University of Nevada, Reno

A Comparison of the Effects of Three Different Weaning Methods on Performance and Behavior of Beef Calves

A thesis submitted in partial fulfillment of the
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by

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Abstract

To assess the effects three different weaning methods have on beef calves' weight gain and behavior, 339 Angus and Angus-cross calves were weaned in 5 trials over 2 years. In each trial calves were equally divided into 3 weaning method treatments: traditional weaning, interval weaning, and fence-line weaning. Behavioral observations began on day 1 and continued to day 5 and included the observation of eating, drinking, walking, standing and lying down behaviors as well as the measurement of the amount of vocalizations emitted by each treatment group. Weights were obtained on days 0, 7, 14, and 28 and average daily gain (ADG) as well as cumulative weight gain was calculated for each period. Fence-line weaned calves vocalized more than interval weaned calves in the evenings ($P = 0.02$) but no other significant differences were seen. Interval weaned calves were observed eating more than traditionally weaned calves ($P = 0.001$). Fence-line calves did not differ from the other 2 groups in eating behavior. Traditionally weaned calves spent more time walking than interval weaned calves ($P = 0.007$). Fence-line weaned calves did not differ from traditionally weaned calves in walking behavior except on days 2 and 3 when they walked less ($P = 0.0001$ for day 2, $P = 0.01$ for day 3). Fence-line and interval weaned calves did not differ in walking behavior. Fence-line weaned calves spent more time lying down than traditionally weaned calves ($P = 0.006$) but no difference was seen between interval weaned calves and the other 2 groups. Fence-line weaned calves did not differ from the other 2 treatments for weight gain data. Interval weaned calves had a greater ADG on week 1 than traditionally weaned calves ($P = 0.0003$) but traditionally weaned calves had a greater ADG for week 2 than interval weaned calves ($P = 0.002$). For cumulative weight gain, interval weaned calves had

greater weight gain than traditionally weaned calves for the 0 through 7 day period but weight gain did not differ between any of the three treatments for the 0 through 14 day period or the 0 through 28 day period. It was concluded that fence-line weaning provided minimal benefits to calf behavior during weaning and no benefits to weight gain compared to traditional weaning where as interval weaning provided benefits to behavior and weight gain during the first week of weaning compared to traditionally weaning making it a likely candidate to replace traditional weaning especially when calves are marketed the week after weaning occurs.

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Table of Contents

List of Tables

List of Figures

Literature Review

Weaning defined.

Natural weaning is the period of time when the rate of parental investment given to one's offspring drops most sharply (Martin, 1984). This definition of weaning involves a gradual shift from an offspring's dependence on nutrition and care provided by the mother to independence. Natural weaning in semi-wild cattle usually occurs when the calf is between 7 and 14 months of age and takes place when the dam begins to prevent suckling. After natural weaning, a considerable amount of physical and social contact is still maintained by the dam and calf (Rienhardt, 2002). It is a common practice in the beef industry to artificially wean calves at a point earlier than natural weaning would occur. Artificial weaning in cattle consists of the breaking of the maternal offspring bond. This is accompanied by the termination of suckling by the calf and then, either simultaneously or eventually, a complete separation of calf and dam. Often, calves are removed to unfamiliar surroundings (i.e. moved to a feed-lot) and nutrition is altered at the time of weaning if calves are removed off pasture and placed on a hay or hay/grain diet. Such artificial weaning practices result in an increase in vocalizations by both calves and cows, which has been suggested as an indication of poor animal welfare (Grandin, 1998; Watts and Stookey, 2000). Within the scope of this paper, the term "weaning" will refer to artificial weaning as it is commonly done in the industry today.

The purpose of weaning.

Calves are artificially weaned at an early date (relative to natural weaning) for multiple reasons. Research indicates that the beef cow's reproductive ability is closely related to her body's fat reserves, as measured by body condition score, at the time of

parturition (Richards et al. 1986). For this reason calves are weaned early to allow cows to increase or maintain body weight so that they are at an acceptable body condition score prior to breeding in order to maximize the cow's ability to successfully rebreed after parturition. Some research also suggests that earlier weaning improves calf's rate of gain, increasing its body weight at the time of sale (Myers et al. 1999; Story et. al., 2000). Marketing considerations and reduction of feed cost also play into the timing of weaning cattle. Lighter calves almost always sell at a higher dollar amount per pound than their heavier counterparts. Also, by selling calves earlier in the year, a rancher can reduce the overall feed needs of the entire cow herd, increasing the length of the grazing season and reducing the amount of feed needed in the winter. This is usually only important in spring calving herds where feed quality is highest in the spring and early summer months.

Age at weaning.

The effects of age at weaning on calf performance vary with the type of management and the environment the cow herd is subjected to. Research has shown that in a spring calving herd, weaning calves at a younger age may increase calf body weight if calves are maintained on farm until weaning would have normally occurred (Story et. al., 2000). When investigating the effects of early weaning (150 day average calf age), normal weaning (210 day average calf age), and late weaning (270 day average calf age) on calf weight, Story et. al. (2000) found that early weaned calves gained significantly more post weaning than their un-weaned counter parts (1.3 kg/day vs. 0.77 kg/day). This was due largely to the fact that weaned calves were placed on a high nutrition diet and normal and late weaned calves stayed on pasture with their dams, facilitating a difference in the nutritional value of each group's feedstuff. An economic analysis in the same study

showed that if calves are sold at the time of weaning, normal weaned calves would return more profit ($1.44/cow) than the calves weaned in the early (-$51.29/cow) or late (-$8.39/cow) weaning systems (Story et. al., 2000).

Conversely, in a fall calving system, calves weaned at a later date tend to gain better than their early-weaned counterparts. Hudson et. al. (2010) found, when comparing normal weaned calves (210 day average calf age) to late weaned calves (300 day average calf age), that late weaned calves had significantly higher body weight at weaning than their counterparts who were weaned at an earlier date (292 kg vs. 276 kg). Furthermore, late weaned calves maintained a higher weight 3 weeks post weaning (Hudson et. al., 2010). The differences between the results in a fall calving and spring calving system are largely due to the environmental differences at the time of weaning. In a fall calving herd, when weaning occurs in the spring, the quality of fresh growing grass feed is such that calves gain better when they can graze and still receive supplemental milk from their dam. In a spring calving herd, when calves are weaned in the fall, nutritive quality of older mature grass feed is such that calves will gain better if they are weaned from their dam and placed on higher quality feed of cured hay or mixed rations (hay and grain).

Weaning methods.

There are three main weaning methods employed in the beef industry today; traditional weaning, fence-line weaning, and two stage weaning. Another novel method used in farmed wapiti, interval weaning, will also be discussed. Traditional, fence-line, and two stage weaning have been studied in cattle with varying results published on the effects of weight gain and behavior. These four methods of weaning are discussed in

more detail below. Table 1 provides a summary of results from studies comparing fence-line, two stage, and interval weaning to traditional weaning.

Traditional weaning. Perhaps the most commonly used weaning method is the traditional weaning method. In traditional weaning, calves and dams are completely (physical barriers to interaction are placed between calves and dams) and abruptly (for all calves and dams within a matter of hours) separated from each other on the first day of weaning. Cows and calves are spatially separated enough to prohibit communication through vocalization. In some cases, calves are shipped off farm at this time for marketing reasons. If calves are maintained on farm post-weaning they may remain on the pasture they were previously housed in before weaning or they may be moved into a dry feed-lot, in which case their feed ration will change at the same time from a diet of the dams milk and pasture feed to a diet of cured hay or a mixed feed diet (hay and grain, etc.).

