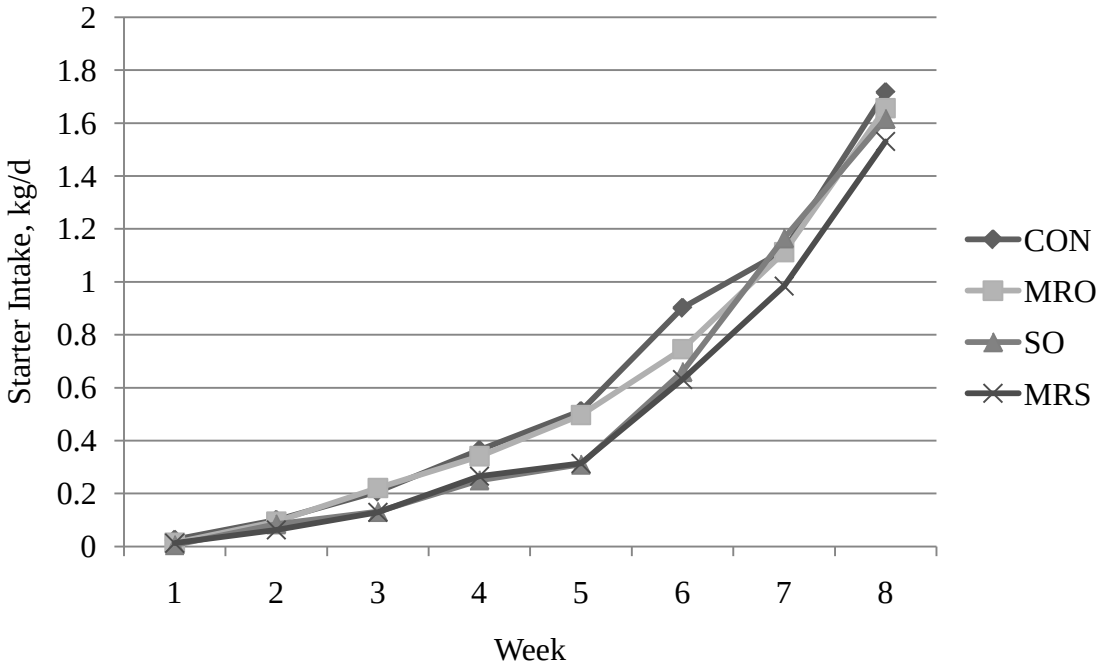

Figure 3.1. Starter intake (kg/d) in Holstein bull calves fed 1 of 4 treatment diets [CON = 20:20 MR and control starter; MRO = 20:20 MR with 10 g/d Essential Calf® and control starter; SO = 20:20 MR and Essential Calf® starter; MRS = 20:20 MR with 10 g/d Essential Calf® and Essential Calf® starter] from week 1 to 8. The treatment by week interaction for starter intake, kg/d ($P = 0.54$) was not significant. There was a tendency for a week interaction for starter intake (kg/d) ($P = 0.08$).

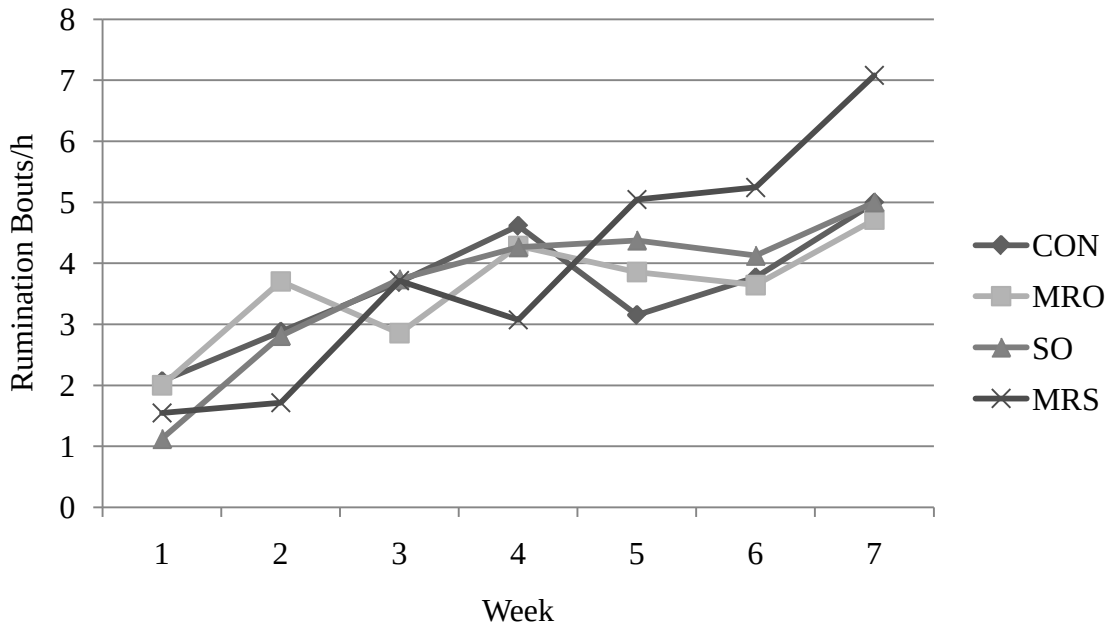

Figure 3.2. Rumination bouts for Holstein bull calves fed 1 of 4 treatment diets [CON = 20:20 MR and control starter; MRO = 20:20 MR with 10 g/d Essential Calf® and control starter; SO = 20:20 MR and Essential Calf® starter; MRS = 20:20 MR with 10 g/d Essential Calf® and Essential Calf® starter] from week 1 to 7. Treatment had no effect on calf rumination ($P > 0.05$). There was, however, a difference in week ($P < 0.05$). Calves on MRO ruminated more on week 2 than calves on MRS. Calves on CON, MRO, and SO treatments ruminated less on week 7 then calves on MRS.

