Effects of Alternative Housing and Feeding Systems on the Behavior and Performance of
Dairy Heifer Calves

A Thesis

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By

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Abstract

Most heifer calves in the dairy industry are housed individually prior to weaning. However, this type of housing limits the calves' ability to display social behavior, which may impede development of normal social responses. Individual housing is often preferred to minimize undesirable behaviors such as cross-sucking. Previous studies have indicated that if calves are fed with a bottle instead of a bucket, these undesirable behaviors may be reduced. The present study investigated the effects of alternative housing and feeding systems on the behavior and performance of dairy calves. Eighty-two female Holstein calves were allocated to treatments at 6 ± 3 d of age and monitored for approximately 9 wk. Treatments were as follows: individual housing fed with a bucket, individual housing fed with a bottle, paired housing fed with a bucket, or paired housing fed with a bottle. Two experimental sites were utilized. Calves were housed in hutches (non-tethered, wire pen in front of hutch) at Site 1 ($n=34$) and in wire-panel pens (single or double) in a feed commodity shed at Site 2 ($n=48$). Calves allocated to the individual housing treatment were housed in a single hutch at Site 1, whereas calves assigned to the paired treatment were housed by joining two adjacent hutches with doubling of the pen size. Milk was fed via bucket or bottle twice per day (6 L/d). Calves had ad libitum access to calf-starter and water. Gradual weaning commenced at wk 6 by reducing the calves' milk allowance by 2 L/wk. Calves were weaned at the beginning of wk 8. Grain consumption and body weight were monitored on a weekly basis and wither

height measured at the beginning and end of the experiment. Live behavior observations were conducted once per week for all calves at Site 1 and video recorded every other week for all calves at Site 2; behavior measures took place for 2 h both in the morning and afternoon. Total DM intake (grain and milk solids) was greater for calves housed in pairs compared to those housed individually (1.76 ± 0.03 versus 1.69 ± 0.03 ; $P = 0.04$). Although not significant, average daily gain (ADG) was numerically higher for Site 1 compared to Site 2 (0.71 ± 0.03 versus 0.64 ± 0.02 kg/d; $P = 0.12$). Calves were noticeably more active around the morning milk feeding, and calves fed with a bottle spent significantly more time ingesting milk than calves fed with a bucket. Individually housed calves spent more time engaged in non-nutritive oral behavior. Cross-sucking behavior results differed by site; this behavior was observed to be reduced in calves fed with a bottle at Site 1, and no difference between feeding treatments was observed at Site 2. Bottles were typically removed shortly after the calves were finished drinking their milk, which may have contributed to the occurrence of cross-sucking behavior in this study. Thus, this experiment provides evidence that housing young heifer calves in pairs allows for social interactions and may enhance feed intake due to social facilitation.

Dedication

Dedicated to my wonderful parents, Stanley and Leigh Pempek, for their unconditional love and support and for always encouraging me to reach for the stars. They are forever in my heart, my mind, and my determination to succeed.

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CHAPTER 1: INTRODUCTION

I. WHAT IS ANIMAL WELFARE?

Animal welfare may be defined as the “state of an individual in relation to its environment.” Additionally, this involves “how much has to be done [by the animal] to cope [with its environment] and how well or badly coping attempts succeed” (Broom, 1991). Animal welfare ranges on a continuum from very good to very poor and is able to be measured scientifically (Curtis, 1986). In the agricultural community, farm animal welfare is not a modern concept; farmers and veterinarians have been concerned about the condition of the animals under their care “for as long as humans have domesticated animals and have articulated a social consensus ethic” (Rollin, 1995). Proponents of a more traditional view of animal welfare largely perceive good welfare as the absence of unnecessary pain and suffering and the provision of timely and effective care to animals that may be ill or injured (Rushen et al., 2010). However, the more recent interest in farm animal welfare has emerged as a salient subset of broadening public concerns about industrial agriculture or the use of intensive husbandry practices.

In recent decades, ethical concerns about the quality of life experienced by animals used for production purposes have increasingly become the focus of both public and scholarly debates. Although animals have always had welfare, humans have become more aware of this concept and have modified their viewpoints over time, especially recently (Broom, 2011). In the mid-1960’s, animal welfare was presented to the public in

the form of a book entitled “Animal Machines” by Ruth Harrison. This controversial book described the inappropriate handling and management practices employed by individuals involved in the animal production industry and claimed that the animals were treated as if they were objects or “machines” instead of living beings (Harrison, 1964). In response to this book and to report on the issue, the British government established the Brambell Report, which included the following “five freedoms”:

1. Freedom from hunger and thirst,
2. Freedom from discomfort,
3. Freedom from pain, injury, or disease,
4. Freedom from fear and distress, and
5. Freedom to express normal behavior.

Although the Brambell Report was influential in many countries, it was scientifically flawed (Broom, 2003).

After struggling to conceptualize and define the term “welfare”, a concrete definition was proposed by Broom (1991), and individuals, such as biologists and veterinarians, began to acknowledge that animals are vulnerable to challenges from their environment (Broom, 2011). Concurrently, ethicists too struggled to articulate animals’ “needs” and “interests”. For instance, Feinberg (1974) compared the needs of an animal to a car’s need for gasoline if it is to run; needs are required in order for a certain function to be performed, and the lack thereof is detrimental to the welfare of the animal, in this case. Accordingly, if something is good for or harmful to the welfare of the need holder, it in turn must have interests (Feinberg, 1974).

Although animal welfare scientists and ethicists may approach the study of welfare using different concepts and vocabulary, the two groups are concerned with

achieving a common goal: to understand and convey the proper relationship between humans and animals (Fraser, 1999). As this area of study continues to progress, animal welfare science and the ethics of animal use, initially two separate fields of study, continue to overlap. In the United States, all states currently have some form of animal cruelty legislation, yet they are considerably different and acceptable practices vary by state (Mench, 2008).

Recently, veal production has been criticized in the United States; a number of veal farms utilize individual stalls, commonly referred to as “crates”, which limit the calves’ movement and prevent them from turning around (Fraser et al., 2001). Calves may also be tethered to the front of the stall, which has been reproved due to the restriction of movement, social interactions between calves, and total body self-grooming (Wilson et al., 1995). These are the concepts that the consuming public and other interested citizens are beginning to grapple with. As consumers question the values underlying current animal industry practices, such debates continue to escalate (Fraser et al., 1997). Thus, society has turned to science for guidance and justification, which constitutes the emerging field of research that was termed by Dawkins (1980) as “the science of animal welfare”.

II. ANIMAL WELFARE ASSESSMENT

Assessing animal welfare has proven at times to be a challenge for scientists; scientists once disagreed about which approach is the most appropriate form of assessment, yet there is a current general consensus to utilize a broad, comprehensive range of measures. The first approach uses physiological metrics, such as stress hormone

levels (e.g., adrenocorticotrophic hormone or cortisol), pain indicators (e.g., endorphins, enkephalins, or substance P), heart or respiratory rates, or body temperature to assess an animal's welfare (Broom and Johnson, 1993). In sum, a change in the animal's welfare causes a change in its physical and physiological states and thus triggers a physiological response (Barnett and Hemsworth, 1990). Measurements of activity in the hypothalamic-pituitary-adrenal cortex and sympathetic-adrenal medullary systems are very useful in the assessment of how difficult it is for an animal to cope with both long- and short-term stressors (Broom and Johnson, 1993).

The second approach utilized is the behavioral approach. One way to measure behavior is by use of a preference test, which is carried out by allowing the animals to choose between various resources (space, toys, bedding materials, flooring surfaces, etc.) provided. Preference is then measured either by the amount of time the animal spends with the resource or simply by which resource is selected (Barnett and Hemsworth, 2003). For instance, a study conducted by Færevik et al. (2005) investigated social preferences in dairy calves. The calves were subjected to a social preference test in the form of a Y-maze; they were equally able to choose between a familiar or unfamiliar calf. Results indicated that calves spent significantly more time in the area near the familiar calf, and the amount of time the familiar calves interacted with one another was greater than the amount of time unfamiliar calves interacted with one another. Abnormal behaviors, such as unresponsiveness, self-mutilation, movement problems, and stereotypies, are also very important behavioral indicators (Broom, 1991). Welfare is also assessed using the natural living or the nature of the species approach. This third approach is defined by the principle that animals should be kept in “natural”

environments and allowed to express “natural” behaviors (Barnett and Hemsworth, 2003). A more theoretical version of this approach was expressed by Rollin (1993) who suggested “animals, too, have natures - the pigness of the pig, the cowness of the cow . . . - which are as essential to their welfare as speech and assembly are to us.” In addition, as mentioned previously, animal welfare may range from very good to very poor, and it is important to integrate these approaches when assessing the welfare of an animal (Barnett and Hemsworth, 2003). Thus, it is ideal to take a multidisciplinary approach.

CHAPTER 2: LITERATURE REVIEW AND HYPOTHESES

In comparison to other animal industries in the United States, the welfare of dairy cattle is often viewed rather positively by members of the general public and may appear to be unproblematic. This may be due in part to efforts led by organizations, such as the California Milk Board, that perpetuate various images and “Happy Cow” commercials of pastured dairy cattle grazing in vast fields among sheep and other animal species (Croney and Anthony, 2011). Nevertheless, as public concerns continue to escalate and levels of scrutiny rise, many widespread industry practices and whole “systems” of housing and management are being challenged (Rushen et al., 2010).

One criticism of modern veal production and dairying concerns the raising and housing of calves separately from their dams (Rushen et al., 2010). Dairy calves are typically separated from the cow soon after birth and housed in individual hutches or pens. Public surveys suggest that this is disturbing to many people who disagree with the restricted space and isolation from other animals (Rollin, 1996). However, little is known about the potential benefits that the provision of a social partner may have on dairy calf welfare. Thus, the goal of this thesis is to enhance the understanding of the potential beneficial effects of housing young heifer calves in dyads.

I. HOUSING SYSTEMS

One of the most contentious issues related to the management of young heifer calves, and one that has attracted a considerable amount of criticism from the public at large along with animal activist groups, is the employment of individual housing systems during the pre-weaning period. The majority of the dairy industry remains in favor of individually housing their calves in an attempt to avoid undesirable social behaviors and the transmission of disease-causing organisms. Preferences for housing calves individually may also stem from the idea that weight gain may increase under these conditions (Maatje et al., 1993). According to the United States Department of Agriculture (2007), approximately 74.9% of dairy farm operations housed their young heifers individually during 2006. This management practice also allows for precise measurement of feed consumption and the monitoring of fecal consistency, which are both primary indicators of calf health (LeBlanc, 1981). However, there is increasing social pressure, particularly by animal activist groups and retailers responding to perceived consumer demands, to adopt alternative housing and management practices that allow farm animals more opportunity to demonstrate a wider range of normal social behaviors.