Fence-line weaning. A method of weaning that has gained popularity in the cattle industry is fence-line weaning. In fence-line weaning, calves are physically separated from their dams but both are housed in adjacent pens for a period of time (usually around 5 to 7 days) to allow vocal and some physical contact. After this, cows are completely separated from their calves to complete the process. Cows and calves may be maintained in a feed-lot or in a pasture.

Presumably, allowing fence-line contact of cows and calves during the weaning process reduces the stress experienced by calves as measured through weight gain and behavior (Stookey and Watts, 2007). The benefits to weight gain using the fence-line method are mixed and perplexing at best. Price et al. (2003) found that calves subjected

to fence-line weaning in a pasture setting gained significantly more in the short term (95% greater weight gain 2 weeks post weaning) and long term (31% greater weight gain 10 weeks post weaning) than calves that were weaned by complete separation from their dams over a variety of conditions including pasture, feed-lot, and feed-lot pre-conditioned (calves are started on feed-lot diet before the weaning process begins). In a study performed by Boland et al. (2008), fence-line calves were weaned on day -7 and traditionally weaned calves were weaned on day 0. Physical separation of fence-line calves and cows occurred on day 0 as well. Weight gain results differed depending on the year of the study with fence-line calves gaining significantly more than traditional calves in year 1 (0.06 kg/d and -0.27 kg/d respectively, $P = 0.0003$) and traditional calves gaining more than fence-line calves in year 2 (1.34 kg/d and 0.88 kg/day respectively) during day -7 through day 0. No significant difference was seen from day 0 to day 7 between fence-line and traditionally weaned calves in this study. Finally, a study performed by Enríquez et al. (2010) found that traditionally weaned calves gained significantly more weight than fence-line weaned calves.

Behavioral differences of calves in each weaning method also vary between studies. Price et al. (2003) found, when comparing a group of fence-line weaned calves on pasture, a group of traditionally weaned calves on pasture (T-P), a group traditionally weaned in a feed-lot preconditioned to hay (T-F-P), and a group traditionally weaned in a feed-lot not preconditioned to hay (T-F-NP), that fence-line weaned calves spent more time eating than the traditionally weaned groups. Price et al. (2003) also found that T-P calves walked more than the other groups. Calves traditionally weaned on pasture spent less time lying down than all the other groups except T-F-NP calves. Fence-line weaned

calves vocalized less than T-P and T-F-NP calves (Price et al., 2003). Another study (Boland et al., 2008) compared fence-line weaned calves and traditionally weaned calves before and after complete separation in which complete separation occurred on the same day for both groups. In this study, before complete separation occurred there was no difference in time spent eating, standing or lying down. After complete separation occurred for both groups, fence-line weaned calves spent significantly more time eating than traditionally weaned calves (45% vs. 33%) but there was no difference in standing or lying down (Boland et al. 2008). Finally, in a similar study performed by Enríquez et al. (2010), traditionally weaned calves vocalized significantly less than fence-line weaned calves (1.79% vs. 2.92%) but time spent walking, eating, and lying down did not differ between groups.

Two stage weaning. A newer method of weaning has been proposed by Haley et. al. (2005) that weans calves in two stages. In this method, calves are fitted with a nose flap to prevent nursing, but not eating and drinking, for a period of time (usually 5 to 7 days) before separation from their dam. This terminates nursing for a period before separation but still allows close proximity for social and physical contact. Nose flaps are removed when complete separation from the dam occurs. The increased social and physical contact is believed to reduce stress during the period of weaning when nursing is terminated, therefore reducing the overall stress of the calf during the weaning process. One drawback of the two stage method is that calves have to be handled twice, once at nose flap fitting and once at complete separation, which may increase stress levels of calves weaned by the two stage method over fence-line weaning (Haley et. al., 2005).

Haley et al. (2005) was the first to test the benefits of two stage weaning over traditional weaning. While assessing differences in weight gain over three different trials (different locations and time periods that the nose flap remained on each calf for each trial) results varied for this study. During the period before separation, the calves subjected to the traditional weaning method tended to gain better than two stage weaned calves ($P < 0.01$ in 2 of the 3 trials, $P > 0.05$ for the other trial). For the first week post separation, two stage calves gained significantly more than control calves (0.42 kg/day more for two stage during trial 1). When compared over the entire post weaning period no difference was seen. The conclusion arrived to by the authors was that there was not enough evidence to support a claim that one group gained more than the other in this study (Haley et al., 2005). Another study found that when comparing two stage, fence-line, and traditional weaning that traditionally weaned calves and fence-line weaned calves had significantly higher weight gain than two stage weaned calves (Enríquez et al., 2010). Finally, in a study performed by Boland et al. (2008), two stage calves gained less than fence-line and traditionally weaned calves before complete separation of all groups had occurred and two stage calves gained significantly less than fence-line calves after complete separation occurred. These results suggest that there is no benefit in weight gain when using the two stage method of weaning.

When studying the behavioral differences between calves weaned in two stages as opposed to other weaning methods Haley et al. (2005) found that traditionally weaned calves vocalized significantly more than two stage weaned calves (20 times more calls/hr). Two stage calves also spent significantly more time eating (23% more time) and lying down (3.1 hrs more) than calves weaned with the traditional method. This study

also found that traditionally weaned calves spent significantly more time walking than two stage weaned calves (146.3 min vs. 30.9 min respectively). Haley et al. (2005) also investigated the distance calves in each weaning method walked by using a pedometer attached to each calf's leg and found that two stage calves walked an average of 2.7 km/d less than traditionally weaned calves. Boland et al. (2008) found that two stage weaned calves spent more time grazing than fence-line or traditionally weaned calves (50%, 45%, and 33% respectively) after complete separation occurred. No treatment difference was found between times spent standing or lying down (Boland et al., 2008). When comparing the behavior of calves before and after complete separation occurred, Enríquez et al. (2010) found that two stage calves vocalized less frequently than fence line weaned calves (1.33% vs. 2.92%,). The study results also showed that two stage calves walked more than traditionally weaned calves (6.63% vs. 7.89%) but no difference was found in the amount of time spent grazing or lying down between weaning methods (Enríquez et al., 2010).

Interval weaning. A method of weaning employed in farmed wapiti operations but not tested on cattle yet is interval weaning (Church and Hudson, 1999). Interval weaning involves the slow removal of dams from their calves in daily intervals. Church and Hudson (1999) removed 2 to 3 dams per day until all dams were removed from the calves (10 days after the beginning of the weaning period). The time period that dams are present with the calves varies depending on the number of dams removed each day and the total amount of calves being weaned. Interval weaning may reduce the overall stress experienced by all calves because of the calming effects of the dams remaining with the calves during weaning. In farmed wapiti, differences in weight gain between complete

separation weaning and interval weaning were measured (Church and Hudson, 1999). This study concluded that there was no difference between treatment groups in the short term (first week post weaning) or the long term (3 weeks post weaning). This study also found that the only observed behavioral difference between the two groups was that complete separation wapiti calves spent more time pacing the fence line than wapiti calves subjected to interval weaning. Complete separation wapiti calves also vocalized more during the observation period while no vocalizations were recorded for the interval group (Church and Hudson, 1999). For a summary of the results from the studies comparing weaning methods, see table 6.

