EFFECTS OF HEAT STRESS AND INCREASED PROTEIN AND ENERGY FED IN MILK REPLACERS ON THE HEALTH AND GROWTH PARAMETERS OF NEONATAL HOLSTEIN BULL CALVES

A Thesis

by

ANDREW JOSEPH KRENEK

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2011

Major Subject: Animal Science

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Approved by:

Chair of Committee,	Glenn Holub
Committee Members,	Tryon Wickersham
	Michael Tomaszewski
Head of Department,	David Forrest

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ABSTRACT

Effects of Heat Stress and Increased Protein and Energy Fed in Milk Replacers on the Health and Growth Parameters of Neonatal Holstein Bull Calves. (August 2011)

Andrew Joseph Krenek, B.S., Texas A&M University

Chair of Advisory Committee: Dr. Glenn Holub

Objectives of the study were to evaluate if calves fed 6 L of high protein milk replacer (HPMR; 1135 g/d, 28% crude protein (CP), 20% fat) had improved performance and health as compared to calves fed 4 L of a conventional milk replacer (CMR; 454 g/d, 20% CP, 20% fat) in heat stress and non heat stress environments. Holstein bull calves (n=52) <3 d of age were assigned to a 2 x 2 factorial trial based on initial BW, physical health score, and total serum protein levels.

One half of each nutrition group was housed indoors with temperature control, non-heat stress (NHS) environment and one half was housed outside under a shaded barn in subjecting them to a heat stress (HS) environment. The study was conducted for 56 d from June 18 to August 13, 2010. Average thermal heat index (THI) was calculated for each day using the average of 24 recorded temperatures and relative humidity (RH%). The 56 d average, low, and high range THI for the HS was 79, 67, and 86, respectively, while THI for the NH was 69, 66, and 74, respectively. Weekly measurements of body weight (BW) in kg, body length (BL), hip width (HW), wither height (WH), heart girth (HG), and hip height (HH) in cm were collected and average daily gain (ADG) was calculated. Water consumption (WC) in mL and starter intake (SI) in grams was measured daily. Feed conversion (FC) was also calculated for each nutritional treatment and environment. Fecal scores (FS) of 1 to 4 (1=hard, firm, 2=soft, firm, 3=no form, and 4=watery) were recorded daily. Calves with a FS of >3 were considered to have diarrhea and required treatment. Respiration rates (RR) were recorded at 0630 (AM) and 1830 (PM) to monitor respiratory challenges while rectal temperatures (RT) were also measured using a digital thermometer daily in AM and PM to monitor febrile events. If RT was greater than 39.2 °C for NHS calves and 39.7 °C for HS calves, they were treated for febrile events (FE). Data was analyzed using PROC MIXED (SAS 9.2). HPMR had a greater ($P < 0.01$) WH, HG, BL, HH, ADG, WC, and FS than the CMR (0.15 vs. 0.11, 0.37 vs. 0.28, 0.27 vs. 0.22, 0.21 vs. 0.14, 0.82 vs. 0.58, 4235 vs. 2656, and 2.05 vs. 1.73, respectively). HS had a greater ($P < 0.01$) WC than NHS (4365 vs. 2526, respectively). CMR had a greater SI and FC ($P < 0.05$) than HPMR (0.942 vs. 0.437, and 1.99 vs. 1.78, respectively). HS had a higher RT AM, RT PM, RR AM, and RR PM ($P<0.01$) than NHS (38.87 vs. 38.77, 39.03 vs. 38.79, 35.79 vs. 32.77, and 55.73 vs. 38.57, respectively. Calves in NHS had a higher FE ($P<0.01$) than the HS calves (6.24 vs. 2.33). There was no significant difference in growth parameters in HS or NHS in calves of like feeding strategies. The results show calves in HS experienced higher RT AM, RT PM, RR AM, and RR PM. The increased protein and energy fed to the HPMR calves resulted in greater FS and increased growth.

DEDICATION

I would like to dedicate this thesis to my family for supporting and guiding me in so many aspects of my life. I would not be where I am today if it were not for them.

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I would like to thank all the student workers who assisted me with the collection of data and set up. If it were not for you this project would have never happened. A special thank you to Dr. Holub for your support, encouragement and giving me the opportunity to complete this thesis project. I would also like to thank my committee members, Dr. Wickersham and Dr. Tomaszewski, for their support and helping me put this paper together. I would also like to thank the staff at the Nutritional and Physiological Center at the Animal Science Teaching, Research, Extension Center facilities for all their help.

NOMENCLATURE

BL	Body Length
CMR	Conventional Milk Replacer
FC	Feed Conversion
FS	Fecal Score
FE	Febrile Events
HG	Heart Girth
HH	Hip Height
HPMR	High Protein Milk Replacer
HS	Heat Stress
HW	Hip Width
NHS	No Heat Stress
RR	Respiration Rate
RT	Rectal Temperature
SI	Starter Intake
WC	Water Consumption
WH	Wither Height

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

TABLE Page

CHAPTER I

INTRODUCTION

One of the challenges dairy farmers must consider during the warmer months is heat stress effects on their cattle. In the United States, the summer season can be long and increased radiant energy over a long period of time with high humidity causes heat stress. Heat stress is a factor which contributes to higher input costs for dairies in the southeast (Ravagnolo et al., 2000). Cattle are able to tolerate higher temperatures at a lower relative humidity because they can release heat effectively by sweating. However, during the warmer summer months, sweating can be inefficient means of temperature control and this can lead to heat stress more quickly than during the cooler months (Bohmanova et al., 2007). Heat stress affects dairy cattle in several ways, which includes increased rectal temperature (RT), respiration rate (RR), water consumption, and reduction of the strength and duration of estrus, milk production, and reproduction efficiency.

Fuquay (1981) reported that heat stress lowers reproductive efficiency of cows. Lowering the reproduction of mature dairy cattle results in a decreased number of calves born. Data has shown that cows bred during the summer season had more open days than those bred during the fall months because the cows had irregular or missed estrus periods or aborted due to heat stress at <10 d after conception.

This thesis follows the style of the Journal of Dairy Science.

Seath and Miller (1947) showed the summer months resulted in heat stress which depressed milk fat percentage and decreased milk production. These responses are attributed to the cow's inability to dissipate heat quickly enough to keep up with heat production during the summer months.

Lactating cows produce a large amount of metabolic heat and collect a large amount of additional radiant energy which produces heat. Build up of heat from metabolic production and the heat from radiant energy collected by the cow throughout the day decreases milk production. Lactating cows producing 32 kg milk/d would lose about 180 kg of production during a 120 d period during the summer season due to heat stress in southeastern United States (West, 2002).

Water consumption is also affected by heat stress. As water is lost due to increased urine output and as water decreases in fecal material as a result of heat stress, the water consumption of the cow will increase (Fuquay, 1981). Much of the water the cow consumes will evaporate from the skin and the respiratory tract during times of heat stress (Berman, 2008).

Research about heat stress and the effects it has on mature Holstein cows demonstrates heat stress affects reproduction, rectal temperature, respiration rate, water, and milk production. Less research has been conducted about heat stress effects in Holstein calves. Quantifying the effects of heat stress on growing heifers and the development of intervention strategies for heat stress may have positive effects on future milk production of these calves. Heat stress likely hinders growth and feed efficiency by increasing maintenance requirements and decreasing feed intake. Rearing calves in heat stress environments reduces growth and delays weaning.

Feeding programs have been enhanced by increased crude protein intake and quantity of milk replacer fed in an effort to achieve a heavier calf at weaning and to do so at an earlier age.

Jasper and Weary (2002) found that when calves were allowed ad libitum consumption of milk, they consumed 89% more milk and weighed 63% more than calves feed conventional amounts of milk.

CHAPTER II

LITERATURE REVIEW

Calves are fed colostrum during the first hours of life to ensure the absorption of immunity antigens. After the calf has received colostrum, a milk replacer is usually used to nourish the calf during the pre-weaning process. In a survey done by Heinrichs et al., (1995), it was reported that 60% of U.S. dairy farms used some form of milk replacer feeding program to feed calves. Two reasons milk replacers are utilized as a feeding regimen are the ease of labor and the economical advantage of using milk replacers as compared to feeding whole milk and waste milk (Heinrich et al., 1994). These reasons make milk replacers good sources of liquid feed for calves. Additionally, the calves' digestive system can effectively utilize the nutrients provided in milk replacer. As the calf grows, its ability to digest more complex feed ingredients improves (Heinrichs et al., 1995). Milk replacers also provide a good source of protein and energy for calves and can be a key factor in determining the outcome of a feeding program. Calves exhibit poor growth if the correct nutrients are not supplied in the appropriate ratios (Khan et al., 2007), (Lee et al. 2008). For this reason, it is important for calves to receive the appropriate amount of milk replacer to optimize performance (Jasper and Weary, 2002; Khan et al., 2007, (Lee et al., 2008).

Feed efficiency and growth increased without negative health effects of calves fed more milk replacer per feeding (Diaz et al., 2001; Khan et al., 2007; Borderas et al., 2009, Huuskonen and Khalili, 2007, and Sweeney et al., 2010). Calves fed a higher quantity of milk replacer (ad libitum) during the first two weeks of life doubled the weight gain of conventionally fed calves. Jasper and Weary (2002) concluded this was the result of greater milk intake.