A. HEALTH EFFECTS

Although individual housing systems are often recommended as a means of reducing disease transmission between calves, research studies that have been conducted to evaluate the relative health of calves housed individually or in groups have produced conflicting results.

Early epidemiological studies of veal calf group housing systems have indicated that diseases, such as respiratory disease, tend to develop among calves housed in group settings, indicating that calf-to-calf contact may advance the proliferation of the disease (Miller et al., 1980). Correspondingly, Webster et al. (1985b) examined the effect of different calf-rearing systems on the incidence of disease, cleanliness, and injury across multiple farms; calves were either home-reared or bought-in for veal production and housed in individual wooden crates or straw-bedded pens in groups. Calves were monitored for 16 wk, and mortality rate was found to be lower for calves housed individually (1.7%) compared to those housed in groups (3.8%). Webster et al. (1985b) also noted that the percentage of bought-in calves treated for respiratory disease was 5 to 6 times greater than calves that were born and reared on the same farm. However, rate of treatment was comparable between group and individually housed animals that were home-reared. The proportion of group-housed veal calves treated for enteric disease, especially during the first 2 wk of life, was significantly greater than those housed individually in crates.

In accordance, Svensson and Liberg (2006) and Svensson et al. (2006) found that rearing young calves in large groups (6 to 30 animals) with automated feeders was associated with earlier onset and more severe cases of scours and increased risk of respiratory disease; such problems were not observed with groups of smaller animals (3 to 8 animals) with manual milk feeding. Together, these results may suggest that health problems associated with group housing systems may be specific to individual farm management practices and are dependant on the size of the group and feeding method.

Although there is clear evidence that health problems may arise when group size is rather large, more recent studies have reported a very good status of health and similar or even improved growth rates among calves reared in modern group housing systems. For instance, a national survey of 1,685 United States dairy operations revealed a positive correlation between group size and mortality; calves housed in groups of 7 or more had a higher incidence of mortality compared to calves housed in smaller groups or individually, which were nearly equivalent (Losinger and Heinrichs, 1996). Kung et al. (1997) also reported that calves housed individually in hutches required 19 d of medication, whereas calves housed in smaller group settings only required 11 d.

Comparison of different housing systems by use of large-scale epidemiological studies, such as those presented, certainly challenge the former claim that individual housing of pre-weaned calves is most advantageous for their health. Smaller-scale studies have recently made an attempt to isolate the potential confounding effects of group housing by controlling various management practices. For instance, Chua et al. (2002) examined the health and performance of young heifer calves (n=30) that were housed individually or in pairs, and each animal was fed and managed identically. This study revealed that pair-housed calves remained healthy, and there were no differences between housing treatments for the incidence of scouring. Before and after weaning, calves in both treatment groups gained weight rapidly, and there were no significant differences in gains, except during wk 6. During this week of weaning, calves housed in pairs continued to gain weight at pre-weaning levels (approximately 1 kg/d), yet calves housed individually gained weight at half of this rate.

A similar study also investigated the potential beneficial effects of group housing on growth performance (Xiccato et al., 2001). The authors observed that calves reared in groups of 4 showed greater final live weights and significantly greater feed efficiency for the entire experimental period than calves reared individually. Thus, these controlled studies seem to reinforce the larger epidemiological studies by showing that young calves are able to be reared in small groups without it being a detriment to their health, if housing, feeding, and management practices are appropriate.

B. BEHAVIORAL EFFECTS

As mentioned previously, the primary disadvantages of individual housing systems, with regard to behavior as a component of calf welfare, are the inability of the calves to engage in social interactions and the lack of space provided for exercise. However, housing calves individually can reduce cross-sucking and aggressive behaviors and decrease competition among calves for food resources (Rushen et al., 2010).

1. Locomotion

The amount of locomotion that young calves will display is largely dependant upon the total area of space they are allotted. Generally, even though the amount of space provided per calf may be similar, calves housed in group pens commonly have access to a greater total amount of available space (Rushen et al., 2010). This, in turn, will shape the form and frequency of locomotor behaviors exhibited.

It is important to closely examine how each individual study examines and scores various movements, as this can distort and lead to the misinterpretation of the result presented. For example, apart from whether calves were housed individually or in

groups, Webster et al. (1985a) concluded that dairy and veal calves spent between 3% and 7% of their time engaged in locomotion. However, specific types of locomotor behaviors were not noted; pacing forwards and backwards by veal calves was scored as the equivalent of play behavior exhibited by group-housed calves. This is certainly not the case, and it is unlikely that these behaviors are of equal importance to the animals.

Conversely, other experiments, which employed a more detailed ethological approach to measure locomotion, have reported that calves reared in group settings moved more than others reared alone. Chua et al. (2002) compared the behavior of calves housed in pairs to those housed individually and determined that pair-housed calves had twice as many movements as did the individually housed calves (1.43% versus 0.64% of the day). In concurrence, Jensen et al. (1998) reported similar findings in a study that aimed to investigate the effect of social contact and space allowance on play behavior in dairy calves kept in pens. In this experiment, 48 heifer calves were assigned to 1 of 4 housing types: (1) small individual pen (0.9 m x 1.5 m); (2) large individual pen (1.8 m x 3.0 m); (3) small group pen (1.8 m x 3.0 m; housing 4 calves); and (4) large group pen (3.0 m x 5.4 m; housing 4 calves). As the authors expected, space availability influenced the quality and quantity of locomotor play exhibited. They reported a significant increase of locomotor play displayed by calves housed in the larger pen treatment groups compared to calves housed in smaller pens. In addition, elements of locomotor play that require elevation of the hind legs, such as galloping, leaping, buck-kicking, and high bucks, were either entirely absent or rarely observed when calves were housed in small individual pens. Thus, the results of the latter studies seem to indicate

that sufficient space is essential for the expression of certain locomotor behaviors and that a more spatial environment may even stimulate such behaviors.

2. Social Behavior

The majority of domesticated animal species are, by nature, social animals, but contact or rearing with conspecifics is often prohibited in captive settings (Chua et al., 2002). Individual rearing systems prevent calves from making physical contact with one another, and raising calves in total isolation prohibits physical and visual contact; both forms of housing may impede social development (Bøe and Færevik, 2003).

Because of the natural complex dominance hierarchies established among dairy cattle, it is important that calves learn how to interact socially with conspecifics, as this may have indirect effects later in life. The establishment and maintenance of a social group is influenced by positive and negative interactions experienced by the animal, specifically related to agonistic social interactions (Kondo and Hurnik, 1990). As defined by Bøe and Færevik (2003), a *group* is a combination of animals that are of the same species and are able to remain relatively stable over time.

The grouping of unfamiliar animals with one another has been found to increase aggression (Collins et al., 1979) and social stress (Nakanishi et al., 1993; Hasegawa et al., 1997). It may also have negative effects on production traits, such as feed intake (Nakanishi et al., 1993) and milk yield (Hasegawa et al., 1997). With regard to social grouping, cows are the focus of the majority of the literature, and very few studies have been conducted to investigate the group stability among young calves. Kondo et al. (1984) investigated the social stability of 12 Holstein steers housed individually from birth to 5 mo of age. Calves were then divided into 2 groups of 6 calves, referred to as

Groups A and B, and Group B was further divided into 3 groups of 2 calves each. Paired calves were re-grouped every 3 d in order to combine and expose all calves in Group B to one another. All calves from Groups A and B were then combined together and observed at 15 min intervals for 153 h. During the first 24 h, the number of aggressive interactions observed was significantly greater for calves from Group B compared to Group A (53 versus 23 bouts of aggression; $P < 0.05$). Thus, calves originally from Group A appeared to establish social stability at a faster rate.

With regard to animal welfare, it has been suggested that if animals are willing to work in order to gain access to a specific resource, their welfare is likely improved if they are further allowed to interact with that particular resource (Broom, 1988). Holm et al. (2002) examined the motivation of dairy calves for 2 different forms of social contact with a known companion calf, with either head-to-head contact through metal bars or full social contact without restrictions, using operant conditioning methods. Calves were reared individually, but they were trained to press a panel located within their pen to open a gate, which allowed them to enter into another pen housing the companion calf.

As the authors predicted, the calves were motivated to work to gain access to the companion calf. When required to press the panel only 6 times in order to obtain social contact, they did so a total of 10 times, with sessions lasting a minimum of 20 min and a maximum of 50 min. As the number of required presses increased, calves did open the gate less often; calves successfully opened the gate half as many times. In addition, calves were prepared to work harder in order to obtain full social access to the companion calf as opposed to head-to-head contact through the metal bars, indicating that calves may find full social contact more valuable than partial. It was also observed that the calves

were socially active throughout 8.3% of the social period when tested for head contact and 54.1% when tested for full social contact. Thus, the type or “quality” of the social interaction seems to be of great importance. The authors ultimately concluded that “calves are willing to work to get access to a conspecific, which point to a behavioral need for social contact . . . as a consequence, calves’ welfare may be threatened if they are not allowed to perform social behaviors” (Holm et al., 2002).

A comprehensive study conducted by Chua et al. (2002) recorded the behavior of calves reared individually or in pairs over a 7 wk experimental period once a week for 24 h. Behavioral results showed that paired calves engaged in social contact for approximately 2% of the day. Another behavioral study, which categorized play as a form of social behavior, found that this behavioral activity was only displayed by calves housed in small groups compared to those housed individually. These results were consistent across both pre- and post- milk feeding periods and all weeks of life under study (Babu et al., 2004). Dannemann et al. (1985) also reported that calves housed in small groups of 5 engaged in social play for a total of 6.75 min in the period from 800 to 1600 h, which corresponds to 3.8% of the active time for social play.

One potential consequence of denying young calves the opportunity for social contact is that they may not develop the social skills necessary to adjust and cope with group housing situations later in life, as they may be either more fearful of conspecifics or more or insufficiently aggressive (Rushen et al., 2010). Several studies have also reported higher weight gains for group-housed calves compared to calves housed individually during the milk-feeding period, which is often attributed to social facilitation (Chua et al., 2002; Xiccato et al., 2002). The studies discussed thus far have measured

social behavior during the pre-weaning phase of life, but it is just as important to evaluate calf welfare and behavior upon being introduced to larger groups of calves post-weaning. Unfortunately, this thesis only examines the milk-feeding period. Ideally, future studies should try to extend beyond the milk-feeding period and continue to follow the calves post-weaning.