Physiological consequences of weaning.

The stress of weaning can have an effect on the physiological functions of calves. These can take the form of both sympathetic and parasympathetic nervous system (adrenal) responses and immune system responses. Adrenal responses include changes in the concentrations of catecholamines and cortisol circulating in the blood, both of which are important because of their effects on the metabolism of carbohydrates (Bela and Allen, 1972). Such stress induced responses can have an effect on animal production (Stott, 1981). Immune responses are important for obvious reasons. For example, impaired immunity due to the stress of weaning increases susceptibility to bovine respiratory infections (Yates, 1982). These responses are considered in more detail below.

The adrenal response. One method of measuring stress is through the specific measurement of catecholamines (epinephrine and norepinephrine) and cortisol. A study performed by Lefcourt and Elaasser (1995) found that plasma concentrations of

epinephrine and norepinephrine increased in weaned calves compared to non-weaned control calves. This stress response was separate from the stress brought on by handling and sample collection because calf catecholamine concentrations subsequently dropped after they were reunited with their dams. No response was seen in the cortisol concentrations of weaned calves (Lefcourt and Elaasser, 1995). Another study performed by Hickey et al. (2003) found an increase in norepinephrine during weaning, but weaning had no influence on the plasma concentrations of epinephrine or cortisol. Analysis of plasma catecholamines and cortisol concentrations can be highly variable because levels fluctuate throughout the day (Fulkerson et. al. 1980). Measuring fecal concentrations of catecholamines and cortisol may prove to be a better method in assessing stress in beef calves during weaning because it is not influenced by stress brought on by handling and sample extraction (Morrow et. al., 2002). Such methods have not been used in weaning trials so it is uncertain at this time how efficient they will be in evaluating catecholamine and cortisol fluctuations. The current study did not measure endocrine responses to stress during weaning.

The immune response. Research indicates that weaning can have an effect on both the humoral and cell-mediated immune responses. In humoral immunity, weaning causes an increase in antibodies concentrations in response to pathogens, particularly IgG1 and IgG2 antibodies (Pollack et al., 1992; Mackenzie et al., 1997). A delayed response (30 days post challenge) in IgM and IgA antibodies has also been seen as a response to weaning (Mackenzie et al, 1997). These results suggest that weaning may increase immunological function if the calf is infected with a disease that is immobilized primarily by humoral immunity. However, if cell-mediated immunity plays an important role this

may not be the case as cell mediated immune function is impaired by weaning in beef calves. Church and Hudson (1999) found an increase in the neutrophil/lymphocyte ratio of farmed wapiti calves when weaned using the traditional method as opposed to no change in the ratio in calves weaned using the interval method that may affect the calf's ability to fight off disease. Hickey et al. (2003) also found an increase in circulating neutrophils a decrease in lymphocytes and, as a result, an increase in the neutorphil/lymphocyte ratio in calves after weaning when challenged with Concanavalin A mitogen. This was not accompanied by an increase in total white blood cells (Hickey et al., 2003). Similar results were also seen in a study performed by Phillips et al (1989) which makes sense because an increase in one white blood cell type is accompanied by a decrease in the other.

Measuring behavior in cattle.

There are many ways of measuring behavior in animals. The type of behavior being measured, sample size, time constraints, and experimental design all go into determining what type of behavioral measurement will be used. It is important to distinguish between sampling methods and recording methods when dealing with measuring behavior. Sampling methods involve how the information was obtained. Two common sampling methods are focal sampling and scan sampling. Focal sampling involves following one animal for the duration of the time period and only observing that particular animal, where as scan sampling involves scanning an animal or a whole group of animals at distinct intervals and noting what behaviors are being performed at those intervals. Recording methods refer to how the behaviors were recorded (Martin and

Bateson, 1993). The following is a description of the most common ways of recording behavior and the sampling methods that can be used with them.

Continuous recording. Continuous recording is a means of determining the true frequency and duration of a behavior of an animal over a period of time. Continuous recording consists of an observer keeping track of what behavior the animal in performing (frequency) and timing how long that behavior is performed (duration). Because a single animal has to be continuously observed over the entire time period, focal sampling is the sampling method of choice when recording behaviors continuously. Continuous recording tends to give true estimates of frequency and durations of behaviors of single animals but durations can be underestimated if the recording of the behavior by the observer is terminated before the behavior itself is terminated by the animal (Martin and Bateson, 1993). Mitlöhner et al. (2001) found that when using focal animals to determine the behavior of a group on animals, 1 out of 10 focal animals was enough to be indicative of the whole group when measuring long duration behaviors (feeding, standing, lying) and 4 out of 10 were needed when measuring short duration behaviors (such as drinking or walking) with continuous recording.

Instantaneous recording. Instantaneous recording is when an animal or group of animals is observed at specific time points or intervals and whatever behavior is being performed by that animal or each animal in the group is recorded for that interval. Time intervals can vary from just a few seconds to up to an hour. Recording behaviors instantaneously can be done when observing a focal animal or when performing scan sampling. For instance, an Instantaneous Scan Sampling with 10 minute intervals would involve an observer scanning a group of animals every 10 minutes and recording the

frequencies of behaviors exhibited by the group at that time. Instantaneous sampling gives frequencies of a behavior occurring but not its' duration. Durations of the behavior are often inferred by multiplying the frequency by the length of the observation period. Instantaneous sampling tends to be more biased towards conspicuous behaviors when long intervals are used but the shorter the interval the more instantaneous sampling approximates continuous recording (Martin and Bateson, 1993). A study performed by Mitlöhner et al. (2001) found that using instantaneous sampling with short interval times (1 to 15 min.) was an accurate way of measuring behaviors that have long durations, such as standing, lying, and feeding, but less accurate at measuring short duration behaviors, such as walking and drinking when compared to continuous recording. Intervals of 30 minutes or greater were found to be imprecise in measuring behaviors.

Introduction

One of the most important periods in the cow cycle is weaning. For the rancher this is the time when the size of the pay check will be determined. For the calf, it is one of the most stressful experiences they will encounter. It is important to complete the weaning process with a minimal amount of sickness and with little decrease in average daily gain (ADG). However, the increase stress inflicted on calves during the weaning process increases the chances of calves contracting respiratory infections (Yates, 1982). Increased occurrences of sickness decreases the ranchers overall pounds of beef sold, significantly reducing the profitability of the operation.

Natural weaning in semi-wild cattle usually occurs when the calf is between 7 and 14 months of age and takes place when suckling is prevented by the dam. After natural weaning, a considerable amount of physical and social contact is still maintained by the dam and calf (Rienhardt, 2002). Contemporary beef management practices wean calves at an earlier date, usually between 3 and 6 months of age in order to increase production of the cow herd. This is accompanied by an increase in vocalizations by both calves and cows, which has been suggested to be an indication of poor animal welfare (Grandin, 1998; Watts and Stookey, 2000).

Traditionally, weaning in cattle has been accomplished by a complete separation of cow and calf, putting as much distance between the two as possible. Recent interest in decreasing the negative effects of weaning (i.e. decreased weight gain or weight loss, and an increase in sickness due to stress) has facilitated the investigation of the benefits of alterative weaning methods, namely fence-line (Price et al., 2003; Boland et. al., 2008; Enríquez et al., 2010) and two-stage weaning in calves (Haley et. al., 2005; Boland et. al.,

2008; Enríquez et al., 2010) and interval weaning in farmed wapiti (Church and Hudson, 1999). Because of differences in experimental design and environment, results from these studies tend to be conflicting. The aim of this current study was to compare traditional, fence-line, and interval weaning in a feed-lot setting in order to test the null hypothesis that no difference in weight gain or behavior can be detected between the three weaning methods: traditional, fence-line and interval weaning.