Brown et al., (2004), reported calves fed a high energy diet had increased ADG compared to calves fed a medium energy diet. This study also demonstrated calves fed the high energy diet had greater wither heights and gain to feed ratios than calves fed the medium energy diet.

Abdelsamei et al. (2005) showed calves allowed increased milk replacer consumption, grew faster and had a greater weaning weight than calves fed less milk replacer. They also reported calves consuming more milk from birth took fewer days to reach the desired slaughter weight (Abdelsamei et al., 2005).

Despite these positive results, producers still believe increased milk intake will lead to diarrhea resulting in decreased weight gain (Jasper and Weary, 2002).

Their concern is valid as Brown et al., (2004) reported, calves fed high protein milk replacer had higher fecal scores than calves fed a medium protein milk replacer (Brown et al., 2004). Quigley et al., (2006) showed calves which received more calf milk replacer tended to have more days with a high fecal score.

Providing proper nutrition is important for the calf to have full potential growth, but for the calf to grow properly, the calf must also be healthy. The health and growth of the calf can be influenced by a combination of factors including management and the nutrition status of the calf (Heinrichs et al., 1994). A calf which is stressed or sick will have decreased performance and growth will be slowed. For this reason, it is important that the calf is healthy and provided with the correct amount of nutrients. Many factors have an effect on health and nutrition of the calf. Some of those factors are: temperature of the water when mixing the milk replacer, feeding milk replacers ad libitum or at restricted amounts, and the amount of milk replacer given at each feeding (Heinrichs et al., 1994).

One of the main influences on a calf's health is the heat load which the calf endures during the summer months. Heat stress effects on calves is not the first priority in research or of dairy producers because the focus is mainly on the mature cows' health and their performance due to the high costs associated with comfort of the mature cow (Mitloehner et al., 2002, West 2002, Mader and Davis, 2004, and Mader et al., 2005). Even though raising calves does not have as much cost associated with this aspect of a dairy farm, they still need to be thought of as a high cost variable. If heifers are to be kept for milk production and to produce a calf at an earlier age, the stresses the heifer endures while young might have an effect on her when she is grown.

Calves which are exposed to temperatures above their thermo-neutral zone or comfort zone have reduced growth and development due to stress. Some of the effects of heat stress on calves are decreased weight gain and feed intake, increased water intake, respiration rate, and rectal temperature, (Spain and Spiers, 1995). Calves will show signs of heat stress by panting, drooling, increased licking of their hair coat, or reluctance to rise (Blackshaw and Blackshaw, 1994). Signs of heat stress can be affected by wind speed, humidity, air temperature, and radiant heat load.

Because heat stress is one of the major problems associated with raising calves during the summer, hutches have been used to house calves during the pre-weaning period. Calf hutches are a good option for raising calves because they decrease the spread of disease, but they do not provide the best protection against high temperatures due to their inability to release heat (Coleman et al., 1996, and Broucek et al., 2008).

Providing shade protected calves from direct solar radiation, but the calves were still exposed to solar energy (Broucek et al., 2008). Shade should still be supplied for calves housed outdoors (Blackshaw and Blackshaw, 1994 and Broucek et al., 2008).

Utilizing calf hutches avoids many of the problems found in calf rearing barns including: elevated ammonia levels, inadequate air movement, and disease spread (Appleman and Owen, 1975 and Spain and Spiers, 1995). Providing shade in addition to a cooling system such as a sprinkler system or fans can be used to cool the calves during times of elevated ambient temperatures when the heat load on calves will be highest (Spain and Spiers, 1995).

Neuwirth (1979), found that heat stress did not occur in calves housed in hutches until the temperature exceeded 32.2 C with a relative humidity of 60%. This study also found when the temperature and humidity were combined; the values reached suggested shaded and un-shaded calves both experienced some degree of environmental heat stress during the afternoon hours (Neuwirth, 1979). In this study, the calves housed under shade had a lower afternoon rectal temperature than the calves housed with no shade. Calves housed under shade consumed less starter feed but had a greater feed efficiency than calves housed with no shade (Neuwirth, 1979)

The respiration rate of calves is a good indicator of heat stress and is used to measure the calf's thermal state during high ambient temperatures. A respiration rate of

20 breaths per minute is said to indicate a normal rate, while 80 breaths per minute indicates a warm condition for the calf (Spain and Spiers, 1995).

Spain and Spiers, (1995), stated a cow will increase her respiration rate to help maintain a homoeothermic state during times of high heat loads. In the same study by Spain and Spiers, (1995), an increase in respiration rate occurred after the air temperature reached 26 C. In the same study, calves in long term exposure to heat stress produced adaptive changes which included a reduction of rectal temperature and respiration rate (Spain and Spiers, 1995).

Seath and Miller (1947) showed air temperature tended to be a major cause for increase in body temperature and respiration rate of lactating cows. They also showed a 1ºC change in air temperature would cause 41 to 43 times more effect on a cow's respiration rate as a 1% change in the humidity. Air temperature affecting the RT and RR of calves is also important. As the calf becomes heat stressed the RT and RR increases (West, 2002).

Heat stress is not the only stress calves must endure during the prenatal phase. Weaning is a stressful period for calves because they have to adjust from a partially liquid diet to a dry diet made entirely of grain and roughage products. Weaning calves slowly over a longer period of time has been shown to better prepare calves for complete weaning. Calves weaned during a longer period of time also lost less weight at weaning (Sweeney et al., 2010). Calves fed large amounts of milk at each feeding which were abruptly weaned tended to lose a larger amount of weight during weaning compared to calves weaned more gradually (Sweeney et al., 2010). Calves weaned gradually consumed more starter feed at the start of the weaning process as compared to those weaned abruptly suggesting that calves consuming less milk replacer consumed more starter feed at the start of the weaning process and were more adapted to the new feed source (Sweeney et al., 2010).

The introduction of starter feed and the calf's ability to consume the starter feed seems to be the major factor influencing weight gain during and after weaning (Quigley et al., 1993). Calves consuming starter feed earlier in life will progress through the weaning process easier and will have less negative effects such as a large weight loss at weaning. Borderas et al., (2009) showed calves consuming a limited amount of milk replacer, or a low volume of milk replacer, had a significant increase in consumption of concentrate intake calves and the high volume milk replacer calves' intake of concentration was low until weaning. Once weaned, the calves fed ad libitum milk increased their consumption of calf starter, but it was lower than that of the calves receiving the limited amount of milk replacer (Borderas et al., 2009). This study also showed the number of visits to the concentrate feeder and the amount of time spent at the feeder was higher for the calves on the limited amount of milk replacer then those fed ad libitum milk replacer. During weaning, the ad libitum fed calves tripled their time spent at the concentrate feeder, but still had significantly lower concentrate consumption than the limited amount milk replacer fed calves. After weaning, both groups spent the same amount of time and had the same number of visits to the concentrate feeder (Borderas et al., 2009). Jasper and Weary, (2002) observed similar results between the conventionally feed calves and ad libitum calves, but the conventionally fed calves had higher consumption of starter than the ad libitum calves during pre-weaning. Once weaned, the starter feed intake was similar between the two groups (Jasper and Weary, 2002).

Consumption of starter feed in calves might help in the development of the rumen allowing the calf to adjust to the weaning process better (Quigley et al., 1994).

Water intake is also important for a calf during the pre-weaning period. Most producers (56%) did not provide any additional water to calves < 3 days of age except for the water in the calves' bottles. After 3 weeks of age, 58% of producers offered water after feeding (Heinrichs et al., 1994).

Ruis Heutinck and van Reenen (2000) showed calves offered water during pre-weaning consumed more water which suggests that the water in the milk replacer is not enough to satisfy the calves' needs. It is also thought that water has an effect on starter intake.

Kertz et al., (1984) found a relationship between starter intake and water intake. As starter intake increased, so did water intake. When the milk replacer is reduced or eliminated from the diet, calves will search for another feed source and thus will increase starter feed and water intake Kertz et al., (1984) also stated that calves consuming ad libitum amounts of water had a greater weight gain than calves not offered water. Gottardo et al., (2002) stated the opposite. Gottardo et al., (2002), stated that drinking water availability had no effect on final live weight and ADG.

Water consumption is also affected by heat stress. As water is lost due to sweating and increased urine output and as water decreases in fecal material as a result of heat stress, the water consumption of the cow will increase (Fuquay, 1981). Water is an essential nutrient in calf diets and must not be overlooked.

Milk replacers are good source of protein for calves during pre-weaning. Protein is important for growth and muscle development. Protein requirements ensure the appropriate amino acids are supplied for rapid and sufficient structural growth (Blome et al., 2003). The suggested amount of protein percent of total feed intake needed for a calf to ensure maximum growth is 13 to 18%. Other studies have reported similar body weight gain using a range of 17 to 18% protein (Akayezu et al., 1994, Brown, et al., 1958, and Leibholz and Kang, 1973).