Veisser et al. (1994) examined the effects of rearing young calves individually or in a group of 4 on subsequent social behavior. After re-grouping the calves at 14 wk of age, more agonistic and fewer affiliative behaviors (positive social behaviors such as playing or allogrooming) were observed in groups of calves that were previously individually housed. Complementary research studies, although scarce in quantity, have investigated the longer-term effects associated with the absence of social behavior in individually reared calves (Jensen et al., 1999). For the first 3 mo of life, calves were housed either in: (1) single pens with open sides; (2) single pens with closed sides (physically and visually isolated); (3) groups of 5 calves; or (4) groups of 5 cow-calf pairs. After weaning, all experimental calves were housed in similar tie-stalls, and at 26 wk of age, they were subjected to an open-field test by introducing them into a novel area containing an unfamiliar heifer. Previously isolated calves housed in pens with closed sides had a longer latency to enter the open-field test arena. Additionally, group-reared calves (both groups of 5 calves and groups of 5 cow-calf pairs) spent more time engaged in mock fighting (interpreted as play behavior) and sniffed and mounted the unfamiliar heifer more than calves housed in single pens (both single pens with open sides and single pens with closed sides). Thus, individual rearing may reduce the calf's ability to cope with unfamiliar animals during initial encounters (Rushen et al., 2010). More research in this

area is needed to fully understand the long-term effects that individual housing systems may impose on social behavior and the welfare of young calves.

II. BEHAVIORAL NEEDS AND MOTIVATION

The inability of an animal to perform behaviors that it is instinctually motivated to perform is viewed as a welfare concern, and this may directly and indirectly affect the welfare of the animal. This is thought to be a direct influence as the performance of the behavior is what the animal prefers and indirectly as the underlying motivation is associated with positive or negative affective states (Rushen et al., 2010). A portion of research in this area has been conducted to examine the primary factors associated with sucking behavior in young calves.

A. SUCKING MOTIVATION

Because the survival of young mammals largely depends on sucking success, it has been suggested that the motivation to suck must be strong and restriction of this behavior may in turn result in frustration and negatively impact the level of welfare the animal experiences (de Passillé, 2001). The main function of sucking behavior may appear to be an obvious one: to obtain milk. Under natural conditions, sucking bouts on the dam have been observed to occur up to 10 times per day, and depending on the age of the calf, may be 7 to 10 min in duration (Spinka and Illmann, 1992). However, under modern production systems and despite having received adequate nutrition, young calves continue to suck on the fixtures of the pen along with each other (de Passillé, 2001). Sambras (1985) suggested that the occurrence of this abnormal behavior is due to an

increased desire to suck, resulting from the lack of opportunity to do so on the dam.

The majority of research examining the factors that may contribute to or inhibit non-nutritive sucking by young calves has been done by experimentally testing how they interact with an artificial, dry rubber teat. One such experiment conducted by de Passillé (2001) examined the motivation of non-nutritive sucking by calves through a series of tests where calves were fed milk replacer by bucket and allowed to suck from a dry, artificial teat. To separate the effects of sucking behavior from milk ingestion, calves did not receive milk through the teat. After the morning and evening meals, calves suckled on the artificial teat an average duration of 5.5 min, yet when provided outside of regular meal times, they sucked on it for less than 1 min. When the provision of the teat was delayed for 10, 30, or 60 min after the milk replacer meal, the experimenters discovered that calves sucked and butted the dry teat less than if offered directly after the meal. These results provide experimental evidence that non-nutritive sucking is elicited rather than reduced by the ingestion of milk and it is specifically the taste of milk that elicits sucking behavior.

B. PHYSIOLOGICAL RESPONSES

In human infants and rats, research has documented non-nutritive sucking to have a calming effect, which mitigates behavioral agitation induced by stressful encounters (McCain, 1995). In young calves, sucking behavior is stimulated by the ingestion of milk. However, the desire to suckle seems to be resolved by sucking behavior or bouts of non-nutritive sucking more so than the ingestion of milk (Rushen and de Passillé, 1995).

Sucking behavior also increases plasma concentrations of cholecystokinin (CCK)

and insulin (de Passillé et al., 1993). Research has documented that CCK elicits the secretion of insulin and increased insulin availability has been shown to correlate positively with increased levels of satiety (Vanderweele, 1982). An experiment conducted by de Passillé et al. (1993) examined this concept as they investigated non-nutritive sucking and its effects on postprandial secretion of CCK, insulin, and gastrin. In order to determine if non-nutritive sucking affected hormone secretion, early-weaned calves were granted access to a dry, artificial teat after completion of their milk meal, and blood samples were taken and analyzed for CCK, insulin, and gastrin. Samples collected from the hepatic portal vein indicated higher concentrations of CCK and insulin 60 min postprandium in calves that were allowed to suck the teat compared to those who were not. The increase in CCK and insulin concentrations was also positively correlated with the duration of time calves spent sucking the artificial teat, but this was not found to be true with the duration of other oral behaviors directed toward the teat. Thus, this signifies that it is the actual sucking behavior that is of importance to young calves rather than the stimulation experienced from merely placing the teat in the mouth. In addition to quantifying hormone concentrations, cardiac activity is also a physiological measure commonly used to assess animal welfare levels; sucking for milk has been associated with a decrease in heart rate during meals and inducing a calmer state in young calves (Veissier et al., 2002).

C. NON-NUTRITIVE SUCKING

Sucking may be classified either as nutritive, where young calves are able to obtain milk, or non-nutritive. Non-nutritive sucking may be observed under natural conditions,

yet more commonly occurs within artificial rearing systems and is directed towards various fixtures of the pen, a dry artificial teat, or if accessible, another calf without receiving any nutritive reinforcement (Jensen, 2003). It is the latter of the 3, referred to as cross-sucking, that is a prime concern for dairy producers and a behavioral advantage for individual housing systems. Cross-sucking is an abnormal behavior defined as non-nutritive sucking directed toward another calf's ears, mouth, navel, scrotum, prepuce, or other body parts (de Wilt, 1985), and this behavior stems from redirection of the calf's natural sucking behavior (Jensen, 2003). One reason dairy producers are reluctant to adopt modern group-housing systems is because this behavior may cause hair loss and inflammation of the part of the body that has been exposed by cross-sucking (Lidfors, 1993).

Although some studies report problems of cross sucking in group-housed calves (Lidfors and Isberg, 2003; Margerison et al., 2003), others report only a low incidence of this behavior (Chua et al., 2002; Mattiello et al., 2002). For instance, Mattiello et al. (2002) reported that when housed in smaller groups of 5 animals, unweaned veal calves performed cross-sucking at low frequencies around milk meals (from 4.70%/2 h observation period at wk 2 to 1.05%/2 h observation period at wk 23) and even lower frequencies at times unassociated with milk delivery. In accordance, Haley et al. (1998) also noted little, if any, obvious sucking on pen fixtures or other calves; all sucking was directed at the teat. With regard to cross-sucking in a group setting, it is of great importance that the feeding method by which the milk is delivered be examined.

III. MILK FEEDING SYSTEMS

The nutrition and type of feeding management systems employed by dairy producers can have marked effects on the health, performance, and welfare of young calves. The majority of feeding programs provide milk from a bucket or pail, minimizing the ability of calves to express their natural sucking behavior (Rushen et al., 2010). For instance, a recent study in Canada acknowledged that a bucket was used to feed milk by 92.0% of dairy producers and a bottle with a teat by only 17.7% (Vasseur et al., 2009). As opposed to the standard practice of feeding by bucket, which was used in this thesis, calves can also be fed with a bottle or a bucket that is fitted with a teat; both methods facilitate sucking behavior.

Research has documented a number of advantages coupled with the allowance of sucking behavior during meals of milk. As previously mentioned, sucking behavior may indirectly increase levels of satiety through the secretion of CCK and insulin (de Passillé et al., 1993). In association with levels of satiety, compared with bucket feeding, Veissier et al. (2002) observed a shorter latency to lie down by calves able to perform nutritive sucking, which also extended the total amount of time spent lying down, especially with the head unsupported by the neck. Moreover, this particular posture has been associated with lower levels of arousal and is related to the occurrence of rapid eye movement sleep (Veissier et al., 1989). There is also evidence supporting the notion that heart rates are lower among teat-fed calves compared to bucket-fed calves (Veissier et al., 2002).

A. BEHAVIORAL EFFECTS

In terms of behavior, teat feeding clearly differs from bucket feeding. Sucking milk through a teat has been noted to significantly reduce the amount of non-nutritive sucking, which may be due in part to an increase in the total amount of time spent drinking (Appleby et al., 2001). For example, Jensen and Budde (2006) conducted a comprehensive study that examined the effects of milk feeding method and group size on feeding behavior and cross-sucking in group-housed dairy calves. The treatments were as follows: (1) pair housing and bucket feeding; (2) pair housing and bottle with teat feeding; (3) group housing and bucket feeding (6 calves per group); and (4) group housing and bottle with teat feeding (6 calves per group). Irrespective of group size, bottle-fed calves spent more time ingesting the milk (4.04 versus 1.39 min/30 min observation) and less time licking the pen fixtures (0.76 versus 1.43 min/30 min observations).

In addition, similar results were reported by Hammell et al. (1988) as they investigated sucking behavior of dairy calves fed ad libitum milk by bucket or teat. All calves were provided with access to a dry, artificial teat, as well. Bottle-fed calves spent more time ingesting milk compared to calves fed by the bucket-feeding method (44.2 versus 17.7 min/d), and calves fed with a teat drank significantly more milk (11.9 versus 8.0 kg/d). Interestingly, bucket-fed calves spent approximately 13 min/d sucking the artificial teat compared to 1 min/d for the bottle-fed calves. Also, calves fed with a bucket were observed to interrupt meals with bouts of non-nutritive sucking, which may indicate that sucking behavior is of equal or greater value than ingesting or drinking milk. These results suggest that the ingestion of milk in itself does not eliminate the sucking

response and thus supports the idea of strong motivation of the young calf to elicit sucking behavior. The authors concluded that “because a calf has such a strong urge to suck, the safest way to limit non-nutritive sucking with its injurious consequences is teat-feeding, i.e. giving the calf the opportunity for nutritive sucking.”

1. Cross-Sucking

From the results of the previous studies, it seems as though cross-sucking in calves tends to occur immediately after meals of milk compared to other times throughout the day (de Passillé, 2001), and very little sucking occurs after the calves are weaned from milk (Lidfors, 1993). Thus, the focus of this review will remain only on the milk-feeding period.