Materials and Methods

Location and animal management. This study was conducted at the University of Nevada's Main Station Field Lab in Reno, Nevada. Three hundred and thirty nine (339) Angus and mixed breed (Angus x Brangus, Angus x Hereford, and Hereford x Brangus) calves were weaned in two trials in the fall of 2010 and three trials in the fall of 2011 (Table 1). Calves were between 97 and 229 days old at the time of weaning and mean beginning age did not differ significantly between treatment groups for each trial (Table 2). Weaning occurred on day 1 of each trial when calves were divided into their treatment groups. For the first week of weaning, calves were maintained in a feed lot (a common practice in the beef industry) and given free choice water and grass hay (mixture of smooth brome (*Bromus inermus* Leyss) orchard grass (*Dactylis glomerata* L.) and tall fescue (*Schedonorus phoenix* (Scop.) Holub)). At the end of this period they were all removed to a shared grass pasture (same forage mix as hay). Calves stayed in their pasture until the end of the study. Each calf in the study was weighed on the day previous to weaning (day 0) to determine beginning body weight. Calves were then sorted by sex and ordered by weight (lightest to heaviest) and then randomly assigned (using a random number generator) to each of the three treatment groups. The average weight of each treatment group did not differ significantly in each trial and treatment groups had similar numbers of male and female calves (Table 3).

Treatment methods. In each trial, calves were divided into three different weaning treatments. The three weaning treatments consisted of a traditional weaning group (TRAD), an interval weaning group (INT) and a fence-line weaning group (FEN). Since traditional weaning is the most widely used weaning method in the industry today, the

TRAD weaned group was considered the control treatment for the purpose of this experiment. In the TRAD weaning group, calves and cows were completely and physically separated from each other on day 1 of weaning. At this point, the cows were removed to a pasture at least 700 m from the calves, the furthest available distance in order to minimize communication of calves and dams through vocalization. Cows remained in this pasture until the end of each trial. In the INT weaning group, half the dams were separated from their calves on day 1, a quarter of the dams were separated on day 2, and the remaining dams were separated from their calves on day 3. After separation from calves, the cows in this treatment group were removed to the same pasture as the cows from the TRAD group where they were housed in common. In the FEN weaning group, calves were physically separated from their dams on day 1 of weaning but housed in adjacent pens in order to prohibit suckling. Cows were completely separated from the calves on day 5 and removed to the same pasture as the cows from the TRAD group.

Behavior. Behavioral data was gathered on each weaning group starting on day 1 of weaning and ending on day 5. Behaviors were observed three times per day from 7:00-8:00, 12:00-13:00, and from 17:00-18:00. On day 1, morning and noon observations were not taken as calves were still being sorted into their groups at those times. On day 5 only the morning observations were taken as behavioral frequencies tended to be the same between groups by this time. Instantaneous scan sampling (Martin and Bateson, 1993) was used in a rotating fashion. Observation began on one group and lasted approximately three minutes than rotated to the next group and finally the last group. Once the order was established it did not change for the remainder of the observational period. Observations

of each group were performed approximately every ten minutes resulting in six observations per weaning group during each observational period. One to two observers performed each observation and all observers were trained by the experiment designer to facilitate consistent observational data. The behaviors that were observed and recorded were eating, drinking, walking, standing, lying down and vocalization. Calves were considered to be eating if their head was down in the feed bunk or they were visibly chewing food within close proximity to the feed bunk (within 2 feet) and to be drinking if their head was down in the water trough. Walking was defined as performing any forward movement, standing if they were on all four limbs and not eating, and lying down if lying prostrate on the ground. Eating, drinking, walking, standing, and lying down were recorded as the number of individuals performing that action in each treatment group. Data was averaged for each observational period then standardized by converting to a percentage to account for the different numbers of calves used in each trial. Vocalizations were recorded as the number of vocal sounds that could be attributed to that particular group of calves over a 30 second period. Vocalizations for each observational period were then totaled and converted into the number of vocalization per minute per calf. For all observational data, the entire group of calves was considered the statistical unit.

Weight gain/loss. Body weights were collected for each calf in all trials on days 0, 7, 14, and 28 of the study and average daily gain (ADG) and cumulative weight gain was calculated from these weights. Multiple weights were taken to assess the short (7 day) and long (28 day) term effects on weight gain associated with each weaning method. Calves were weighed on a floor scale situated in the alleyway leading up to the working

squeeze chute after being removed off of feed and water for one hour (shrink period). Individual calves were identified by a unique ear tag number and then their weight was recorded. Weighing for each trial began at approximately 8:00 A.M. and calves were weighed in the order in which they loaded into the alleyway on their own accord. After each weight was recorded calves were released into a feed-lot pen until the weighing session had ended at which point they were returned to the same pasture they were occupying previous to being weighed. Weights for day 14 of trial 4 and day 7 of trial 5 were not included in analysis because of a scale malfunction that occurred on those days. In trial 5, only behavioral data on six calves was used because their weights were approximately 200 lbs lower than the average calf weight for that trial. For weight gain/loss data, each individual calf was considered a statistical unit.

Statistical analysis. All field data was hand recorded and subsequently transferred to Microsoft Excel data spreadsheets. All variables were analyzed using a univariate analysis for repeated measures in JMP (JMP, Version 9. SAS Institute Inc., Cary, NC, 1989-2007). All behavioral variables except for standing were square root transformed to meet normality of variance assumptions. Behavioral data was analyzed in two different ways, by period of the day (morning, noon, and evening) to determine if a period effect was present and by day to determine if there was an effect over the whole weaning period. Results were indexed by averaging each treatment within each trial by period and by day. Day indexes were weighted to account for only one observation on day 1 and day 5. Behavioral data was tested for effects of treatments, year of trials, and interactions between treatment and years or treatment and period or day. No year or treatment year interactions were present in the behavioral data so they were eliminated from the final

behavioral model. Weight data was also analyzed in two different ways. ADG was calculated for each weekly period (week 1, week 2 and weeks 3&4), and cumulative weight gain was analyzed for each weighing (from day 0 to day 7, 14, and 28). Weight data was tested for effects of treatment, year, sex, and interactions between these variables, as well as week and treatment week interactions. No sex effect, sex interactions or treatment year interactions were significant so they were dropped from the final model. Results were considered to be significant at the $\alpha = 0.05$ level. Significant differences were seen for; Period of day and day of trial analysis for main treatment affects of eating, walking, and lying down behavior, treatment day and treatment period interactions for walking and vocalizing behavior, and treatment period interactions for ADG and cumulative weight gain analysis. For these overall differences, post-hoc Tukey's HSD tests were performed to determine pair-wise differences.

Results

Results for the two tests used to analyze the behavioral data (by period and by day) and the weight gain data (ADG and cumulative weight gain) were in close agreement to each other. Behavioral results are summarized in Table 4. Graphical representations of behaviors that were found to be significantly different are presented in Figures 1 through 3. Weight gain results are summarized in Table 5. Graphical representations of weight gain data are presented in Figures 4 and 5.