Milk replacers which have higher amounts of crude protein are thought to increase growth and performance because of the higher amounts of protein they contain. Also, calves fed a higher crude protein percent milk replacer will reach the needed body weight more quickly than calves fed the conventional milk replacers containing a lower protein percentage. Gerrits et al., (1996) and Blome et al., (2003), showed an increase in crude protein content improved the growth of calves. When all calves started with similar initial body weights.

Blome et al., (2003) showed final body weight, ADG, and efficiency of gain increased as the amount of crude protein in the diet increased.

Bartlett et al. (2006) found similar results as Blome et al., (2003), except found that feeding a higher amount of crude protein (1.75% of body weight) increased the ADG compared to calves consuming a lower crude protein amount (1.25% body weight). The gain to feed ratio also was greater as crude protein increased with the greatest being at 22% crude protein.

In the study performed by Blome et al., (2003), rate of change of the wither heights increased as the dietary crude protein increased and the final heart girth, rate of change in the heart girth, and the rate of change in body length, and final body length all increased as crude protein of the diets increased. Bartlett et al. (2006) also recorded body growth measurements and found that ADG, final body weight, heart girth, body length, and wither heights were greater for calves as the crude protein increased.

CHAPTER III

MATERIALS AND METHODS

Holstein bull calves served as a model for heifer development for this study. The pre-weaning study was conducted in College Station, Texas commencing on June 18, 2010 and concluding on August 13, 2010. Sixty calves were used to initiate the study, with all animals managed similarly. All care and sampling was approved by the Institutional Animal Care and Use Committee of Texas A&M University (AUP #2009-106).

Sixty Holstein bull calves were purchased from two dairy farms located in Muleshoe, Texas. All calves met the following criteria: were considered Holstein by color markings, were one to two days of age, and were fed colostrum twice before purchase. Calves were transported overnight, (9.5 hours) to the Nutrition and Physiology Center located at the Texas A&M University Animal Science Teaching, Research, and Extension Center five miles West of College Station, Texas, in a covered aluminum trailer. On arrival, the calves were ear tagged for identification and blood was drawn for total serum protein (TSP) and glucose determination. Calves were fed 2 L of milk replacer at arrival and again in the late afternoon and were allowed to rest in a temperature controlled cool environment after transport. Calves were weighed and initial hip height, hip width, wither height, body length, and heart girth measurements were collected.

On d 1, calves were placed in individual pens and stratified into treatment groups using the initial weights and measurements, TSP status, and visual health scores from attending veterinarians. Individual pens were made from 4.88 m x 1.22 m cattle panels bent into the shape of a half circle. Treatments were arranged in a 2 x 2 factorial design. Pens were placed 60 cm apart to prevent nose to nose contact.

Nutritional Treatments

Nutritional treatments included two milk replacer regimens for 56 d. Thirty calves were place on a nutritional treatment group which received 28% crude protein, 20% crude fat at 0.82 kg (0.77 dry matter) milk powder Cornerstone 28:20 Bov. ® (Purina Mills LLC, St. Louis, MO) per day for the first two weeks of the study, followed by 1.14 kg (1.03 kg dry matter) of milk powder per day for the remainder of the study and was mixed in 1790 mL of water per bottle at each of two feedings. The control group of thirty calves received 20% crude protein, 20% crude fat at 0.45 kg (0.41 kg dry matter) of milk powder High Energy Nurse Gro. #100 BVT ® (Purina Mills LLC, St. Louis, MO) per day for the entire study and was mixed in 1480 mL of water per bottle at each of two feedings.

Water and starter feed were provided ad libitum in plastic pails and placed on the pen in a metal bucket holder. Water consumption was measured daily at 1600 h in mL using a graduated cylinder to measure water offered and water refused. Starter feed consumption was measured daily at 1700 hours. The calf starter used throughout the pre-weaning study was 20% crude protein, 2% crude fat Cornerstone Ampli-calf DX 30 ® calf starter (Purina Mills, St. Louis MO).

A reduction in milk replacer began on d 50 in preparation for total weaning. This entailed giving a bottle of milk at the morning feeding and a bottle of warm water at the evening feeding. The amount of milk replacer was also gradually reduced each day. This process was performed over the course of the last seven days until the end of the trial at day 56. Milk replacer power amounts were reduced by 50% for d 50 and 52, an additional reduction of 20% on d 53, 54, and 55, and an additional reduction of 20% on d 56.

Environmental Treatments

Thirty calves (15 of each nutritional treatment) were housed indoors in a temperature controlled environment exposed to an average temperature of 22.6ºC, a low temperature of 21.9ºC and a high temperature of 24.4ºC, for the duration of the pre-weaning study while the thirty calves (15 of each nutritional treatment) were housed in the outdoor barn exposed to moderate heat stress conditions with an average temperature of 28.8ºC, a low temperature of 22.1ºC and a high temperature of 31.5ºC. Calves housed indoors in the controlled environment were divided with eighteen pens in a large room with an average temperature of 22.7ºC, and twelve pens were housed in a smaller room with an average temperature of 22.5ºC. The controlled environments were expected to be similar during the 56 d trial, however, differences were noted between the temperature and humidity levels of the rooms which required statistical analyses. Indoor housed calves were subject to more constant temperature and relative humidity, while the outdoor calves were subject to more diurnal temperature variation and relative humidity variation.

The temperature humidity Index (THI) was calculated using ambient temperature and relative humidity obtained from data loggers (H08-003-02 HOBO® devices, Onset Computer Corporation, Pocasset, MA, USA) mounted near the calves in both indoor rooms and the outdoor barn. The THI equation used in this study was; THI=ambient temperature – [0.55 - (0.55*relative humidity/100)]* (ambient temperature – 58.8), where ambient temperature was recorded in Fahrenheit and relative humidity was recorded as a percentage. The average THI for the outdoor calves was 86. The average THI for the indoor calves was 74. The average THI for the small indoor room was 67, and the average THI for the large room was 71.

Health

All illnesses were treated to reduce stress of the calves in strict procedures outlined in the Animal Use Protocol. Attending veterinarians and regulatory inspections by veterinarians monitored the study on an ongoing basis.

Vaccinations were given to calves by an attending veterinarian. Calves received 1cc intranasal vaccine of PMH Manheimia Heamolytica + Pasteurella Multocida and 2cc TSV-2 Parainfluenza 3 + Rhinotracheitis on the day of arrival.

On day three, all calves received metaphalaxis treatment of 10 cc Tetradure® (Merial Limited, Duluth, GA) administered subcutaneously.

Rectal temperatures were taken twice daily using a digital thermometer and respiration rates were also measured twice daily. Rectal temperatures were taken at 0530 and 1730 hours. Respiration rates were taken after milk replacer feeding at 0630 and 1830. Respiration rates were obtained by visual observations of the costal region while the calf was at rest for a duration of fifteen seconds. The number obtained was then multiplied by four to calculate the breaths per minute. Calves were given two feedings of milk replacer per day, one at 0600 and another at 1800 hours. Calves not consuming their entire bottle at each feeding were encouraged to consume the rest of their bottle. If any calf refused any portion of their bottle, the amount of milk refused was recorded and the calf was monitored for anorexia at the next feeding. Calves which exhibited signs of dehydration due to scouring or refusal of milk replacer were given 93 g of Land-O-Lakes ® electrolytes complete (Land O' Lakes, Black River Falls, WI) mixed with 2 L of warm water in a bottle and offered via nipple. If calf refused to suckle bottle with electrolyte solution, the calf was given the electrolytes through esophageal tube to prevent dehydration.

Fecal scores were recorded daily on a scale of 1 to 4; 1= firm, 2= soft, but formed, 3= soft, no form, and 4= watery. Calves with a fecal score ≥ 3 were treated for gastrointestinal problems with 60 cc of Kao-Pectin (Agri Laboratories LTD. St. Joseph, MO). Antibiotic treatment was used for calves which exhibited fecal scores >4 combined with other symptoms, (eyes not bright and alert, calf not appearing alert) or at the advice of attending veterinarian.

Calves were treated for febrile events with 1 cc of flunixin meglumine (Banamine®) (Intervet/Schering Plough Animal Health, Summit, NJ) orally or intravenously, dependent on the consultant veterinarian's recommendations. Calves housed indoors with a rectal temperature > 39.2°C were considered to have a fever and were treated accordingly. Calves housed outdoors with a rectal temperature > 39.7°C were considered to have a fever and were treated accordingly.

Calves were treated for respiratory illness if they had a cough or nasal discharge based on the treatment recommended by the attending veterinarian.

Growth

On d zero, the calves were weighed and hip width, hip height, wither height, heart girth, and body length was measured for growth in centimeters. The feed conversion was calculated by dividing the total feed and milk consumed by the weight gained for each individual calf. Three of the calves were excluded from the study due to a heart defect (n=1), morbidity (n=2), or death due to respiratory illness, bacterial meningitis, or unknown causes (n=5). As a result, fifty-two calves were used for analysis of the final results. Twenty seven of the calves were housed inside and twenty five calves were housed outside. Twenty-seven calves were in the nutritional treatment group and twenty-five were in the nutritional control group.