Few studies have reported cross-sucking as being a problem or injurious to calf health. However, a large majority of the experiments that did find this to be a concern only offered milk to calves in a bucket or trough; neither bottles nor buckets fitted with a teat were provided as a method for comparison nor were artificial teats present to manage sucking behavior (Margerison et al., 2003). According to Rushen et al. (2010), cross-sucking may be controlled by the utilization of proper management practices and the adoption of a suitable feeding program. For instance, when calves were provided the same amount of milk and only the method of delivery varied, calves fed with a bucket spent significantly more time cross-sucking than teat-fed calves (1.91 versus 0.16 min/30 min observations) (Jensen and Budde, 2006). The cross-sucking that did occur was directed toward the head and around the muzzle, which was smeared with milk after completing a meal.

In addition to the use of individual bottles, automated milk feeders also promote

sucking behavior and may be employed as a method to reduce cross-sucking. For example, in a study where the milk was delivered slowly in a bucket and calves were allowed to suck on a floating teat placed within, calves were observed to perform significantly less cross-sucking compared to other calves that did not have access to a floating teat (Loberg and Lidfors, 2001). The authors attributed this to the combination of low milk flow rate and the opportunity for young calves to exhibit sucking behavior. Access to a dry, artificial teat coupled with milk feeding in open buckets can also significantly reduce the occurrence of cross-sucking behavior in young calves housed in small groups (de Passillé and Caza, 1997).

However, the use of automated teat-feeding systems are not invariably associated with a decline in cross-sucking behavior. A study conducted by Veissier et al. (2002) reported an increase in cross-sucking in group-housed calves that were fed with an automatic device fitted with a teat compared to bucket-fed calves. The authors postulated that this may have been due in part to the fact that each treatment was only observed once throughout the experimental period; more observation periods may have been needed. These results suggest that in addition to feeding method, feeding management practices are of great importance to reduce cross-sucking behavior.

B. HEALTH AND PERFORMANCE EFFECTS

The rate at which a calf consumes milk directly affects the rate at which it is able to pass through the digestive tract. It has been previously noted that calves fed with a bucket or open pail spend less time ingesting milk compared to teat-fed calves (Hammell et al., 1988; Jensen and Budde, 2006), which results in a higher rate of passage of milk to

the lower gut (Abe et al., 1979). The slower consumption rate, attributable to teat feeding methods, seems to enhance various physiological processes of digestion. For instance, lipase is secreted in the mouth in saliva, and additional saliva production increases the amount of salivary lipase that is secreted and incorporated with the milk before it is swallowed by the calf. Lipase is necessary for the digestion of fats, which are a vital energy source. Previous research has reported the amount of saliva produced by teat-fed calves to be significantly higher than the amount produced by calves fed with a bucket (Moran, 2002). In addition, feeding from an open pail or bucket fails to stimulate the secretion of abomasal enzymes as readily as sucking from a teat (Radostits and Bell, 1970).

Furthermore, the method by which milk is offered may also affect the health and performance of young calves. Several studies have evaluated the 2 primary methods of milk feeding. Wise and LeMaster (1968) compared the health, performance, and physical appearance of calves fed with an open bucket or a bottle. Initially, calves were fed milk at 7% of body weight (BW), increasing to 10% by 14 d of age, and remaining at this rate until d 56. The authors reported no significant differences imposed between the 2 feeding treatments on the calves' health, physical appearance, or weight gain. In agreement, Quigly et al. (1992) discovered that feeding method did not appear to have a significant effect on BW, average daily gain (ADG), nutrient intake, or feed efficiency. Other studies have compared the health and performance of calves fed ad libitum milk from artificial teats to the standard feeding method of providing milk in buckets twice daily (5% BW/feeding) (Appleby et al., 2001). Ad libitum feeding by this method reduced overall incidence of diarrhea compared to calves fed from buckets. The authors

suggested that this decrease occurred primarily because the calves were able to suck from the teat and noted that sucking behavior had 2 positive effects: (1) this behavior stimulated the function of the esophageal groove, allowing milk to pass directly to the abomasum and (2) increased secretion of metabolic hormones important for nutrient absorption. Ad libitum feeding from artificial teats also considerably increased milk consumption and weight gain; calves assigned to this feeding treatment weighed 15% more than calves fed with a bucket by the end of the experimental period.

IV. SUMMARY OF HYPOTHESES

In this chapter, the individual and group housing systems have been reviewed that are currently in use for young calves throughout the dairy industry and investigated as to how each system may directly or indirectly affect the health, performance, and thus, welfare of the animals under each system. In addition, teat and bucket feeding methods have been reviewed, as were cross-sucking behavior and the underlying factors that contribute to this behavior. Collectively, based on this information, the hypotheses for this study were:

1. Calves fed with a bottle would exhibit less cross-sucking and non-nutritive sucking than calves fed with a bucket,
2. Bucket-fed and calves housed in pairs would have a higher feed intake than bottle-fed and calves housed individually, and
3. Housing calves in pairs would not be a detriment to their overall health or performance.

CHAPTER 3: MATERIALS AND METHODS

This research study was conducted from July through December at Twin Oak Dairy, LLC located in South Solon, Ohio, approximately 40 miles southwest of The Ohio State University. Calves were separated from their dams and fed colostrum (4 L first feeding; 2 L second feeding) within 12 h of birth. Eighty-two female Holstein calves were allocated to treatments in order of birth at 6 ± 3 d of age and monitored for approximately 9 wk. Calves were assigned to blocks according to date of birth; within blocks, the calves were allocated to either individual housing or pair housing and balanced for milk feeding method (bucket or bottle) and age. Calves assigned to the pair housing treatment were also balanced for weight. Under a 2 x 2 factorial design, the 4 treatments were as follows: calves in individual housing fed with a bucket, calves in individual housing fed with a bottle, calves paired and fed with a bucket, and calves paired and fed with a bottle.

I. SERUM PROTEIN LEVELS

Blood samples were collected in 5-mL Vacutainer serum collection tubes (BD Vacutainer Plus Blood Clot Collection Tubes, Franklin Lakes, NJ) via jugular venipuncture immediately before the calves were placed on trial (6 ± 3 d of age). Samples were stored on ice and allowed to clot at room temperature for at least 30 min before centrifuging at 3500 RPM for 15 min. Serum protein was analyzed using a JorVet

clinical hand-held refractometer (Jorgesen Laboratories, Inc., Loveland, CO). All calves used in the study had a total serum protein level > 5.5 g/dl (Site 1: 7.09 ± 0.14 g/dl; Site 2: 7.45 ± 0.11 g/dl).

II. HOUSING

Two experimental sites were utilized. Calves were housed in hutches (non-tethered, wire pen) at Site 1 ($n = 34$) and in wire-panel pens in a feed commodity shed at Site 2 ($n = 48$). Straw bedding was provided for all calves housed at Sites 1 and 2. Calves allocated to the individual treatment were housed in a single hutch at Site 1, whereas calves assigned to the paired treatment were housed by joining two adjacent hutches with doubling of the pen size (Figure A.1); individually housed calves had a panel 0.91 m in width by 1.52 m in length attached to the front of the hutch, and calves housed in pairs had a panel 0.91 m in width by 3.05 m in length attached to the front of the hutch. The hutches used were 0.91 m in width and 1.83 m in length. Calves allocated to the individual treatment at Site 2 were housed in a 1.22 m x 1.83 m pen, and calves assigned to the paired treatment were housed in a 1.22 m x 3.66 m pen (Figure A.2).

III. PERFORMANCE MEASUREMENTS

Grain fed was weighed daily and refusals collected each morning. The weekly refusals were weighed and daily intake calculated by week. Refusals were averaged for calves that were housed in pairs. Grain was fed to all calves in a bucket and remained inside of the hutches at Site 1 and pens at Site 2. Water was available at all times throughout the experiment. Calves were weighed once per week, and wither height

measurements were taken at the beginning and end of the experiment using a wither height stick.

IV. FEED

Pasteurized whole milk (Westwaard Pasteurizer, Dairy Tech, Inc., Lynden, WA; 102°F) was fed via bucket or bottle twice per day, and calves were given a quantity of 6 L per day. The calves were fed at approximately 0700 (2 L of milk) and 1700 h (4 L of milk). A small number of calves housed at Site 1 received only 4 L/d of milk compared to other calves receiving 6 L/d in total. One additional bottle-fed treatment group at Site 1 received 6L/d, which confounded site and feeding method with regard to milk dry matter intake. Gradual weaning commenced at wk 6 by reducing the calves' milk allowance by 2 L each week, and calves were weaned at the beginning of wk 8. All calves had ad libitum access to water and calf-starter, which averaged 95.7% dry matter and 21.1% crude protein (Table 3.1; Premier Feeds, Wilmington, Ohio).

A. MILK SAMPLE ANALYSIS

Before each morning feeding, milk was sampled throughout the study. Each week, milk samples were submitted to DHI Cooperative, Inc. (Columbus, OH) and analyzed for concentrations of fat, protein, somatic cell count (SCC), lactose, and other solids using infrared spectroscopy (B2000 Infrared Analyzer, Bentley Instruments, Chaska, MN) and milk urea nitrogen (MUN) (Skalar SAN Plus segmented flow analyzer, Skalar, Inc., Norcross, GA). The composition of the milk is listed in Table 3.1.

B. FEED SAMPLE ANALYSIS

Samples of fresh calf-starter were collected on a weekly basis and were then composited per two-week period. Each individual sample was weighed (100 g/sample) and dried for 48 h at 55°C. Samples were then ground and submitted to Cumberland Valley Analytical Services, Inc. (Maugansville, MD) for the following wet chemistry standard analysis: dry matter (Goering and Van Soest, 1970; Shreve et al., 2006), crude protein (Krishnamoorthy et al., 1983), neutral detergent fiber (NDF) (Van Soest et al., 1991), acid detergent fiber (ADF) (AOAC, 2000b), ash (AOAC, 2000a), minerals (AOAC, 2000c), and starch (Hall, 2009) (Table 3.1).

PARAMETER	STARTER ¹	MILK ²
DM (%)	95.69	ND ³
CP (%)	21.14	3.41
NDF (% of DM)	21.86	ND ³
ADF (% of DM)	12.45	ND ³
Fat (%)	ND ³	3.99
Starch (% of DM)	4.00	ND ³
Ash (% DM)	5.15	ND ³
Lactose (%)	ND ³	4.60
Other solids (%)	ND ³	5.49
Ca (% of DM)	0.49	ND ³
Cu (% of DM)	46.00	ND ³
P (% of DM)	0.45	ND ³
Mn (% of DM)	115.63	ND ³
Fe (PPM)	150.00	ND ³
K (% of DM)	1.19	ND ³
Mg (% of DM)	0.26	ND ³
Na (% of DM)	0.13	ND ³
Zn (% of DM)	182.75	ND ³
SCC (x 1,000/mL)	ND ³	914.05
MUN (mg/dL)	ND ³	9.69

¹Calf-starter diet (Premier Feeds, Wilmington, Ohio).