Behavior

For vocalizations, no main treatment effect was seen for the period analysis in the amount of vocalizations between treatments. An interaction between period and treatment was seen for the amount of vocalizations coming from each pen with FEN weaned calves vocalizing more than INT weaned calves in the evenings (0.7 voc $calf^{-1}$ min^{-1} vs. 0.09 voc $calf^{-1}$ min^{-1}, P = 0.02). No significant difference was seen between treatments for the morning or evening observations and no period treatment interactions were seen between TRAD weaned calves and the other treatments. No significant main treatment effect for the day analysis was seen and no treatment day interactions were present for vocalizations per calf.

For eating behavior, a significant main effect for the period analysis was found with TRAD weaned calves spending less time eating than INT weaned calves (18.6% vs. 33.6%, P = 0.01). No difference was seen between FEN weaned calves and the other treatments and there was no significant treatment period interactions present. A main treatment effect by day also occurred with INT weaned calves (37.9%) spending more time eating than TRAD weaned calves (22.6%, P = 0.001)(Figure 1). Fence-line weaned

calves did not differ from either the TRAD or INT weaned calves. No interaction was seen between treatment and day between any of the treatment groups.

For walking, a main treatment effect for period was seen with TRAD weaned calves (14.1%) spending more time walking than both INT (3.3%, P = 0.0003) and FEN weaned calves (4.3%, P = 0.001). Fence-line weaned calves did not differ from INT weaned calves and no treatment period interaction was present for walking behavior. A main treatment effect for the day analysis was significant with TRAD weaned calves spending more time walking (10.3%) than both INT (2.5%, P = 0.001) and FEN weaned calves (3.8%, P = 0.007) (Figure 2). No significant difference was seen between INT and FEN weaned calves. A treatment day interaction was also observed. On day 2, TRAD weaned calves (25.4%) spent more time walking than both INT (4.01%, P = 0.0001) and FEN weaned calves (8.3%, P = 0.002). On day 3, TRAD weaned calves (15.2%) also spent more time walking than both INT (3.3%, P = 0.01) and FEN weaned calves (3.3%, P = 0.01). There was no significant difference between INT and FEN weaned calves for day 2 or day 3.

For the lying down behavior, there was a main effect for the period analysis with TRAD weaned calves spending less time lying down than FEN weaned calves (6.9% vs. 16.9%, P = 0.005). No significant difference was seen between INT weaned calves and the other 2 weaning treatments and no significant treatment period interactions were present. A similar main effect for day analysis was also seen between TRAD (4.6%) and FEN weaned calves (16.9%, P = 0.006)(Figure 3). No interaction effects were seen between treatments and days and no differences were detected between the INT weaning treatment and the other 2 treatment methods.

No significant main or interaction effects were found when treatment groups were analyzed by either period or day in drinking or standing behavior.

Weight Gain

For ADG measurements, a significant effect of year of trial was seen with calves' ADG significantly higher in year 2 (0.7 kg/day) than in year 1 (0.2 kg/day, $P < 0.0001$). No main treatment effects were seen but a significant treatment week interaction was present with differences observed in week 1 and week 2. Traditionally weaned calves ADG (-0.3 kg/day) was less than INT weaned calves (0.7 kg/day, $P = 0.0003$) for the first week. The opposite was true on week 2 where TRAD weaned calves (1.2 kg/day) had a higher rate of gain than INT weaned calves (0.5 kg/day, $P = 0.002$) (Figure 4). Fence-line weaned calves' ADG was not significantly different from the other 2 treatment groups for either week 1 or week 2 and no significant differences in average daily weight gain were present between groups for weeks 3 and 4 of the study.

For cumulative weight gain, a main year effect was significant with calves in year 2 gaining more than calves in year 1 (20.5 kg vs. 4.5 kg, $P < 0.0001$). There was no significant main treatment effect for cumulative weight gain. A significant treatment period interaction was seen for the day 7 cumulative weight gain. On day 7 TRAD weaned calves had lost 1.7 kg and INT calves gained 3.2 kg ($P = 0.005$) (Figure 5). Fence-line weaned calves did not differ from the other 2 treatment group on day 7 and no difference was seen between each treatments weight gain on the day 14 or day 28 weights.

Discussion

Because vocalizations have been considered an important tool in assessing an animal's state of well being (Grandin, 1998; Watts and Stookey, 2000) it is an important factor in assessing a weaning protocol's effectiveness in lowering the negative effects on behavior. In this study, no significance differences for overall vocalizations were seen but FEN weaned calves did vocalize more in the evenings compared to INT weaned calves. The present study differed from past research in that Price et. al (2003) found that FEN weaned calves vocalized less than TRAD weaned calves. Conversely, Enríquez et. al. (2010) found that FEN weaned calves vocalized more than TRAD weaned calves. In farmed wapiti, Church and Hudson (1999) found that INT weaned wapiti calves vocalized less than TRAD weaned wapiti calves. Our current study indicates that neither INT weaning or FEN weaning provided any benefit in the reduction of vocalizations during the weaning process. However, INT weaned calves may be better then FEN weaning as INT weaned calves vocalized less in the evenings than FEN calves.

In eating behavior, INT weaned calves spent more time eating than TRAD weaned calves but FEN weaned calves eating behavior did not differ from the other two weaning groups. This paralleled the higher weight gain in INT calves compared to TRAD weaned calves in the first 7 days of the study. Between TRAD and FEN weaned calves, these results are in agreement with a study performed by Enríquez et. al. (2010) who found that the eating behavior of FEN weaned calves and TRAD weaned calves did not differ over the entire observation period, however, a treatment day interaction was seen with TRAD weaned calves having a lower grazing frequency than FEN calves on days 1, 2, and 3 after complete separation had occurred. Conversely, Boland et. al. (2008) found

that TRAD weaned calves spent less time eating than FEN weaned calves. These results could be misleading though as FEN weaned calves had been separated from their dams by a fence line for 7 days prior to the complete physical separation of both FEN weaned calves and TRAD weaned calves. The TRAD weaned calves were also shipped by truck on the day of weaning, which may have compounded the stress experienced by those calves. Similar to Boland et. al. (2008), a study performed by Price et. al. (2003) found that calves allowed fence line contact with their dams during weaning spent more time eating than calves weaned in a traditional manner. For INT weaning, Church and Hudson (1999) found that there was no difference in eating behavior between INT and TRAD weaned wapiti calves, which are in contrast to the finding of the present study where INT weaned beef calves were found to spend more time eating than TRAD weaned beef calves. A possible explanation for this could be the fact that the Church and Hudson (1999) study was performed on pasture and the present study took place in a feed-lot. Generally, calves go through a period of adjustment when placed in a feed-lot during which they need to discover the location of feed and water and how to eat out of a feed bunk instead of grazing off the ground. In the present study, the cows that remained with the calves in the INT weaning group could have taught calves subjected to that weaning method how to bunk feed and facilitated greater eating behavior. This would not be necessary in a pasture setting as calves would have already been trained to graze on pasture by their dams. The current study suggests that INT weaning encourages a greater amount of eating behavior in calves during the first week of weaning and therefore greater weight gain than the TRAD weaning method.