Statistical Methods

Statistical analyses were performed using PROC MIXED procedure of SAS version 9.2 (SAS Inst. Inc., Cary, NC). The main effects were treatment, housing, day, treatment × housing, and treatment × housing x day. The factors evaluated included: ADG, starter intake, water intake, rectal temperature am, rectal temperature pm, respiration rate am, respiration rate pm, fecal score, feed conversion, hip height, hip width, heart girth, wither height, and body length. P-values less than 0.05 were considered statistically significant.

CHAPTER IV

RESULTS AND DISCUSSION

Effects of Nutritional Treatment on Growth Parameters

The HPMR calves had a greater body weight each week compared to the CMR fed calves during the pre-weaning period. (Figure 1). The advantage in weight gain continued throughout the entire eight week pre-weaning period. Similarly, Jasper and Weary, (2002), found calves which were fed a higher protein content and higher quantity of milk replacer had an increase in weight gain double of the conventional fed calves.

The HPMR calves had a greater overall weight gain and final weight, than the CMR calves (Table 1).

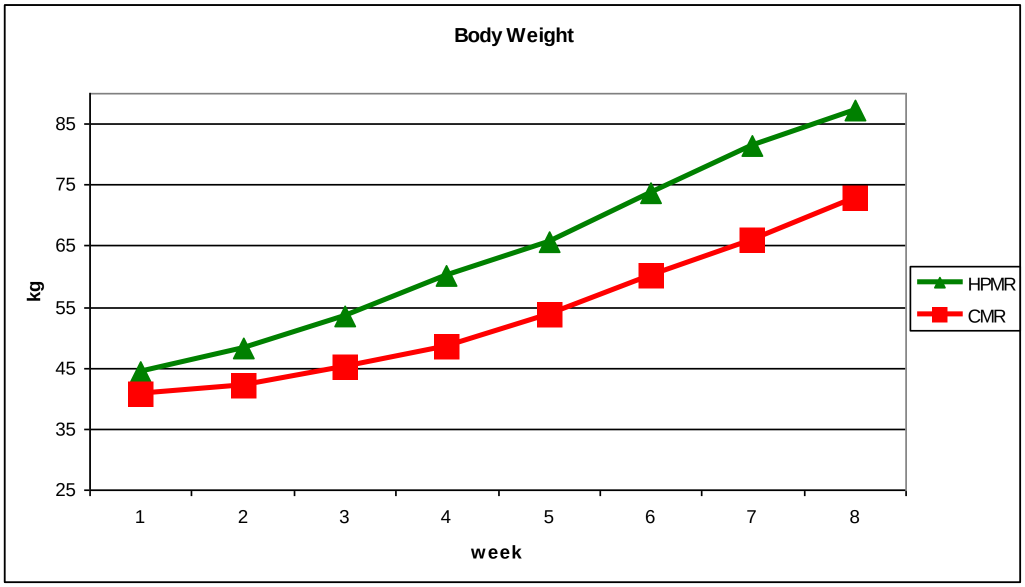
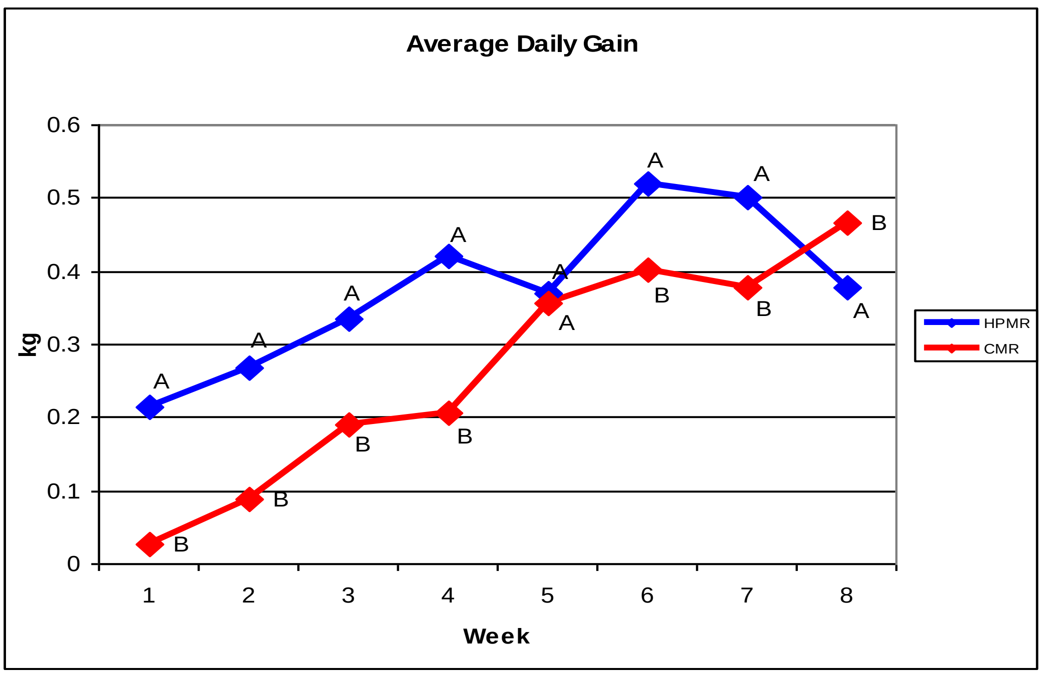


Figure 1. Comparison of the body weight gained during pre-weaning between the nutritional treatments.

Average Daily Gain

There was a significant difference between the two nutritional treatments in the overall ADG for the pre-weaning period. The HPMR had a greater ADG than the CMR (0.82 vs. 0.59, P <0.01). (Table 1) The environment and the interaction between nutritional treatment x environment and the three way interaction between environment x nutritional treatment x week had no effect on the ADG (P> 0.1). Week was significant between the two nutritional treatments (P <0.01) (Figure 2).



A-B means within the same row different by subscripts differ (P<0.05).

Figure 2. Comparison of the average daily gain during pre-weaning between the nutritional treatments.

The ADG of the HPMR was significantly higher than the CMR except for week 8 where the CMR had a higher ADG than the HPMR, and during week five, both nutritional treatments are similar (Figure 2). From week seven to week eight, as milk replacer amounts were reduced, the CMR had a higher ADG than the HPMR because the CMR fed calves consumed more starter. When the milk replacer powder was reduced during week seven, the CMR fed calves met their protein and energy requirements with starter feed while the HPMR calves which were accustomed to meeting their protein and energy requirements with the milk replacer did not consume enough starter to meet their protein requirements and thus the ADG decreased for the HPMR calves during this period of time.

There was a significant difference between the two nutritional treatments in the daily HH change for the pre-weaning period. The HPMR calves had a greater daily HH increase than the CMR fed calves (0.21 vs. 0.15, $P < 0.01$). (Table 1) The interaction of nutritional treatment x environment was not significant ($P > 0.1$).

There was a significant difference between the two nutritional treatments in the daily WH change for the pre-weaning period. The HPMR calves had a greater daily WH increase than the CMR fed calves (0.15 vs. 0.11, $P < 0.01$) (Table 1) for the duration of the trial. The interaction of nutritional treatment x environment was not significant ($P > 0.1$). (Table 1)

The HPMR calves had a greater increase in daily WH change throughout the pre-weaning trial; however, during week eight the CMR fed calves gained more rapidly and increased daily WH more than the HPMR calves.

There was no significant difference between the two nutritional treatments and the interaction of nutritional treatment and environment in the daily change of HW for the pre-weaning period (P>0.1).

Table 1. Comparison between the Nutritional Treatments for Growth Parameters and Interactions.

	HPMR		CMR			P values		
	HS	NS	HS	NHS	SE	MR	ENV	MR x ENV
Initial weight (kg)	40.8	40.1	40.5	40.1	ns	ns	ns	ns
Final Weight (kg)	87.6	86.9	76.0	70.3	ns	<.0001	ns	ns
Weight Gain (kg)	46.8	46.9	35.5	30.2	ns	<.0001	ns	ns
ADG (kg)	0.82	0.82	0.59	0.55	0.063	< 0.001	ns	ns
Heart Girth (cm)	0.36	0.37	0.29	0.26	0.012	< 0.001	ns	0.0238
Hip Height (cm)	0.21	0.19	0.15	0.14	0.012	< 0.001	ns	ns
Wither Height (cm)	0.15	0.15	0.11	0.11	0.011	0.0004	ns	ns
Hip Width (cm)	0.07	0.07	0.06	0.06	0.005	ns	ns	ns
Body Length (cm)	0.27	0.28	0.24	0.19	0.017	0.003	ns	ns
Milk Replacer DMI	56.95	56.92	24.05	24.48	0.352	<0.0001	ns	ns
Starter DMI	22.02	20.98	44.19	39.18	6.525	<0.0001	ns	ns
Total DMI	78.96	77.90	68.25	66.85	6.658	0.0002	ns	ns
Feed Conversion	1.80	1.77	1.95	2.03	0.059	0.001	ns	ns

ns means not significant by (P <0.05).

ENV means environment.MR means milk replacer.

There was a significant difference between the two nutritional treatments in the daily BL change for the pre-weaning period. The HPMR calves had a greater change in daily BL in cm than the CMR fed calves (0.27 vs. 0.24, $P < 0.01$). (Table 1). The interaction of nutritional treatment x environment was not significant ($P > 0.1$).