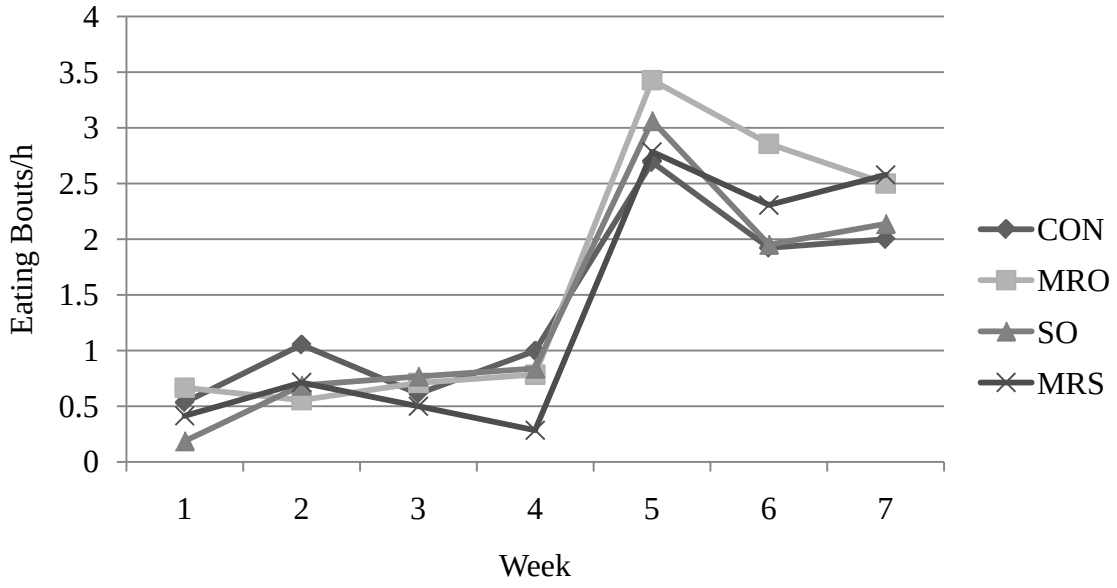

Figure 3.3. Eating bouts for Holstein bull calves fed 1 of 4 treatment diets [CON = 20:20 MR and control starter; MRO = 20:20 MR with 10 g/d Essential Calf® and control starter; SO = 20:20 MR and Essential Calf® starter; MRS = 20:20 MR with 10 g/d Essential Calf® and Essential Calf® starter] from week 1 to 7. Eating bouts were similar among treatments. Eating bouts significantly increased ($P < 0.05$) with calf age. There was a difference in week ($P < 0.05$) for eating bouts. CON calves were observed to have a greater number of eating bouts compared with MRS calves on week 4.

Chapter 4

Conclusions and Implications

In recent years there has been an increased interest in milk replacer feeding frequency and plane of nutrition or combining milk replacer and starter additive blends as two different strategies to promote calf health and growth. Based on the findings of this research, there are many benefits from the use of these two feeding strategies, but there are also challenges. These challenges include environmental stressors, labor requirements, and feed costs.

The experiment in Chapter 2 involving the use of a conventional and modified milk replacer program fed either two or four times daily is the first known experiment where two different milk replacers were utilized at two manual feeding frequencies. Results in Chapter 2 show that feeding calves a conventional 20% CP, 20% fat milk replacer resulted in higher starter intake. The higher starter intake resulted in 5.2 kg additional body weight gain for calves fed four times daily through day 56. The effects of season of rearing, however, still needs to be explored in order to better understand the effects of feeding frequency and the environment on calf performance.

The feed additive blend experiment in Chapter 3 determined that feeding calves Essential Calf® in either the MR or calf starter did not result in improved calf performance compared to control fed calves. It was concluded that elevated feeding amounts of essential oils may reduce nutrient intake and cause palatability problems resulting in negative responses. Bull calves from commercial dairies fed an adequate

plane of nutrition did not respond to a combination of feed additives. It was hypothesized that incorporating the additive mix into the milk replacer would result in improvements in calf health during the first three weeks of the nursery phase when compared to additive mix in the starter alone. Unfortunately, due to palatability issues associated with the milk replacer and starter additives and subsequent calf health issues, the hypothesis was unable to be cleanly tested. Future research should continue to evaluate the benefits of milk replacer additives versus starter additives during the nursery phase. Additionally, titration studies should determine the optimal feeding rates of essential oils.

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