In this study, TRAD weaned calves walked more than both INT and FEN weaned calves, especially on days 2 and 3. Walking is an important behavior to monitor because an excess of walking can negatively affect body weight gain through increased utilization of calories. The findings of this study mirror the findings of a study by Price et. al. (2003) which found that FEN weaned calves spent less time walking than TRAD weaned calves. However, other studies of this nature found no difference in the amount of time spent walking between TRAD weaned calves and INT weaned calves (Church and Hudson, 1999) or FEN weaned calves (Enríquez et. al. 2010). Also, in a study that used pedometers to measure the amount of steps calves weaned by the TRAD and FEN methods found that TRAD and FEN calves did not differ in the total distance traveled between groups (Boland et. al., 2008). The use of pasture or feed-lot to house calves does not completely explain the difference in results here as all studies except the present one utilized pastures. The results of this study suggest that some contact with calves' dams in INT and FEN weaning protocols provided a benefit in the reduction of walking behavior during weaning.

When considering lying down behavior, this study found that TRAD weaned calves spent less time lying down than FEN weaned calves. Lying down is generally considered to be a non-reactive state and therefore can be considered a low stress behavior. Results from previous studies vary but the present study is in agreement with that of Price et. al. (2003) which found that under most conditions, TRAD weaned calves spent less time lying down than FEN weaned calves. Church and Hudson (1999) found that farmed wapiti calves weaned by the TRAD and INT methods did not differ in the amount of time spent lying down. Conversely, other research found no difference in the

amount of time beef calves spent lying down when weaned by the TRAD and FEN methods (Boland et. al., 2008; Enríquez et. al., 2010). This research suggests that FEN weaning facilitates an increase in lying down behavior compared to TRAD weaning.

Generally, standing behavior is not associated with an animal's welfare status and therefore is not measured when looking at behavioral effects of weaning methods. There was no significant difference in standing behavior in this study. Similarly, Church and Hudson (1999) found no difference in the amount of time spent standing between TRAD and INT weaned farmed wapiti. In beef calves Boland et. al. (2008) also found no difference in the amount of time spent standing in TRAD and FEN weaned calves. This study confirms that standing behavior is not indicative of the level of stress brought on by weaning in beef calves.

Like standing, drinking is not often measured in behavioral analysis because it occurs at a low frequency and many behavioral sampling methods fail to register drinking behavior. In this study no difference was found in drinking behavior. Other studies in farmed wapiti (Church and Hudson, 1999) and beef calves (Boland et. al., 2008) found no difference in drinking behavior between TRAD, INT, and FEN weaned calves. These findings suggest that drinking behavior does not alter based on weaning method.

Weight gain during the weaning process is important for economic reasons. In this study, ADG for INT weaned calves was greater than TRAD weaned calves for the first week. But in the second week the TRAD weaned calves' ADG was greater than in INT weaned group. As a result, TRAD weaned calves weight gain in the second week was sufficient enough to compensate for the weight lost in the first week. This is also characterized by our analysis of cumulative weight gain, which showed a significant

difference in gain between INT and TRAD calves for the first week, but no difference for the first two weeks. Neither weight gain analysis showed any significant difference between FEN weaned calves and the other 2 weaning methods. ADG was insignificant for the last 2 weeks in our study as was cumulative weight gain over the whole 4 week period. These results agree with a study performed by Boland et. al. (2008) which found no difference in weight gain between FEN weaned calves and TRAD weaned calves. Results from other research differ from the present study. Price et. al. (2003) found that not only did FEN weaned calves gain more than TRAD weaned calves in the first 2 weeks post weaning but at 10 weeks post weaning as well. Conversely, Enríquez et. al. **(**2010) found that TRAD weaned calves gain weight better than FEN weaned calves. In farmed wapiti, Church and Hudson (1999) found no difference between wapiti calves weaned by the INT and TRAD methods. Differences in the nutritive quality of the feed may help explain the differences in results seen between studies. Boland et. al. (2008) suggested that an increase in feed nutrition may result in higher increases in weight gain for TRAD weaned calves than FEN weaned calves. The results from this study illustrate that when calves are weaned on grass hay in a feed-lot, INT weaned calves may have higher ADG than TRAD weaned calves in the first week but TRAD weaned calves can gain enough in the second week so that cumulative weights may not differ after. This study also suggests that FEN weaning provides no benefits in weight gain over TRAD weaning in a feed-lot setting.

This study was not designed to measure the effects of weaning methods on morbidity or mortality on calves but a review of the MLSF veterinary records following the experiment revealed the following. In trial 1, a single calf from the traditionally

weaned group, and 2 calves each from the interval and fence-line weaned groups were diagnosed with pneumonia and received at least one treatment of antibiotic (Oxytetracycline 200 mg/ml). In trial 4, one calf died in the interval weaning group and 1 calf was treated for foot root in the traditionally weaned group. Analysis of variance results for the effects of weaning treatment on morbidity and mortality included together showed a lack of significant differences between treatment groups ($P = 0.87$).

If one considers behavior as an indicator of distress in beef calves during weaning, than this study shows that FEN weaning provided some benefit in reducing distress during the first five days of weaning by increasing the time spent lying down over the whole period and decreasing the time spent walking for the second and third days post weaning. However, this was not accompanied by an increase of weight gain during the first week post weaning or at 28 days post weaning, suggesting that the behavioral differences had little, if any effect on calf growth. However, INT weaning did provide benefits in reducing distress by increasing eating time and decreasing time spent walking over the entire 5 day observation period and increasing weight gain during the first week of weaning.

The findings of this study show that allowing social contact to at least some dams during weaning has an effect on the behavioral indices related to distress in beef calves. Solely looking at the benefit to production in the form of weight gain, fence-line weaning provides no benefit to weight gain of calves either during the weaning process or after weaning has occurred. Interval weaning does benefit calf weight gain during the weaning process but 2 weeks after weaning occurs the benefits disappear. If calves are to be sold in the first week after weaning, interval weaning may be a good option for increasing calf

weights at the time of sale. However, if calves are maintained on farm for a period greater than 2 weeks all three weaning methods appeared to perform equally well. The practice of maintaining calves on farm for a period after weaning is becoming increasingly popular for a variety of reasons, one of which is preconditioning. Preconditioning consist of weaning, training calves to feed out of a bunk, and vaccinating over a period of time ranging from 24 to 45 days following weaning. Recent research (Seeger et. al., 2011) has shown a steady increase in the amount of calves sold that were preconditioned and an increase in the cash premium offered to such sales. This research shows that calves that are maintained on farm for a preconditioning period (at least 24 days) would perform equally as well when measuring weight gain. Producers also need to consider increases in cost associated with alternative methods. Fence-line weaning may involve an increase in fencing cost so infrastructure can support close separation of cows and calves and interval weaning may involve additional labor cost as cows are sorted from calves over a period of days instead of within a 1 day period (Table 7). When such considerations are included, alternative weaning methods may not provide any benefit over traditional weaning.

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Table 1. Summary of the results of studies testing the effects of alternative weaning methods on calf weight gain and behavior, current study included. Results are given relative to traditional weaning. + = greater weight gain, vocalizations, or time observed performing behavior, 0 = no significant difference, - = less weight gain, vocalizations, or time observed performing behavior.

Method Tested	Weight Gain	Eating	Walking	Drinking	Lying Down	Standing	Vocalization	Source
Fence-line	+	+	-		+		-	Price et. al. 2003
	0	+			0	0		Boland et. al. 2010
	-	0	0		0		+	Enríquez et al.5 2010
	0	+	-	0	+	0	0	Current Study
Two stage	0	+	-		+		-	Haley et. al. 2005
	-	+			0	0		Boland et. al. 2010
	-	0	+		0		0	Enríquez et al. 2010
Interval	0	0	-		0	0	-	Church and Hudson, 1999
	0	+	-	0	0	0	0	Current Study

Table 1. N, beginning dates, and ending dates for each trial (n = amount of calves in the whole trial).