The HPMR calves had a significant increase in all daily growth parameters except HW. In studies by Blome et al. (2003) and Bartlett, et al. (2006), WH, HG, BL and body weight gained increased as the dietary crude protein and quantity of milk replacer increased. They stated higher intake of milk by calves provided more energy and protein than the calf required.

Dry Matter Intake

There was a significant difference between the nutritional treatments in DMI of milk replacer, starter and the total DMI. The HPMR fed calves had a greater DMI of milk replacer, and total DMI (56.95 vs. 24.05, $P<0.01$), and (78.96 vs. 68.25, $P<0.01$). (Table 1). The HPMR calves received a larger amount of milk replacer than the CMR calves (1.14 vs. 0.45 kg) throughout the trial contributing to the higher milk DMI and eventually to their higher total DMI. The CMR calves had a greater starter DMI than the HPMR calves (44.19 vs. 22.02, $P<0.01$). (Table 1).

Feed Conversion

There was a significant difference between the two nutritional treatments in the FC for the pre-weaning period. The CMR fed calves had a greater FC than the HPMR calves (195 vs. 1.8, P <0.01). (Table 1). To convert feed to gain the CMR calves had to consume a greater amount of starter for one kg of gain, than did the HPMR calves. The interaction of nutritional treatment and environment had no effect on FC (P> 0.1). The HPMR calves started the pre-weaning trial with a greater FC, but decreased after period of three weeks. The HPMR calves consumed a higher percentage protein milk replacer and a larger quantity of milk per feeding which met their protein and energy requirements, therefore, did not consume as much starter as the CMR calves and thus their FC was lower.

Effects of Environment Treatment on Growth Parameters

THI

The average THI for the entire pre-weaning study was calculated for each environment. Figure 3 shows the difference between the two environments during the pre-weaning trial. Those calves housed outdoors were exposed to higher THI conditions than calves housed indoors. The Average THI for the heat stress environment was 80 and the average THI for the non-heat stress environment was 68.

Heat stress seemed to have no effect on body weight per week between the two environmental treatments. (Figure 4). The HS calves did not have a significantly decrease weight gain per week as expected.

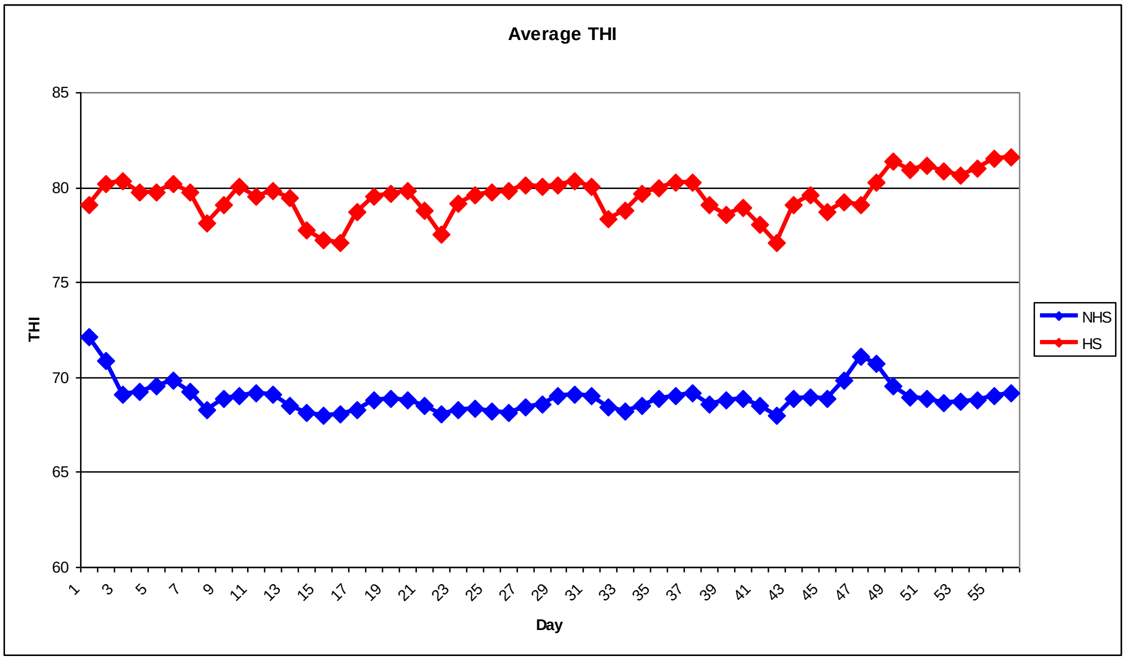


Figure 3. Comparison of THI between environments during pre-weaning.

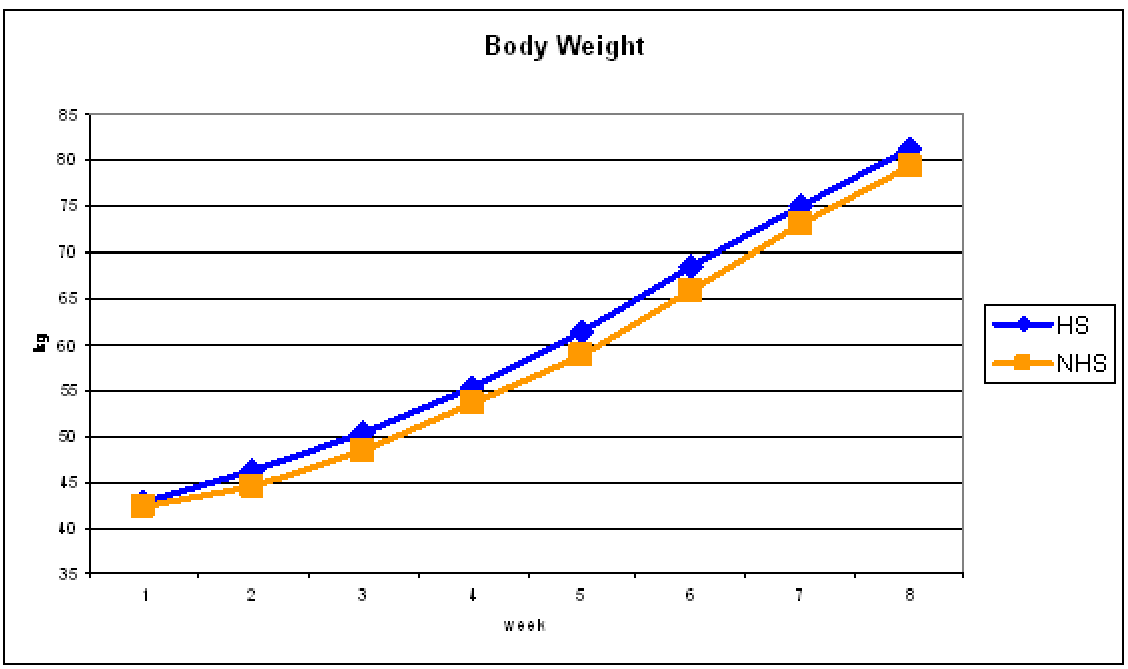


Figure 4. Comparison of environments and body weight gained during pre-weaning.

There was no significant difference between the calves in ADG in different environments (0.59 vs. 0.55, P> 0.1), (Table 1) nor was there a significant difference between the two environments in the daily change of HG for the pre-weaning period (0.29 vs. 0.26, P>0.1). (Table 1)

There was also no significant difference between the two environments in daily change of HH (0.14 vs. 0.15, P> 0.1), BL (0.24 vs. 0.29, P> 0.1), HW (0.06 vs. 0.06, P> 0.1), or WH (0.11 vs. 0.11, P> 0.1). (Table 1)

Feed Conversion

Feed conversion for the calves in the non heat stress environment vs. the heat stress environment was not significantly different (2.03 vs. 1.95, P>0.01). (Table 1)

Effects of Nutritional Treatment on Health Parameters

Rectal Temperature

Nutritional treatment had no effect on the calves RT AM and RT PM (P> 0.1). (Table 2) The interaction between nutritional treatment was not significantly different (P>0.1).

Respiration Rate

Respiration rate was not significantly different between the two nutritional treatment groups in daily RR AM or RR PM (P>0.05). (Table 2)

Fecal Score

There was a significant difference between FS for the nutritional treatments during the pre-weaning period. The HPMR calves had a greater FS than the CMR calves (2.1 vs. 1.7, P <0.01). (Table 2). The higher protein (28%) and/or the higher volume of milk replacer (1.14 kg) per day of milk replacer powder contributed to the higher fecal scores (Figure 5). The interaction of nutritional treatment and environment had no effect on FS (P> 0.1).