²Whole milk.

³ND = Not determined.

TABLE 3.1. MEAN CHEMICAL COMPOSITION OF CALF-STARTER AND MILK.

V. BEHAVIORAL MEASUREMENTS

A. SITE 1 OBSERVATIONS

The behavior of the calves at Site 1 was recorded directly once per week at milk feeding in the morning for 90 min and for 120 min 2 h after the completion of morning

observations, generally from 1130 to 1330 h. Calves did not appear to be interested in or disturbed by the presence of the observer. In addition to the primary observer, two additional individuals were trained to monitor the calves' behavior; a detailed ethogram was provided (Table 3.2) and used throughout the study. Through several training observation periods, the primary observer monitored and scored the behavior of the calves with the other observers to ensure that behaviors were scored in the same manner.

During an observation period, the observer walked in full view of the calves that spanned the length of one row; each row consisted of 12 calves. First, as the observer passed in front of each calf, a mutually exclusive, instantaneous scan-sample was obtained. On average, the observer took 2 s to observe, identify, and record the posture and behavior performed by one calf. After the initial scan-samples were collected, each calf was observed in a pre-determined, randomized order for 1 min continuously. Continuous behavior observations were not mutually exclusive. Each calf was scored instantaneously and observed continuously once every 20 min for a total of 10 instantaneous scores and 10 min of continuous observation per calf per week, yielding 80 scan-samples and 80 min of observation obtained over the course of the study per calf. The behaviors recorded are defined in Table 3.2 and examples of behaviors classified as solitary play are given in Figure B.1.

Behavior	Description
Lying	The calf is resting on the ground; head may be supported or unsupported by the neck
Lying same hutch	Pair-housed calves only: Companion calves are both resting on the ground within the same hutch; head may be supported or unsupported by the neck
Standing	The calf is standing with all four legs on the ground
Walking	The calf is engaged in forward locomotion at a relaxed speed
Other	The calf is idle, ruminating, urinating or defecating
Interacting with pen fixtures	The calf's tongue is out of its mouth and is in contact with or biting any fixtures of the pen; may include bucket if milk is not available at the time of observation
Self-grooming	The calf's tongue is out of its mouth and in contact with its own body
Solitary play	The calf is engaged in a gallop, leap, buck-low, buck-high, buck-kick, or turn
Starter interaction	The calf is consuming calf-starter from a bucket
Water interaction	The calf is ingesting water by drinking from a bucket
Milk interaction	The calf is ingesting milk either by sucking on the teat or by drinking from a bucket; may include sucking on the teat without the ingestion of milk
Cross-sucking	Pair-housed calves only: The calf is sucking on the body of another calf; the sucking movements are performed with the body part in the mouth
Allogrooming	Pair-housed calves only: The calf's tongue is out of its mouth and in contact with the head, neck, or body of the companion calf
Social play	Pair-housed calves only: The calves are standing front to front, butting head against head/neck in a playful manner; the calf is engaged in a gallop, leap, buck-low, buck-high, buck-kick, or turn with companion calf

TABLE 3.2. DESCRIPTION OF THE RECORDED BEHAVIORS OBSERVED AT SITE 1.

B. SITE 2 OBSERVATIONS

Video cameras (JVC GZ-HM300, Yokohama, Japan; Canon Optura 30, Ōta, Tokyo, Japan) were positioned above the pens to record the behavior of 4 calves per observation period at Site 2. Calves were taped for approximately 90 min around the morning feeding and for 120 min 2 h after the completion of the morning recording, generally from 1100 to 1300 h in the afternoon, at 1, 3, 5, and 7 wk of age. Posture and

behaviors were scored by one observer from the videotape by scan-sampling 1 frame every 10 min, beginning 10 min after the cameras were set to record. On average, this sampling method provided 9 observations per calf during the morning recording period and 12 observations per calf during the afternoon. Over the course of the experiment, each calf was scored instantaneously for a total of 36 observations during the morning and 48 observations during the afternoon.

The behavior of the calves was also observed continuously from the video recordings during week 1 and 7 of the experiment. Once again, the behaviors measured continuously were not mutually exclusive. During the morning milk feeding, the continuous observations began the instant the calves had access to milk and continued for 20 min, providing 40 min in total per calf. For each calf, one observer recorded the behavioral elements that are defined in Table 3.3.

As discussed, behavior observations for Sites 1 and 2 were conducted differently. This was primarily due to the limited amount of cameras available for use, which did not allow for calves housed in hutches at Site 1 to be video-recorded. Thus, calves housed at Site 1 had to be observed using direct-sampling methods.

Behavior	Description
Lying	The calf is resting on the ground; head may be supported or unsupported by the neck
Lying (adjacent)	Pair-housed calves only: Companion calves are both resting on the ground directly next to one another; head may be supported or unsupported by the neck
Standing	The calf is standing with all four legs on the ground
Walking	The calf is engaged in forward locomotion at a relaxed speed
Other	The calf is idle, ruminating, urinating or defecating
Interacting with pen fixtures*	The calf's tongue is out of its mouth and is in contact with or biting any fixtures of the pen; may include bucket if milk is not available at the time of observation
Self-grooming*	The calf's tongue is out of its mouth and in contact with its own body
Solitary play	The calf is engaged in a gallop, leap, buck-low, buck-high, buck-kick, or turn
Starter interaction	The calf is consuming calf-starter from a bucket
Water interaction	The calf is ingesting water by drinking from a bucket
Milk interaction*	The calf is ingesting milk either by sucking on the teat or by drinking from a bucket; may include sucking on the teat without the ingestion of milk
Cross-sucking*	Pair-housed calves only: The calf is sucking on the body of another calf; the sucking movements are performed with the body part in the mouth
Social play*	Pair-housed calves only: The calves are standing front to front, butting head against head/neck in a playful manner; the calf is engaged in a gallop, leap, buck-low, buck-high, buck-kick, or turn with companion calf; also includes allogrooming
* Behaviors included in continuous observation sampling.	

TABLE 3.3. DESCRIPTION OF THE RECORDED BEHAVIORS OBSERVED AT SITE 2.

VI. DATA ANALYSIS

A. PERFORMANCE ANALYSIS

In the first part of the analysis, treatment and site differences for performance measurements, such as milk DMI, grain DMI, total DMI, average daily gain (ADG), and change in wither height, were tested by obtaining the mean value for each calf throughout

the experimental period. Means were then compared using PROC MIXED in SAS (Version 9.2, SAS Institute Inc., Cary, North Carolina). Least square means and standard errors were determined using the LSMEANS statement in the MIXED procedure. The basic model used was $Y = \mu + \beta_i + S_j + FM_k + H_l + \sum_{(ijkl)}$ and included the fixed effects of Site (S; Sites 1 and 2) feeding method (FM; bucket or bottle) and housing method (H; individual or pair), while block was included as a random effect. The interactions between site, feeding method, and housing method were initially included in the model, yet were removed due to lack of significance.

B. BEHAVIOR ANALYSIS

In the second part of the analysis, the behavior data collected from Site 1 and Site 2 were analyzed separately due to the differences by which the observations were conducted; scan-sampling and continuous data were analyzed independently, as well. Nonetheless, these data were subjected to analyses similar to the performance data. The mean proportion of the behaviors displayed by all calves regardless of housing treatment were transformed using the arcsin transformation (Snedecor and Cochran, 1967) and compared using PROC MIXED in SAS (Version 9.2, SAS Institute Inc., Cary, North Carolina). The arcsin transformation refers to the arcsin of the square root of the proportion. Least square means and standard errors were again determined using the LSMEANS statement in the MIXED procedure. The standard error of the mean was then used to calculate individual 95% confidence intervals. The basic model used was $Y = \mu + \beta_i + S_j + FM_k + H_l + \sum_{(ijkl)}$ and included the fixed effects of Site (S; Sites 1 and 2) feeding method (FM; bucket or bottle) and housing method (H; individual or pair), while

block was included as a random effect. However, the behavior variables limited to calves housed in pairs (Site 1 - lying in the same hutch, cross-sucking, allogrooming, and social play; Site 2 – lying (adjacent) and social) were transformed using the arcsin transformation and analyzed using a χ^2 test in SAS (Version 9.2, SAS Institute Inc., Cary, North Carolina). The interactions between feeding method and housing method were initially included in the model, yet were removed due to lack of significance. All transformed data were back-transformed for reporting in tables. Means were deemed significant if $P < 0.05$ and a trend if $P < 0.10$.

CHAPTER 4: RESULTS

I. PERFORMANCE RESULTS

Milk dry matter intake (DMI) was higher ($P < 0.05$) for calves housed at Site 2 and for those fed with a bottle (Table 4.1). Because the total amount of milk available was limited as mentioned previously, a small number of calves housed at Site 1 received only 4 L/d of milk compared to other calves receiving 6 L/d. One additional bottle-fed treatment group at Site 1 received 6 L/d, which addresses the significant differences observed between feeding treatments for milk DMI. Calves housed at Site 2 had higher ($P < 0.05$) grain DMI (1.46 ± 0.02 kg/d) compared to Site 1 (0.86 ± 0.03 kg/d). Calves housed in pairs also had higher grain DMI compared to calves individually housed (1.22 ± 0.03 versus 1.10 ± 0.03 kg/d; $P < 0.05$). Total DMI (grain and milk solids) was higher ($P < 0.05$) for calves housed in pairs (1.76 ± 0.03 kg/d) compared to those housed individually (1.69 ± 0.03 kg/d). Grain and total DMI and average daily gain (ADG) of calves fed with a bottle was similar to those fed with a bucket. ADG was not significantly different ($P > 0.05$) between calves housed at Site 1 compared to those housed at Site 2 (0.71 ± 0.03 versus 0.64 ± 0.02 kg/d, respectively). Change in wither height was greater ($P < 0.05$) for calves housed at Site 1 compared to Site 2 (13.5 ± 0.5 versus 9.5 ± 0.4 cm/d, respectively) and for calves housed individually compared to calves housed in pairs (12.2 ± 0.4 versus 10.8 ± 0.5 cm/d; ($P < 0.05$), respectively).