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
n	93	72	39	75	60
Day 1 of Weaning	11/2/2010	11/10/2010	8/30/2011	9/7/2011	9/13/2011
Day 28 of Weaning	11/29/2010	11/30/2010	9/26/2011	10/4/2011	10/10/2011

Table 2. Mean calf age (in days) with standard deviation by trial and treatment. TRAD = Traditionally weaned, INT = Interval weaned, FEN = Fence-line weaned. P-values for difference of age by trial also presented.

	TRAD	INT	FEN	P-value
Trial 1	208.56 ± 10.22	209.73 ± 9.04	211.65 ± 9.96	0.41
Trial 2	215.93 ± 12.57	216.93 ± 8.98	202.63 ± 24.95	0.21
Trial 3	141.84 ± 16.57	144.92 ± 19.22	139.08 ± 20.75	0.74
Trial 4	138.81 ± 13.80	139.47 ± 13.50	138.57 ± 14.09	0.93
Trial 5	149.82 ± 11.31	151.75 ± 11.14	143.00 ± 14.14	0.15

Table 3. Mean beginning body weight with standard deviation by trial and treatment. TRAD = Traditionally weaned, INT = Interval weaned, FEN = Fence-line weaned. P-values for difference in beginning body weight by trial also presented

	TRAD	INT	FEN	P-value
Trial 1	510.45 ± 51.00	509.29 ± 56.28	514.06 ± 60.15	0.94
Trial 2	512.50 ± 79.14	513.75 ± 82.17	513.00 ± 76.04	0.99
Trial 3	403.38 ± 46.40	402.15 ± 60.59	409.23 ± 44.08	0.93
Trial 4	387.52 ± 64.23	392.32 ± 66.89	389.92 ± 65.11	0.97
Trial 5	436.00 ± 38.31	436.00 ± 47.26	438.44 ± 45.76	0.98

Table 4. Means for behavioral results with standard error by day. Entries in rows with different letters are significantly different ($P < 0.05$). All behavioral results except for Standing are square root transformed. Columns on the right are results back transformed. Results are the mean percentage of calves exhibiting that behavior for each day. TRAD = Traditionally weaned, INT = Interval weaned, FEN = Fence-line weaned.

	Day	TRAD	INT	FEN	Std. Err.	TRAD	INT	FEN
Vocalizations	1	0.60	1.04	1.20	± 0.14	0.37	1.09	1.44
	2	0.83	1.09	0.94	± 0.09	0.69	1.18	0.89
	3	0.60	0.61	0.83	± 0.09	0.36	0.37	0.69
	4	0.42	0.39	0.47	± 0.09	0.18	0.15	0.22
	5	0.36	0.18	0.23	± 0.14	0.13	0.03	0.05
	Overall	0.56	0.66	0.74	± 0.06	0.31	0.44	0.55
Eating	1	3.57	5.18	4.64	± 0.81	12.73	26.79	21.51
	2	3.67	5.29	4.90	± 0.46	13.44	27.99	24.04
	3	4.85	6.72	5.87	± 0.46	23.56	45.22	34.48
	4	5.00	6.30	5.31	± 0.46	24.97	39.70	28.15
	5	6.70	7.28	7.05	± 0.81	44.86	53.05	49.64
	Overall	4.76^{a}	6.16^{b}	5.55^{ab}	± 0.26	22.62	37.88	30.84
Drinking	1	1.27	1.03	1.62	± 0.31	1.62	1.07	2.63
	2	0.91	1.17	0.80	± 0.19	0.82	1.37	0.65
	3	1.09	1.08	1.40	± 0.19	1.18	1.16	1.96
	4	1.10	1.02	1.33	± 0.19	1.21	1.05	1.76
	5	0.80	1.54	1.10	± 0.31	0.64	2.38	1.21
	Overall	1.03	1.17	1.25	± 0.12	1.07	1.37	1.56
Walking	1	3.20	1.64	3.27	± 0.45	10.26	2.68	10.69
	2	5.03^{a}	2.00^{b}	2.88^{b}	± 0.31	25.34	4.01	8.27
	3	3.89^{a}	1.81^{b}	1.82^{b}	± 0.31	15.17	3.29	3.30
	4	2.55	1.74	1.10	± 0.31	6.49	3.02	1.20
	5	1.37	0.68	0.60	± 0.45	1.89	0.46	0.36
	Overall	3.21^{a}	1.57^{b}	1.93^{ab}	± 0.25	10.31	2.48	3.73
Standing	1	67.28	56.64	52.55	± 8.99			
	2	53.06	48.37	48.10	± 5.46			
	3	41.24	34.68	41.46	± 5.46			
	4	50.32	31.90	34.36	± 5.46			
	5	42.17	39.23	35.91	± 8.99			
	Overall	50.81	42.16	42.48	± 3.71			
Lying Down	1	0.43	2.44	2.32	± 0.48	0.19	5.97	5.36
	2	2.32	3.94	4.24	± 0.28	5.36	15.55	17.98
	3	3.70	3.59	4.06	± 0.28	13.70	12.91	16.50
	4	3.76	4.49	5.81	± 0.28	14.17	20.15	33.80
	5	0.24	0.40	1.89	± 0.48	0.06	0.16	3.58
	Overall	2.09^{a}	2.97^{ab}	3.67^{b}	± 0.31	4.37	8.84	13.43