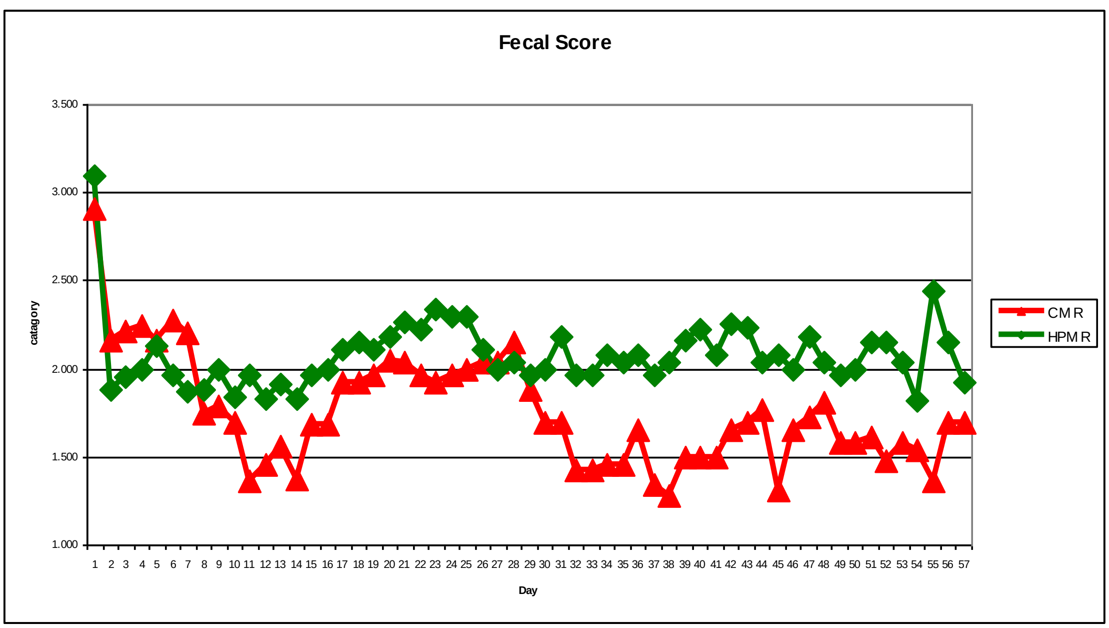


Figure 5. Comparison of fecal scores during pre-weaning between the nutritional treatments.

The variable Day was also significant (P<0.01) as calves generally have higher FS during the early weeks of life and while they are adjusting to milk replacer which decreased as they age and begin to consume more starter feed and ruminate. However, a FS of 1 is not necessarily desirable in all stages of MR consumption.

Similar results for fecal scores related to nutrition were found in studies by Brown, et al., (2004) and Quigley, et al., (2006), which showed calves fed higher percent protein milk replacer and higher amounts of milk replacer (6 L) had higher fecal scores than calves on a lower protein milk replacer and the standard amount of milk replacer given (4 L).

Starter Intake

There was a significant difference between the nutritional treatments for SI during the pre-weaning period. The CMR fed calves had a greater SI (g) (Figure 6), than the HPMR calves 0.72 vs. 0.41, P <0.01). (Table 2). The CMR fed calves received a lower amount (0.454 kg) of milk replacer powder and lower volume of milk replacer (2 L) per feeding. The HPMR calves were receiving greater amounts of protein (1.14 kg) and larger volumes of milk replacer (3 L) per feeding.. A study performed by Borderas, et al., (2009) showed calves that consumed a lower amount of milk replacer had higher concentrate (starter feed) consumption compared to calves fed a higher amount of milk replacer. Once weaning was initiated and milk powder was decreased, both the low and high volume milk replacer groups increased their concentrate consumption, but the lower volume group was still higher during week 8 as milk replacer was reduced.

The interaction of nutritional treatment and environment was not significant for SI (P> 0.1). Starter intake for the CMR fed calves was higher than the HPMR calves throughout the entire pre-weaning period.

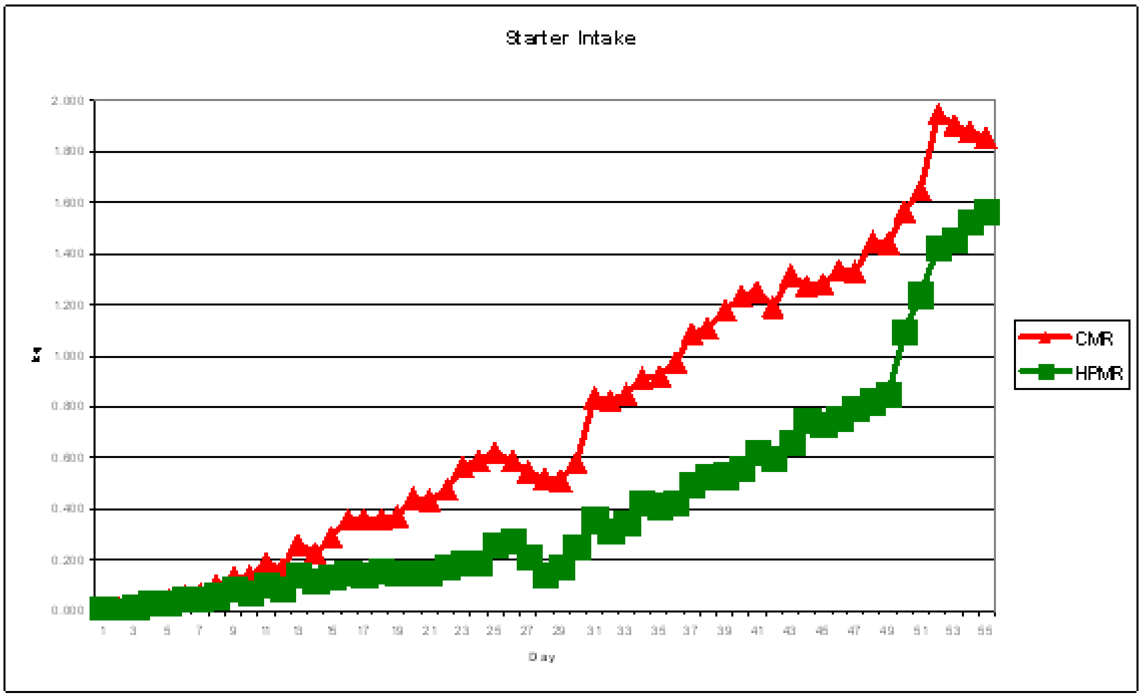


Figure 6. Comparison of starter feed intake during pre-weaning between the nutritional treatments.

Water Consumption

There was a significant difference between the two nutritional treatments for WC during the pre-weaning period. The HPMR calves had a greater WC (ml) than the CMR fed calves (5019 vs. 3711, P <0.01). (Table 2) The interaction between the nutritional treatment and environment was not significantly different (P> 0.1). The HPMR calves had a greater WC than the CMR fed calves which could be linked to the higher protein in the milk replacer given those calves. The HPMR calves required more water to excrete excess protein in their urine. (Figure 7).

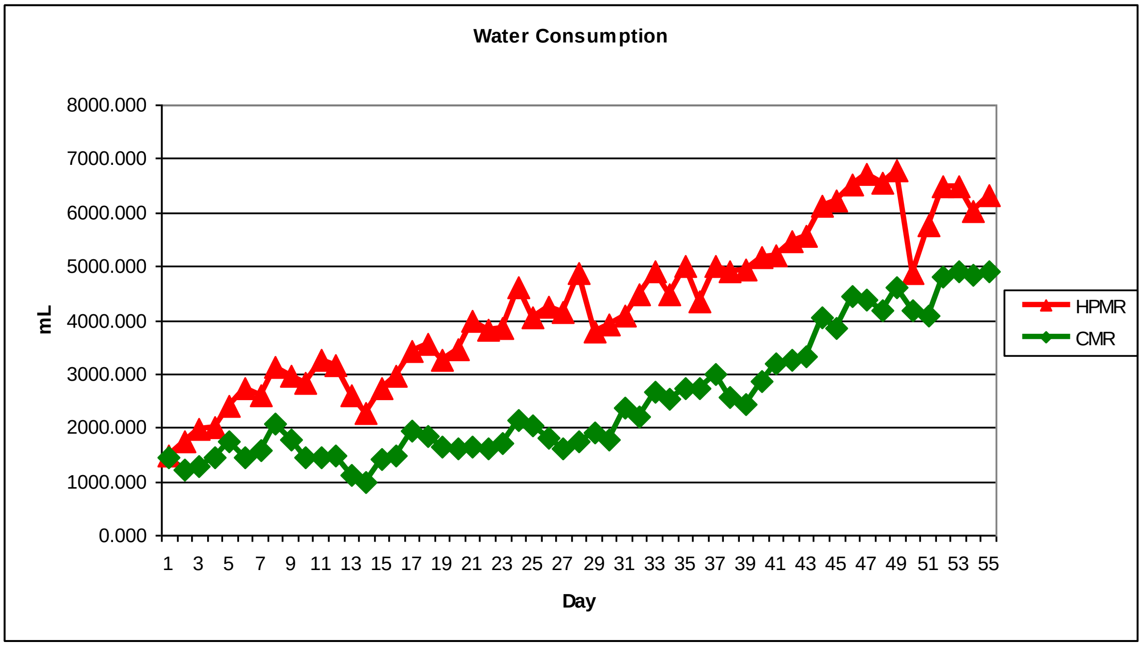


Figure 7. Comparison of water consumption during pre-weaning between the nutritional treatments.