	LOCATION		HOUSING TREATMENT		FEEDING TREATMENT	
	Site 1	Site 2	Single	Pair	Bucket	Bottle
Milk DMI (kg/d)	0.58±0.01 ^a	0.68±0.01 ^b	0.63±0.01	0.63±0.01	0.61±0.01 ^a	0.65±0.01 ^b
Grain DMI (kg/d)	0.86±0.03 ^a	1.46±0.02 ^b	1.10±0.03 ^a	1.22±0.03 ^b	1.14±0.03	1.18±0.03
Total DMI (kg/d)	1.48±0.03 ^a	1.97±0.03 ^b	1.69±0.03 ^a	1.76±0.03 ^b	1.70±0.03	1.75±0.03
ADG (kg/d)	0.71±0.03	0.64±0.02	0.65±0.03	0.70±0.03	0.64±0.03	0.71±0.03
cWH (cm)	13.5±0.5 ^a	9.50±0.4 ^b	12.2±0.4 ^a	10.8±0.5 ^b	11.8±0.5	11.2±0.4

^{ab} Means within a location, housing treatment, or feeding treatment are significantly different ($P < 0.05$).

TABLE 4.1. MEAN (± SEM) DRY MATTER INTAKE (DMI), AVERAGE DAILY GAIN (ADG), AND CHANGE IN WITHER HEIGHT (CWH).

II. BEHAVIOR RESULTS: SITE 1

A. SCAN-SAMPLED BEHAVIORS

Behavior results revealed that calves were more active in the morning and spent significantly more time lying and less time standing and walking in the afternoon (Table 4.2). For example, lying time increased ($P < 0.05$) from 21.4% in the morning to 74.3% in the afternoon. Calves housed in pairs and fed with a bottle were observed lying in the same hutch with their companion more ($P < 0.05$) often than calves housed in pairs and fed with a bucket (Table 4.2). Also, calves that were fed with a bucket were observed standing more frequently than calves fed with a bottle (53.8 versus 41.6%; $P < 0.05$). Interacting with pen fixtures was significantly higher in the morning compared to the afternoon (8.59 versus 3.88%; $P < 0.05$). Interacting with pen fixtures was significantly greater ($P < 0.05$) in calves housed individually (7.70%) compared to calves housed in

pairs (4.54%). When fed with a bottle, calves spent more ($P < 0.05$) time engaged in solitary play behavior than when fed with a bucket (0.824 versus 0.081%), which was also observed more frequently in the morning compared to the afternoon (0.829 versus 0.079%; $P < 0.05$). Calves fed with a bottle spent significantly more time interacting with milk than did calves fed with a bucket (4.27 versus 1.07%; $P < 0.05$). No significant differences between feeding treatments were observed for cross-sucking, yet calves fed with a bottle tended to ($P < 0.10$) exhibit less cross-sucking than calves fed with a bucket (Table 4.2). Lastly, there were no significant differences in allogrooming behavior for calves fed with buckets compared to those fed with bottles, and social play behavior was similar for calves fed with a bucket versus a bottle (46.8 versus 53.2% of total social play observations; Table 4.2).

	TIME OF DAY		HOUSING TREATMENT		FEEDING TREATMENT	
	AM	PM	Single	Pair	Bucket	Bottle
Lying	21.4 ^a (18.1, 24.9)	74.3 ^b (70.5, 78.0)	47.9 (43.8, 52.1)	47.0 (42.7, 51.3)	45.0 (40.5, 49.6)	49.9 (46.0, 53.8)
Lying same hutch [†]	—	—	—	—	31.2 ^a	68.8 ^b
Standing	70.5 ^a (61.1, 79.1)	25.4 ^b (17.2, 34.5)	45.8 (36.1, 55.7)	49.5 (39.5, 59.6)	53.8 ^a (43.3, 64.1)	41.6 ^b (32.3, 51.2)
Walking	4.58 ^a (1.76, 8.64)	0.119 ^b (0.238, 1.38)	1.61 (0.202, 4.32)	1.51 (0.150, 4.24)	1.13 (0.035, 3.75)	2.05 (0.403, 4.91)
Other	67.9 ^a (59.3, 75.9)	87.2 ^b (80.5, 93.6)	76.2 (68.2, 83.3)	80.1 (72.3, 86.8)	80.9 (72.8, 87.8)	75.3 (67.5, 82.3)
Interacting with pen fixtures	8.59 ^a (4.26, 14.3)	3.88 ^b (1.18, 8.06)	7.70 ^a (3.63, 13.1)	4.54 ^b (1.54, 9.02)	6.51 (2.70, 11.8)	5.55 (2.22, 10.3)
Self-grooming	2.37 (1.33, 3.70)	1.59 (0.747, 2.73)	2.47 (1.41, 3.81)	1.51 (0.684, 2.65)	2.35 (1.23, 3.81)	1.60 (0.815, 2.65)
Solitary play	0.829 ^a (0.170, 1.98)	0.0793 ^b (0.049, 0.614)	0.493 (0.043, 1.43)	0.240 (0.0003, 0.996)	0.081 ^a (0.061, 0.664)	0.824 ^b (0.182, 1.92)
Starter interaction	3.19 (1.56, 5.37)	2.66 (1.18, 4.70)	2.52 (1.11, 4.47)	3.34 (1.64, 5.63)	2.68 (1.11, 4.89)	3.17 (1.60, 5.23)
Water interaction	0.437 (0.087, 1.05)	0.599 (0.162, 1.31)	0.444 (0.092, 1.06)	0.591 (0.153, 1.31)	0.518 (0.102, 1.25)	0.511 (0.136, 1.12)
Milk interaction	—	—	2.42 (0.069, 7.96)	2.41 (0.059, 8.02)	1.07 ^a (0.090, 5.53)	4.27 ^b (0.632, 10.9)
Cross-sucking [†]	—	—	—	—	67.3 [*]	32.7 [*]
Allogrooming [†]	—	—	—	—	43.5	56.5
Social play [†]	—	—	—	—	46.8	53.2

^{ab} Means within the time of day, housing treatment, or feeding treatment are significantly different ($P < 0.05$).

^{*} Means within the time of day, housing treatment, or feeding treatment tend to differ ($P < 0.10$).

[†] Analyzed using χ^2 test; percentage of total observations for behavior.

TABLE 4.2. MEAN (95% CONFIDENCE INTERVAL) PERCENTAGE OF THE TIME CALVES AT SITE 1 SPENT ENGAGED IN EACH OF THE BEHAVIORS MEASURED USING SCAN-SAMPLING.

B. CONTINUOUSLY SAMPLED BEHAVIORS

Behaviors observed continuously (Table 4.3) mirrored and were nearly identical to the behaviors measured using the scan-sampling method (Table 4.2). Thus, to avoid repetition, these results will not be reiterated. Between the two sets of data, the only behavioral differences in need of mention are the total amount of time calves spent consuming starter and engaged in cross-sucking. Continuous sampling methods revealed a significant difference ($P < 0.05$) between the morning and afternoon observation periods, whereas scan-sampling methods revealed a trend ($P < 0.10$). Thus, by continuous observation, 5.93% of the morning was dedicated to eating starter and only 3.54% in the afternoon (Table 4.3). Additionally, calves housed in pairs and fed with a bottle spent less time cross-sucking compared to calves fed with a bucket (30.0 versus 70.0% of total cross-sucking observations; $P < 0.05$).

	TIME OF DAY		HOUSING TREATMENT		FEEDING TREATMENT	
	AM	PM	Single	Pair	Bucket	Bottle
Lying	26.7 ^a (22.8, 30.9)	73.4 ^b (69.1, 77.4)	47.4 [*] (42.8, 51.9)	52.8 [*] (48.1, 57.5)	47.9 (42.9, 52.9)	52.2 (47.9, 56.6)
Lying same hutch [†]	—	—	—	—	32.8 ^a	67.2 ^b
Standing	70.2 ^a (62.3, 77.5)	26.1 ^b (19.1, 33.8)	49.2 (41.0, 57.5)	46.6 (38.2, 55.2)	53.0 ^a (44.1, 61.7)	42.9 ^b (35.0, 51.0)
Walking	7.48 ^a (4.67, 10.9)	1.59 ^b (0.441, 3.45)	4.21 (2.17, 6.88)	3.83 (1.84, 6.52)	3.13 (1.28, 5.76)	5.01 (2.85, 7.75)
Other	63.7 ^a (58.3, 68.9)	88.0 ^b (84.1, 91.4)	73.5 ^a (68.6, 78.2)	80.3 ^b (75.5, 84.6)	78.0 (72.8, 82.8)	76.0 (71.4, 80.2)
Interacting with pen fixtures	14.0 ^a (10.2, 18.2)	7.36 ^b (4.63, 10.7)	14.5 ^a (10.7, 18.8)	6.96 ^b (4.28, 10.2)	10.4 (6.97, 14.3)	10.5 (7.28, 14.2)
Self-grooming	4.65 (3.63, 5.80)	3.74 (2.81, 4.80)	4.63 (3.61, 5.75)	3.77 (2.82, 4.84)	5.08 ^a (3.91, 6.39)	3.37 ^b (2.55, 4.30)
Solitary play	1.42 ^a (0.653, 2.47)	0.119 ^b (0.002, 0.538)	0.631 (0.171, 1.38)	0.554 (0.124, 1.29)	0.239 ^a (0.006, 0.812)	1.10 ^b (0.463, 2.01)
Starter interaction	5.93 ^a (3.56, 8.86)	3.54 ^b (1.75, 5.93)	4.57 (2.53, 7.18)	4.76 (2.62, 7.49)	5.56 (3.14, 8.63)	3.84 (2.03, 6.19)
Water interaction	0.747 (0.368, 1.26)	0.751 (0.369, 1.27)	1.22 ^a (0.720, 1.84)	0.420 ^b (0.145, 0.838)	0.751 (0.342, 1.32)	0.785 (0.415, 1.27)
Milk interaction	—	—	8.84 (6.50, 11.5)	6.12 (4.06, 9.41)	5.67 ^a (3.59, 8.20)	9.38 ^b (7.10, 11.9)
Cross-sucking [†]	—	—	—	—	70.0 ^a	30.0 ^b
Allogrooming [†]	—	—	—	—	51.0	49.0
Social play [†]	—	—	—	—	47.2	52.8

^{ab} Means within the time of day, housing treatment, or feeding treatment are significantly different ($P < 0.05$).
^{*} Means within the time of day, housing treatment, or feeding treatment tend to differ ($P < 0.10$).
[†] Analyzed using χ^2 test; percentage of total observations for behavior.

TABLE 4.3. MEAN (95% CONFIDENCE INTERVAL) PERCENTAGE OF THE TIME CALVES AT SITE 1 SPENT ENGAGED IN EACH OF THE CONTINUOUS BEHAVIORS MEASURED.