Effects of Environment Treatment on Health Parameters

Rectal Temperature

There was a significant difference in RT AM for the pre-weaning period between the two environments. (Figure 8) The HS calves had a greater RT AM than the NHS calves (38.9 vs. 38.7, P <0.01) (Table 2). This was attributed to the higher ambient temperatures the calves were exposed to throughout the day. On day 7 and 9, the NHS calves had higher RT AM, but after day 9 the HS calves had higher RT AM. Calves housed outside were exposed to a greater heat and humidity, and had to endure the hot and humid conditions and thus had increased greater RT AM than the NHS calves. The interaction between nutritional treatment and environment was significant (P<0.01). (Table 2). The environment contributed to more of the significance in the nutritional and environmental interaction than the nutritional treatment, but in HPMRxNHS and CMRxNHS interactions, nutritional treatment seems to contributed more to the interaction than environment. This is due to the HPMR calves consuming a larger volume of milk replacer as well as higher protein levels than the CMR calves. Nutritional treatment had no effect on the calves RT AM (P> 0.1).

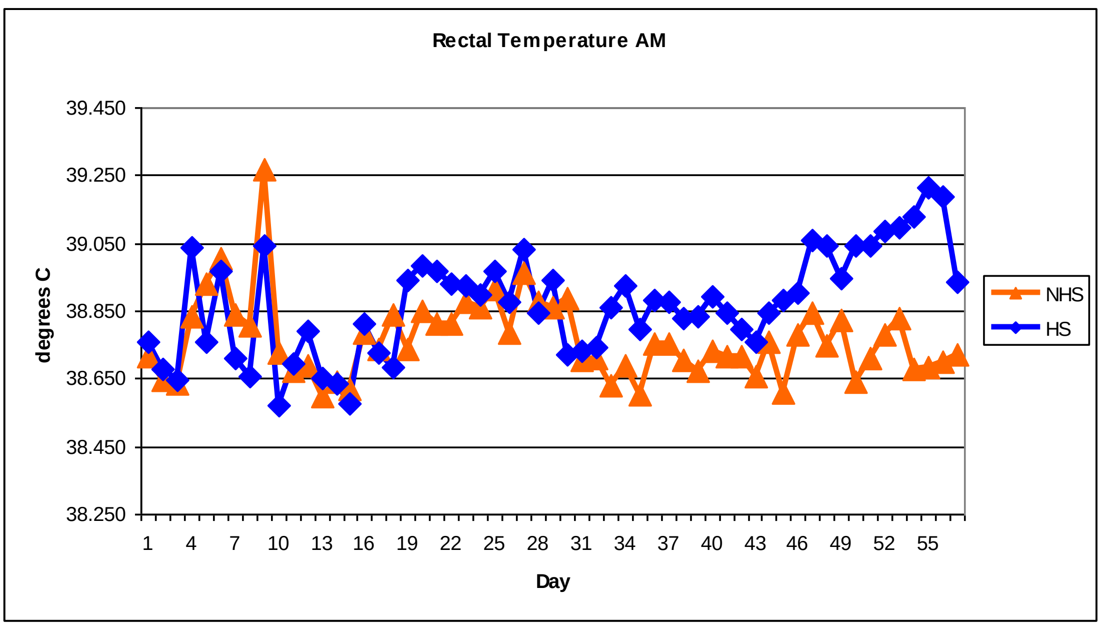


Figure 8. Comparison of rectal temperature AM during pre-weaning between the environments.

There was a significant difference in RT PM between the environments during the pre-weaning period as HS calves had a greater RT PM than the NHS calves (39.1 vs. 38.8, P <0.01). (Table 2). The HS calves were exposed to higher ambient temperatures and in response to the higher temperatures and higher exposure to solar absorption their RT PM increased. Nutrition and the interaction of nutritional treatment and environment had no effect on the calves RT PM (P> 0.1). As the summer progressed, the PM temperature increased causing the RT PM of the calves in HS environment to also increase (Figure 9).

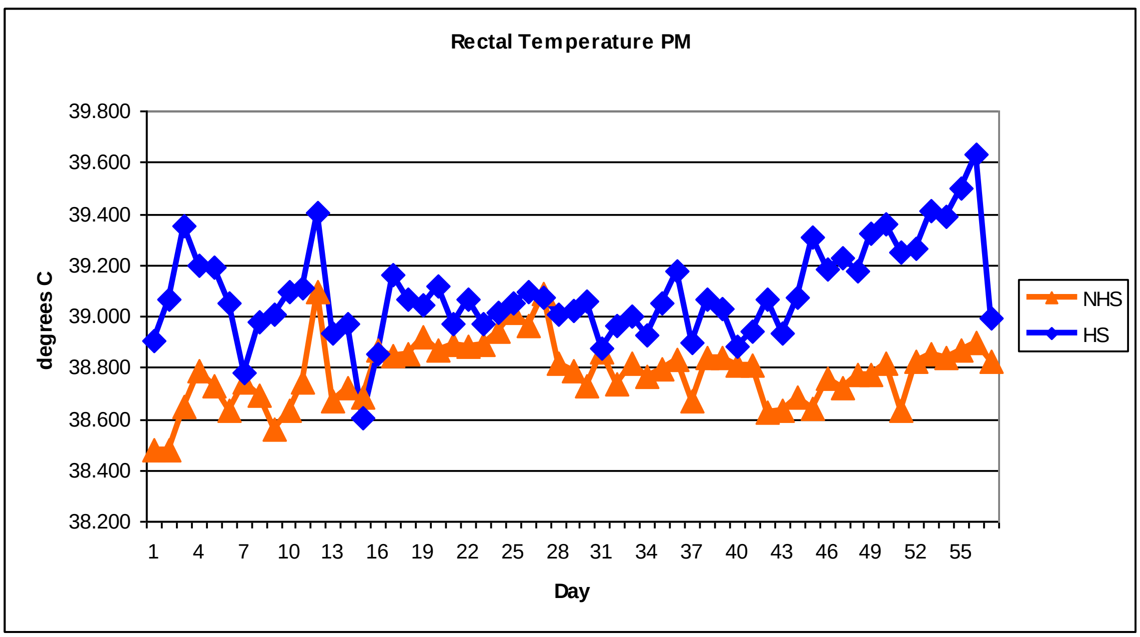


Figure 9. Comparison of rectal temperature PM during pre-weaning between the environments.

Respiration Rate

There was a significant difference between the two environments for RR AM during the pre-weaning period. The HS calves had a greater RR AM than the NHS calves (36.2 vs. 32.4, P <0.01). (Table 2) Nutritional treatment and the interaction of nutritional treatment and environment had no effect on the calves RR AM (P> 0.1) (Figure 10).

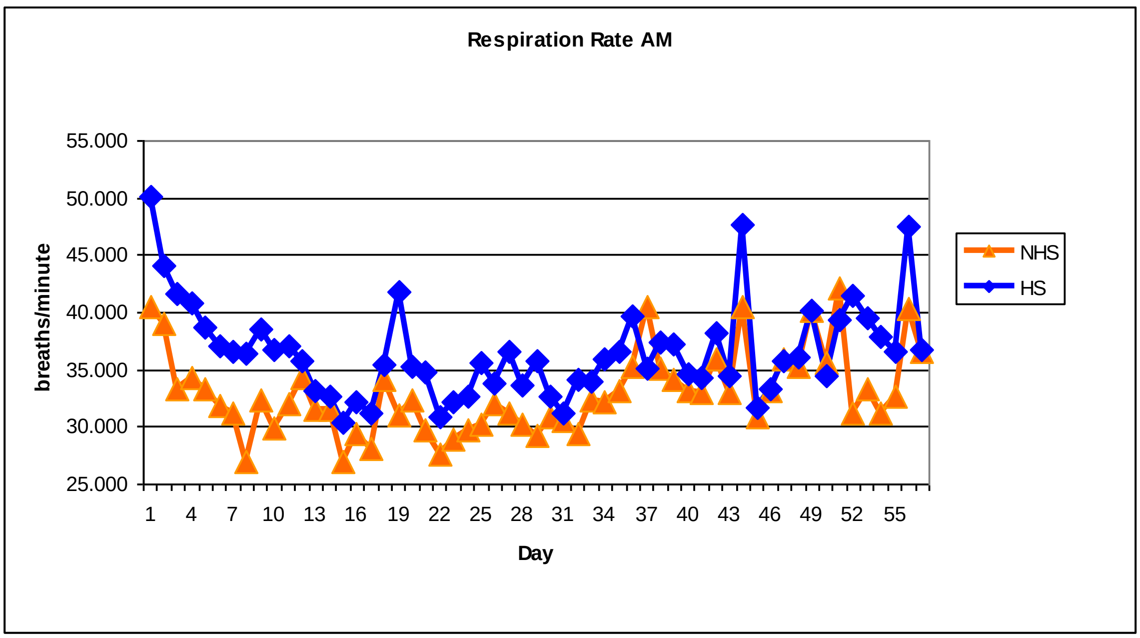


Figure 10. Comparison of respiration rate AM during pre-weaning between the environments.