II. BEHAVIOR RESULTS: SITE 2

A. SCAN-SAMPLED BEHAVIORS

Behavior results revealed that lying time increased ($P < 0.05$) and even doubled in the afternoon (87.3%) compared to the morning (41.5%), and calves spent significantly more ($P < 0.05$) time standing in the morning in contrast to the afternoon (Table 4.4). Postures were similar between housing treatments (individual or pair). In addition, walking tended to ($P < 0.10$) decrease from the morning to the afternoon and was significantly higher for calves fed with a bottle compared to calves fed with a bucket (0.568 versus 0.181%; $P < 0.05$). Interacting with pen fixtures was significantly higher in the morning compared to the afternoon (3.20 versus 1.04%; $P < 0.05$). In addition, calves housed individually tended to exhibit more self-grooming behavior compared to calves housed in pairs (2.61 versus 1.49%; $P < 0.10$). Calves housed in pairs tended to exhibit more solitary play behavior compared to calves housed individually (0.034 versus $0.001\% \pm 0.01$; $P < 0.1$). Associated with milk ingestion, cross-sucking behavior largely ($P < 0.05$) occurred in the morning (2.83%) when milk was available and was minimal in the afternoon (0.016%). In addition, although individually housed calves were able to exhibit this behavior, they did so less often than calves housed in pairs (0.268 versus 1.67%; $P < 0.05$). Feeding method had no effect on the incidence of cross-sucking. Calves spent more ($P < 0.05$) time consuming calf-starter and water during the morning observation period (Table 4.4). Also, feeding method significantly affected the amount of time calves spent interacting with milk; those fed with a bottle spent more time engaged in milk interactions than did calves fed with a bucket (4.60 versus 1.03%; $P < 0.05$). Calves housed in pairs spent less time interacting milk compared to calves housed

individually (3.46 versus 1.69%; $P < 0.05$). Lastly, bucket-fed calves engaged in social play less than bottle-fed calves (Table 4.4).

	TIME OF DAY		HOUSING TREATMENT		FEEDING TREATMENT	
	AM	PM	Single	Pair	Bucket	Bottle
Lying	41.5 ^a (36.4, 46.8)	87.3 ^b (83.6, 90.6)	66.9 (61.9, 71.8)	66.0 (60.9, 70.9)	66.7 (61.6, 71.6)	66.3 (61.2, 71.2)
Lying (adjacent) [†]	—	—	—	—	64.2	35.8
Standing	57.1 ^a (52.1, 62.0)	11.2 ^b (8.29, 14.6)	31.1 (26.6, 35.8)	32.5 (27.9, 37.3)	32.5 (27.9, 37.3)	31.1 (26.6, 35.8)
Walking	0.553 [*] (0.231, 1.01)	0.189 [*] (0.029, 0.488)	0.208 (0.037, 0.518)	0.523 (0.211, 0.972)	0.181 ^a (0.026, 0.474)	0.568 ^b (0.241, 1.03)
Other	74.3 ^a (70.9, 81.8)	91.6 ^b (89.3, 95.9)	84.5 (81.6, 90.5)	83.3 (80.3, 89.5)	84.8 (82.0, 90.8)	82.9 (80.0, 89.2)
Interacting with pen fixtures	3.20 ^a (2.19, 4.38)	1.04 ^b (0.503, 1.76)	2.25 (1.42, 3.27)	1.71 (1.00, 2.62)	2.04 (1.25, 3.01)	1.91 (1.15, 2.85)
Self-grooming	1.63 (0.894, 2.59)	2.43 (1.51, 3.57)	2.61 [*] (1.62, 3.82)	1.49 [*] (0.805, 2.39)	1.90 (1.10, 2.91)	2.13 (1.26, 3.22)
Solitary play	0.041 ^a (0.008, 0.099)	0.0002 ^b (0.00, 0.016)	0.001 [*] (0.00, 0.021)	0.034 [*] (0.005, 0.088)	0.004 (0.00, 0.032)	0.023 (0.001, 0.070)
Cross-sucking	2.83 ^a (2.04, 3.74)	0.016 ^b (0.00, 0.145)	0.268 ^a (0.069, 0.597)	1.67 ^b (1.08, 2.39)	0.938 (0.510, 1.49)	0.712 (0.347, 1.21)
Starter interaction	6.86 ^a (5.16, 8.79)	0.589 ^b (0.168, 1.27)	2.84 (1.77, 4.15)	2.95 (1.86, 4.28)	2.79 (1.73, 4.09)	3.00 (1.90, 4.35)
Water interaction	0.445 ^a (0.199, 0.788)	0.039 ^b (0.001, 0.176)	0.128 (0.019, 0.335)	0.257 (0.082, 0.530)	0.201 (0.039, 0.447)	0.174 (0.039, 0.408)
Milk interaction	—	—	3.46 ^a (1.91, 5.45)	1.69 ^b (0.669, 3.17)	1.03 ^a (0.280, 2.24)	4.60 ^b (2.78, 6.84)
Social play [†]	—	—	—	—	39.3 ^a	60.7 ^b

^{ab} Means within the time of day, housing treatment, or feeding treatment are significantly different ($P < 0.05$).
^{*} Means within the time of day, housing treatment, or feeding treatment tend to differ ($P < 0.10$).
[†] Analyzed using χ^2 test; percentage of total observations for behavior.

TABLE 4.4. MEAN (95% CONFIDENCE INTERVAL) PERCENTAGE OF THE TIME CALVES AT SITE 2 SPENT ENGAGED IN EACH OF THE BEHAVIORS MEASURED USING SCAN-SAMPLING.

B. CONTINUOUSLY SAMPLED BEHAVIORS

Behaviors measured continuously were as follows: interacting with pen fixtures, self-grooming, cross-sucking, milk interaction, and social play behavior. Although similar between feeding method treatments, interacting with pen fixtures was significantly higher for individually housed calves compared to calves housed in pairs (6.62 versus 2.25%; $P < 0.05$). Self-grooming behavior was similar between feeding methods (bucket or bottle) and housing treatments (individual or pair) (Table 4.5). In addition, cross-sucking behavior did not differ significantly across either treatment. Once more, calves fed with a bottle spent more time interacting with milk than did calves fed with a bucket (36.8 versus 19.6%; $P < 0.05$), and calves housed in pairs interacted with milk for a longer duration than calves housed individually (24.8 versus 30.9%; $P < 0.05$). Lastly, for calves housed in pairs, social play was significantly affected by feeding method (Table 4.5). Social play was observed more ($P < 0.05$) frequently when calves were fed with a bottle (60.8% of total social play observations) compared to calves fed with a bucket (39.2% of total social play observations).

	HOUSING TREATMENT		FEEDING TREATMENT	
	Single	Pair	Bucket	Bottle
Interacting with pen fixtures	6.62 ^a (3.48, 10.7)	2.25 ^b (0.605, 4.90)	3.34 (1.27, 6.33)	5.07 (2.28, 8.89)
Self-grooming	4.11 (2.09, 6.76)	2.89 (1.24, 5.18)	3.54 (1.72, 5.98)	3.40 (1.54, 5.95)
Cross-sucking	11.0 (5.87, 17.6)	17.3 (10.8, 25.0)	14.9 (9.07, 21.8)	13.3 (7.33, 20.6)
Milk interaction	30.9 ^a (26.6, 35.4)	24.8 ^b (20.8, 29.0)	19.6 ^a (16.1, 23.3)	36.8 ^b (32.1, 41.7)
Social behavior [†]	—	—	39.2 ^a	60.8 ^b

^{ab} Means within housing treatment, or feeding treatment are significantly different (P < 0.05).
[†] Analyzed using χ^2 test; percentage of total observations for behavior.

TABLE 4.5. MEAN (95% CONFIDENCE INTERVAL) PERCENTAGE OF THE TIME CALVES AT SITE 2 SPENT ENGAGED IN EACH OF THE CONTINUOUS BEHAVIORS MEASURED.

CHAPTER 5: DISCUSSION

I. PERFORMANCE

Dairy producers may be reluctant to make the transition to group housing because of the potential for deleterious effects on calf health and performance (Maatje et al., 1993). In the current study, pair-housed calves remained healthy and gained weight rapidly. Comparable to the results reported by Chua et al. (2002) and Wise and LeMaster (1968), other than diarrhea, no signs of disease were observed, and the prevalence of this ailment was very low for all treatments, although not formally measured in this study. In addition, some individual housing systems, such as pens or crates, may still allow oral and nasal contact between calves either from above or between the pen partitions, which would not inhibit the transmission of airborne organisms (Friend and Dellmeier, 1998). Urine and fecal matter can harbor infectious organisms, as well (Chua et al., 2002). Thus, in combination with the type of housing system employed, proper management practices, such as cleanliness and adequate ventilation, may play an equally or potentially more important role with regard to disease susceptibility of preweaned calves.

Although numerically greater, the results show that housing calves in pairs did not significantly influence weight gain. Data recorded on the effects of group housing on calf performance are rather contrasting. Previous studies have reported increased weight gains for group-housed calves (Xiccato et al., 2001; Chua et al., 2002). Xiccato et al. (2001) attributed this improvement to the possibility for movement in larger areas.

However, in accordance with the results of the present study, Smits and de Wilt (1991) also did not observe any differences in weight gain between group or individually-housed calves.

Pair-housed calves ingested more calf-starter during the preweaning period than did individually housed calves, which primarily contributed to this treatment group also having a greater total DMI. In agreement with de Paula Vieira et al. (2010), the higher starter intake may be attributed to social facilitation; paired calves spent more time at the feeder, visited the feeder more often, and ingested more concentrate, such that calves housed in pairs gained more weight (de Paula Vieira et al., 2010). It is hypothesized that group activity and early socialization allow calves to learn at a faster pace, and thus they spend comparatively more time consuming solid feed than those that are individually reared (Babu et al., 2004). Although the primary focus of this study was during the milk-feeding period, others (Babu et al., 2004; Hepola et al., 2006) have reported similar effects over a longer experimental feeding period. For instance, Hepola et al. (2006) reported that group-housed calves started to eat hay at an earlier age and consumed more hay and concentrate than calves housed individually over a 12 wk period.

In contrast to initial hypotheses, bucket-fed calves had a grain DMI similar to bottle-fed calves; other than milk DMI, which was confounded by milk allowance. Feeding method did not have a significant effect on any of the performance variables measured. These results disagree with those reported by Appleby et al. (2001) who found that during days 21-28 of age, calves fed milk from buckets ate more than twice as much starter as those on teats.