There was a significant difference in RR PM between the two environments during the pre-weaning period as HS calves had a greater RR PM than the NHS calves (54.6 vs. 38.1, P <0.01). (Table 2). Nutritional treatment and the interaction of nutritional treatment and environment had no effect on the calves RR PM (P> 0.1). As the summer progressed the temperature increased and the HS calves were experienced the higher humidity and temperature and this caused increased RT and increased RR as the calves attempted to dissipate the heat accumulated from the outdoor environment (Figure 11).

HS calves attempted to cool themselves and reach homothermic state by increased RR AM and RR PM in an attempt to dissipate heat.

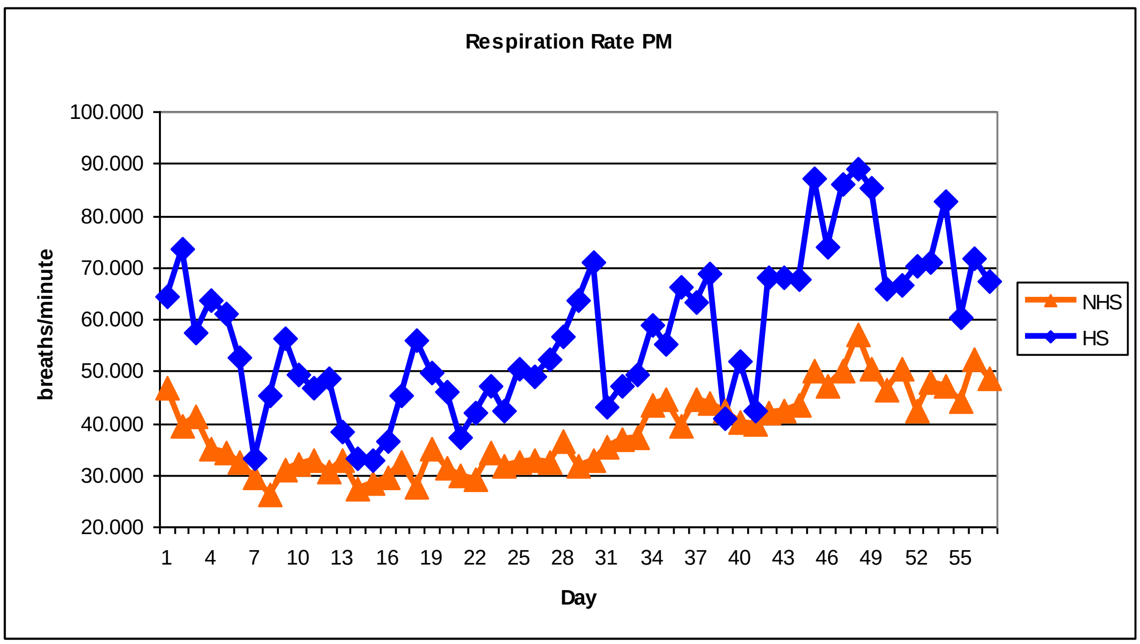


Figure 11. Comparison of respiration rate PM during pre-weaning between the environments.

Spain and Spiers, (1995) showed mature cows will increase respiration rates in an attempt of maintain a homoeothermic state during times of high heat loads. The HS calves attempted to lower the stress by increasing their RT and RR.

Table 2. Comparison between the Environmental Treatments for Health Parameters and Interactions.

	HPMR		CMR			P values		
	HS	NS	HS	NHS	SE	MR	ENV	MR x ENV
Rectal Temperature AM (^{o}C)	38.9	38.7	38.9	38.8	0.032	0.107	<0.0001	0.0002
Rectal Temperature PM (^{o}C)	39.1	38.8	39.2	38.8	0.073	0.646	<0.0001	ns
Respiration Rate AM	35.4	33.1	36.2	32.4	0.426	0.7946	<0.0001	ns
Respiration Rate PM	56.8	39.1	54.6	38.1	0.848	0.062	<0.0001	ns
Fecal Score	2.1	2.0	1.7	1.7	0.049	< 0.001	ns	ns
Starter Intake (kg)	0.41	0.47	0.72	1.17	0.533	0.0416	ns	ns
Water Consumption (mL)	5019	3451	3711	1602	144.61	< 0.001	<0.0001	ns
Febrile Events	2.6	4.9	2.1	7.5	1.33	1.3782	0.0051	ns

ns means not significant (P<0.05).
ENV means environment and MR means milk replacer.

Fecal Scores

Environment had no effect on FS. (Table 1). As the calves became older and consumed more starter feed, their digestive system developed and FS firmed.

Starter Intake

Starter intake was not significant between the different environments (0.47 vs. 0.41, P> 0.1). (Table 2)

Water Consumption

There was a significant difference for WC between the environments. (Figure 12) The HS had a higher overall WC (ml) than NHS (3711 vs. 1602, P <0.01). (Table 2). HS consumed more water in attempt to reach homeothermic state.

Fuquay, (1981) and Berman, (2008) stated that, water loss due to increased urine output and from the skin by evaporation would cause water consumption to increase

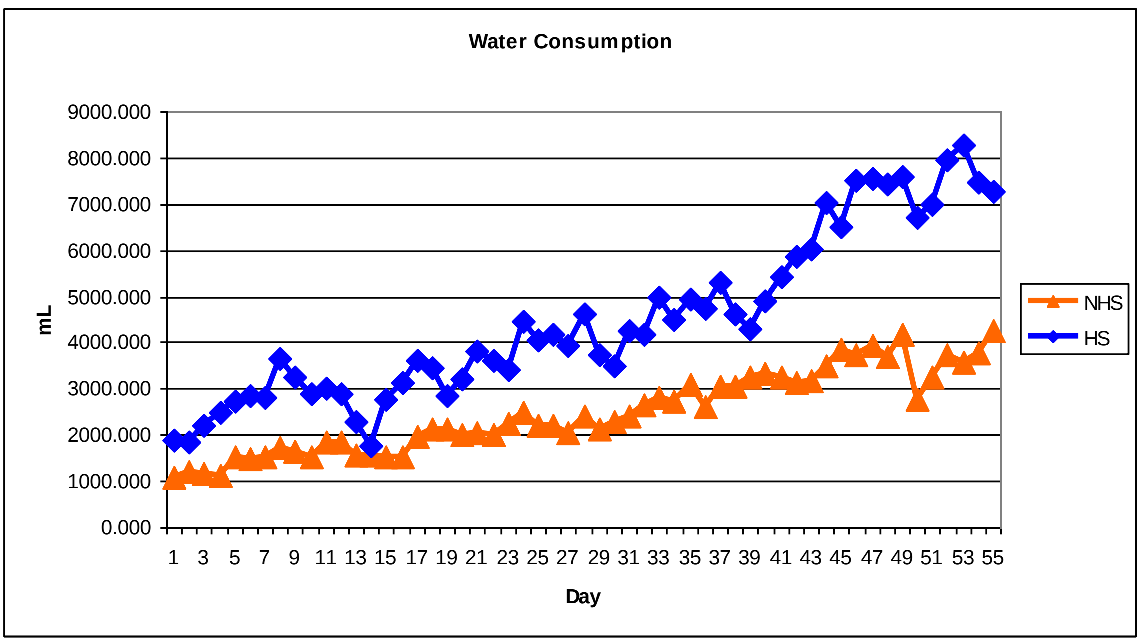


Figure 12. Comparison of water consumption during pre-weaning between the environments.

Febrile Events

There was a significant difference between the two environments in the FE for the pre-weaning period. (Table 2) The NHS calves had a greater number of FE than the HS calves (7.5 vs. 2.1, $P < 0.01$). Nutritional treatment and the interaction of nutritional treatment and environment were not significant for FE ($P > 0.1$).

CHAPTER V

CONCLUSIONS

There needs to be more research performed on heat stress in dairy calves. There have been numerous studies using mature Holstein cows, but very few on neonatal calves. The lactating cow is important on the farm because of the ability to produce milk and reproduce, but the stress a heifer calf endures during neonatal growth might have an effect on the ability to produce milk and reproduce when mature.

Growth of calves was influenced by the amount of protein received. The HPMR calves had a greater increase in HH, HG, WH, BL and ADG than the CMR calves. This agrees with Blome et al., (2003), (Khouri and Pickering, 1968; Gerrits et al., 1996; Diaz et al., 2001) (Bartlett et al., 2006) which showed the ADG, rate of change of the wither height, final heart girth, rate of change in the heart girth, and the rate of change in body length, and final body length all increased as crude protein of the diets increased. The greater quantity of milk replacer received by the HPMR calves enabled them to have a lower SI than the CMR calves. These results were also observed by Borderas et al. (2009) who found that calves consuming a low volume of milk replacer had a significant increase in the amount of concentrate consumed while the high volume milk replacer calves' intake of concentration was low until weaning.

The health of a calf was also influenced by the quantity of milk replacer, higher protein intake, and the environment. A heat stress environment seems to have no effect on the body weight per week and the growth of the calves; however, WC was higher for calves in the HS environment than calves in NHS environments, HS calves had higher

RT AM and RT PM than the CMR calves, and higher RR AM and RR PM. Spain and Spiers (1995) suggested calves exposed to temperatures above their thermo-neutral zone or comfort zone would have a decrease in growth, increased water consumption, and increased RR and RT.

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