The results show that change in wither height was greater for calves at Site 1 and

for those housed individually. These differences, especially between housing treatment, were unexpected. The greater change in wither height for Site 1 corresponded to the numerically higher ADG for that site. Pair-fed calves had significantly higher grain and total DMI and numerically higher ADG, but lower change in wither height. Wither height is a useful measure of bone growth and frame size but not a good measure of live weight because this measure is not influenced by body condition. This measure also does not incorporate the genetic differences of body size (Heinrichs et al., 1992). Another factor that may have contributed to this difference is milk allowance. Because milk was unfortunately limited at times throughout this study, calves at Site 1 received more milk than calves housed at Site 2. In addition, this resulted in bottle-fed calves having greater milk DMI compared to calves fed with a bucket. Although location was confounded with milk allowance, other studies have reported an improvement in performance when calves are not limited and are fed milk ad libitum. Such studies have linked this to the development of the esophageal groove stimulated by sucking behavior (Appleby et al., 2001).

II. BEHAVIOR

Behavior will at first be discussed separately by site, but general conclusions observed between locations and cross-sucking behavior will be presented at the end of this chapter.

A. SITE 1: SCAN AND CONTINUOUSLY SAMPLED BEHAVIORS

Both scan- and continuous-sampling methods indicated that calves were more

active in the morning around milk feeding. During the morning observation period, the following behaviors were observed significantly more compared to the afternoon observation period: standing, walking, interacting with pen fixtures, playing, and consuming starter. These results are similar to those reported by Babu et al. (2004) who also observed lying time to increase significantly in the evening. Thus, in this study, young calves exhibited the majority of their behavioral repertoire in the morning, a time associated with milk feeding, compared to the afternoon observations, which were not associated with feeding. However, this conclusion cannot be extended so as to assume that an observed increase in activity is associated with feeding time, in general, because behavioral observations were not conducted around the evening milk feeding.

In addition, calves housed individually spent more time interacting with fixtures of the pen and self-grooming compared to calves housed in pairs. As noted by Babu et al. (2004), non-nutritive behaviors, such as licking pen fixtures or other inanimate objects are considered to be detrimental to calf health and performance. The ingestion of non-feed particles (soil, metal oxides, hair, etc.) as a result of this behavior has a direct effect on stomach upset and on absorption, leading to other health complications (Broom, 1991). This increase may have been due to the fact that calves housed individually did not have the opportunity to engage in social behavior. Calves housed in pairs certainly interacted with one another, a finding supported by many (Jensen et al., 1998; Chua et al., 2002; Babu et al., 2004; Jensen and Budde, 2006). Social activity exhibited by the paired calves likely relates in part to the increase in total space available, which appears to be important for locomotion (Chua et al., 2002). In addition, social behavior was observed to be similar between calves fed with a bottle and calves fed with a bucket. Calves

housed in pairs were also observed laying in the same hutch a majority of the time, which once again reiterates their desire for social companionship.

Although only numerical, behavioral results revealed that calves fed with a bottle spent more time lying than calves fed with a bucket, which may indicate a higher level of satiety experienced by calves in this treatment group. Veissier et al. (2002) also observed a shorter latency to lie down by calves fed with a bottle compared to calves fed with a bucket. They too attributed this to having satisfied the calves' natural desire to suck by being able to perform nutritive sucking.

B. SITE 2

1. Scan-Sampled Behaviors

Similar to the behavior results of Site 1, scan-sampling methods indicated that calves were significantly more active in the morning. During the morning observation period, the following behaviors were observed significantly more compared to the afternoon observation period: standing, walking, interacting with pen fixtures, playing, cross-sucking, and starter consumption. In general, these results with regard to time of day are similar to those reported previously for Site 1.

In addition, this sampling method revealed that calves housed in pairs were more active than those housed individually; calves spent more time walking and engaged in play behavior. Jensen et al. (1998) also observed a greater level of activity among pair-housed calves and Babu et al. (2004) observed this among groups of six calves. This is primarily due to the amount of space that is available to the calf; sufficient space is essential for the expression of certain behaviors, especially play (Chua et al., 2002).

Jensen et al. (1998) noted that play behavior is generally regarded as a positive indicator of welfare and is more likely to occur when calves are housed in groups.

2. Continuously-Sampled Behaviors

During the 20 min immediately following milk delivery, continuous behavioral sampling revealed that calves housed individually spent more time interacting with fixtures of the pen compared to calves housed in pairs. Once again, this increase may have been observed due to the deprivation of social behavior from calves housed individually. These results also suggest that competition for milk was greater among pair-housed calves compared to those individually housed; the time spent interacting with milk was lower among calves housed in pairs. Jensen and Budde (2006) reported a similar trend; the rate of ingesting milk was higher in calves housed in groups of six compared to calves housed in pairs. The authors also reported that group-housed calves changed more often to another teat or bucket than calves in pairs. Although this was not quantified in this thesis, calves housed at Site 2 appeared to switch between buckets or bottles more frequently than calves housed in pairs at Site 1. This may have been due to the fact that calves housed in pairs at Site 1 were fed in separate hutches and were unable to see each other during their milk meals. In contrast, calves housed in pairs at Site 2 were able to see each another at all times, as they did not have a barrier to separate them.

Lastly, irrespective of group size, calves fed with a bottle spent more time interacting with milk than did calves fed with a bucket. This has been reported by several studies (Hammell et al., 1988; Appleby et al., 2001; Jensen and Budde, 2006). Hammell et al. (1988) provided milk ad libitum and reported that teat-fed calves ingested significantly more milk than bucket-fed calves, and this intake took much longer. Milk

sucking has also been reported to continue far beyond the presumed nutritional need of the calf (Hammell et al., 1988; Appleby et al., 2001). This increase may be an immediate function of the need for sucking, and it is possible that sucking behavior is more, or at least equally, reinforcing than the ingestion of milk.

C. CROSS-SUCKING

The overall frequency of cross-sucking in this study was low and was typically directed toward the mouths of other calves. Chua et al. (2002) also reported cross-sucking as a percentage of the daily activities performed by preweaned calves, yet observed no problems due to the occurrence of this behavior. In addition, the percentage of time dedicated to this behavior in this study was greater in the morning, mostly after feeding, compared to the afternoon. Babu et al. (2004) and de Wilt (1985) reported similar findings; “an increase in cross-sucking of the mouth after milk feeding is presumably because of stimulated temporary persistence of sucking behavior due to contact with milk” (Babu et al., 2004).

Cross-sucking behavior results differed by site; this behavior was observed to be reduced in calves fed with a bottle at Site 1, and no difference between feeding treatments was observed at Site 2. Because behavioral observations were conducted differently between locations, it is not possible to directly compare the cross-sucking behavior results. Results from Site 1 agree with a number of previous studies (Jensen and Budde, 2006; Rushen et al., 2010; Loberg and Lidfors, 2001), as bottle-feeding significantly reduced cross-sucking behavior. Cross-sucking may discourage producers from rearing preweaned calves in groups, despite labor advantages (Kung et al., 1997). Thus, it is

important to understand and try to reduce this behavior.

Calves housed individually at Site 2 were able to exhibit cross-sucking behavior because the wire pens were adjacent to one another, and during the 20 min following milk delivery, the occurrence of cross-sucking was similar between calves housed individually and calves housed in pairs. According to Jung and Lidfors (2001), cross-sucking may not be reduced if calves are not able to continue to suck on the teat after milk ingestion. Bottles were typically removed shortly after the calves were finished drinking their milk, which may have contributed to the occurrence of cross-sucking behavior in this study. Also, the amount of time that the bottles were left with the calves may have varied by location, as different individuals fed the calves. Milk flow rate is also an important factor with respect to prevention of cross-sucking behavior (Loberg and Lidfors, 2001), which was not investigated in this study. Thus, several factors contribute to the occurrence of cross-sucking behavior and must all be considered in order to reduce this undesirable behavior. Overall, cross-sucking behavior did not contribute to or cause any problems with regard to calf health or performance in this study.

III. STUDY LIMITATIONS AND FUTURE RESEARCH

Because it was conducted on farm under a practical industry setting, all aspects of this experiment could not be controlled as they may be in a laboratory setting. For instance, the total frequency and amount of time dedicated to observing the calves' behavior was rather limited. It would have been ideal to observe the calves' behavior multiple times per week and also to utilize continuous-sampling over a 24 h period. In addition, although video observations are superior to direct observations, calves housed

in hutches at Site 1 were unable to be filmed due to the amount of cameras available for use. Also, the behavior of the calves inside the hutch would have been very difficult to observe accurately via video camera recordings due to low light levels inside the hutch.

As acknowledged previously, it would have been appropriate to standardize the amount of time that the bottle remained in the pen or hutch with the calf. It is possible that cross-sucking behavior among calves fed with a bottle may have been reduced if the calves had access to the bottle for at least 20 min postprandium.

Future studies should focus on the potential long-term effects of housing pre-weaned heifer calves in pairs. It would be interesting to observe the behavior of the companion calves after being introduced to a larger herd and compare it to the behavior of the calves that were previously housed individually. Performance measures should also be included in future studies to determine how dairy replacement rearing systems affect the lifetime productivity of the cow.

IV. IMPLICATIONS

In modern production systems, dairy cattle are ultimately housed in rather large groups. Because of their natural complex dominance hierarchies, it is important that they learn how to interact socially with conspecifics, as this may have indirect effects later in life. Early social contact has also been shown to facilitate normal social responses and decrease the amount of agonistic behaviors exhibited (Veissier et al., 1994, 1997; Jensen et al., 1997). The findings of this study show that housing young calves in pairs provides opportunity for socialization, increases the amount of space accessible, and results in a higher level of activity and play behavior. The ability to display such behaviors may be

advantageous to the calves later in their life; calves reared in groups are socially more confident and less fearful than calves reared individually (Bøe and Færevik, 2003).

Performance results revealed that calves housed in pairs consumed more grain than did the calves housed individually. Several studies have also reported higher weight gains for group-housed calves compared to calves housed individually during the milk-feeding period. This indicates that housing calves in pairs may enhance feed intake due to social facilitation. In conclusion, housing preweaned calves in pairs appears to be viable in terms of health, performance, and behavior of calves, and this form of housing is not a detriment to their overall welfare.

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APPENDIX A: EXPERIMENTAL PEN DESIGN

Figure A.1. Experimental set-up of calf hutches at Site 1. Each feeding treatment group consisted of two individually housed calves and one set of pair-housed calves.

Figure A.2. Experimental pen set-up at Site 2. Each feeding treatment group consisted of two individually housed calves and one set of pair-housed calves.

APPENDIX B: EXAMPLES OF PLAY BEHAVIOR

Figure B.1. Various examples of the behaviors scored as play behavior (Jensen et al., 1998).