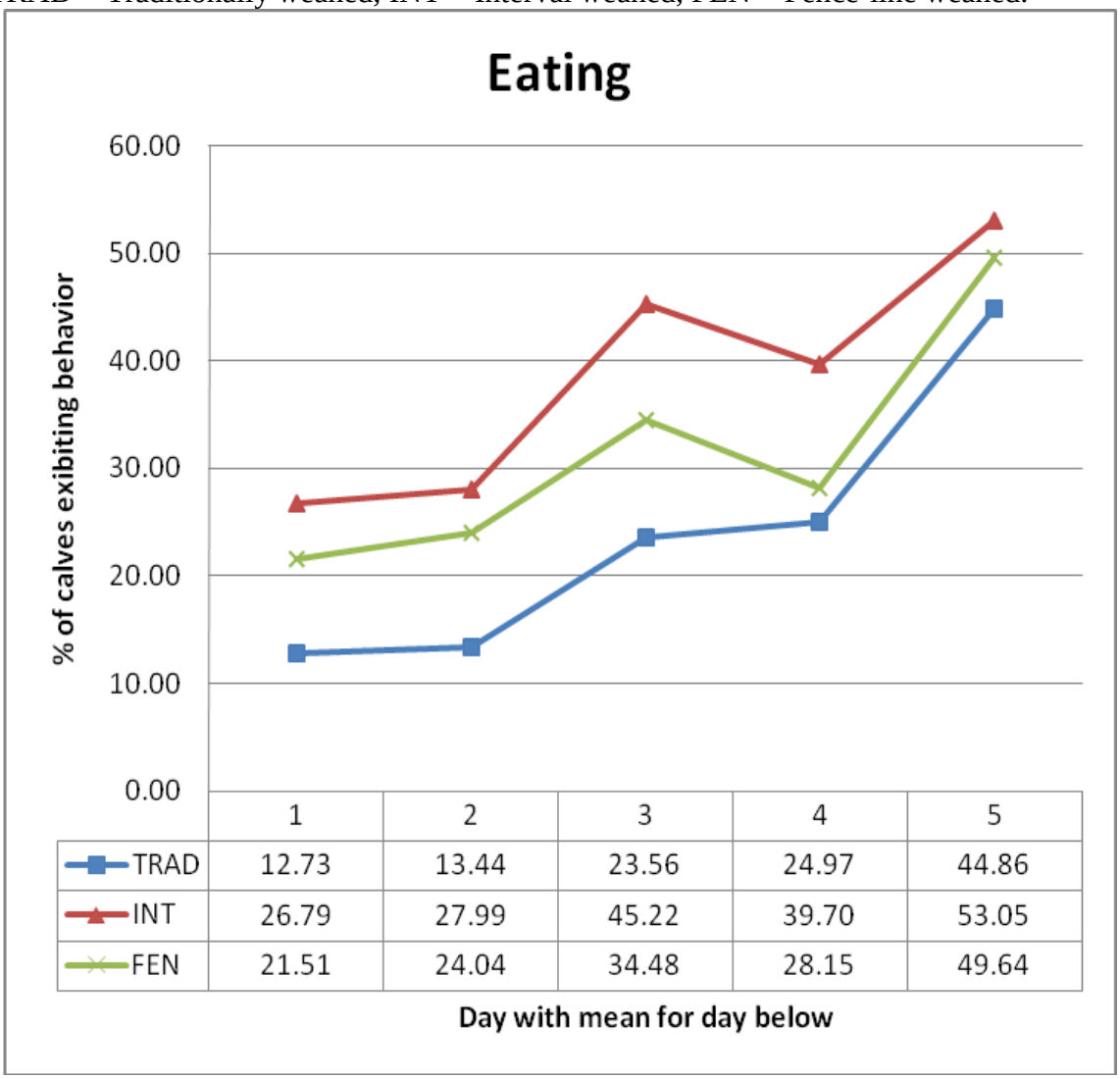
Table 5. Least square means for weight gain results with standard error by period. Entries in rows with different letters are significantly different ($P < 0.05$).
TRAD = Traditionally weaned, INT = Interval weaned, FEN = Fence-line weaned.

	Period	TRAD	INT	FEN	Stand. Err.
ADG	0-7	-0.32[a]	0.37[b]	0.13[ab]	± 0.11
	7-14	1.16[a]	0.45[b]	0.85[ab]	± 0.13
	14-28	0.55	0.49	0.40	± 0.11
	Overall	0.47	0.44	0.46	± 0.05
Cumulative	0-7	-1.74[a]	3.23[b]	1.87[ab]	± 0.92
Weight Gain	0-14	5.09	5.67	7.12	± 0.95
	0-28	12.06	12.63	12.90	± 0.86

Table 7. Estimated benefit and cost of alternative weaning methods compared to traditional weaning. + = greater benefit or cost, 0 = no change in benefit or cost, - = less benefit or cost.

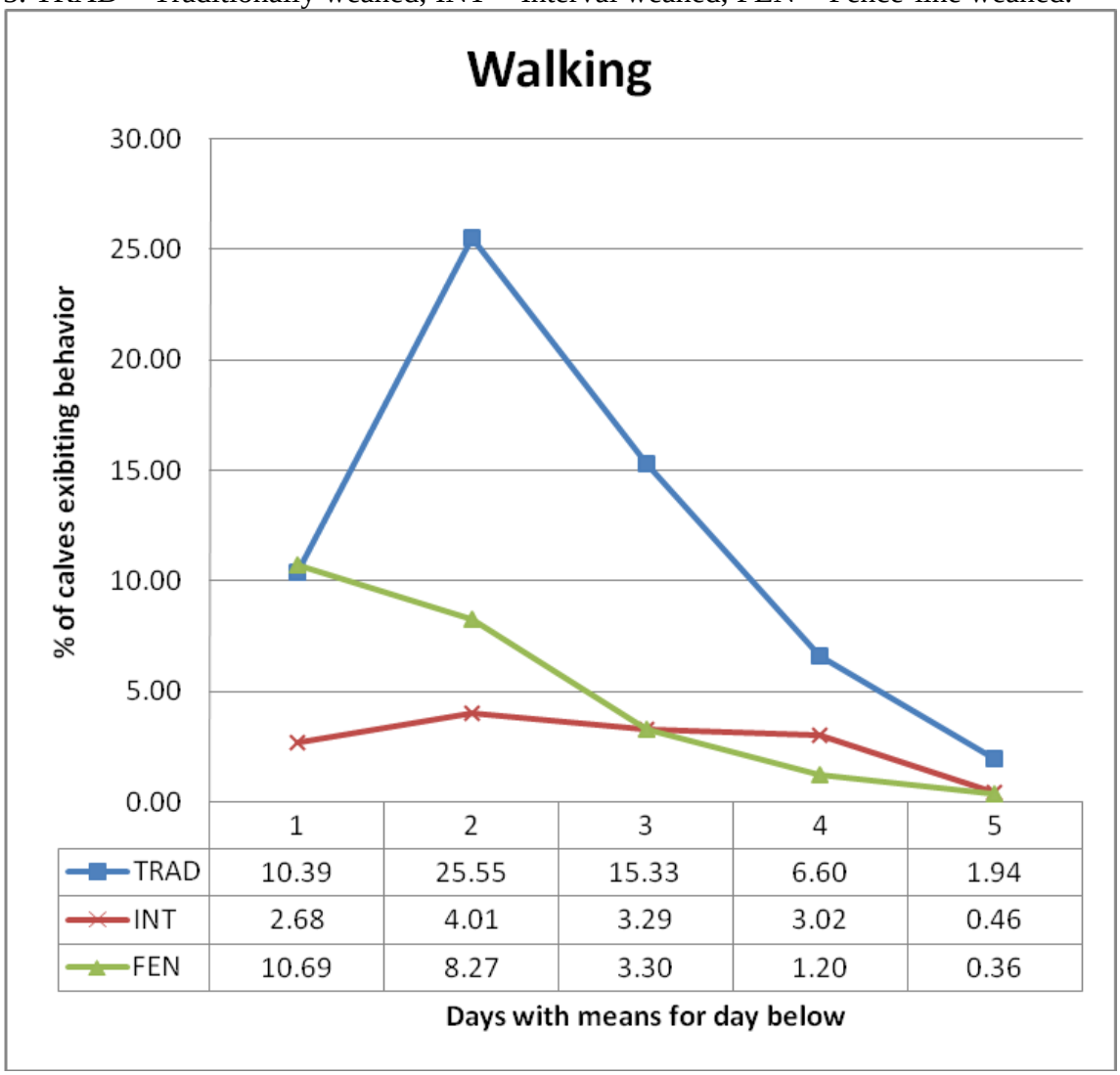
	Weight Gain	Labor	Infrastructure	Add. Components
Fence-line	0	0	+	0
Two stage	-	+	0	+
Interval	0	+	0	0

Figure 1. Means for percentage of calves exhibiting eating behavior for days 1 through 5. TRAD = Traditionally weaned, INT = Interval weaned, FEN = Fence-line weaned.



	1	2	3	4	5
TRAD	12.73	13.44	23.56	24.97	44.86
INT	26.79	27.99	45.22	39.70	53.05
FEN	21.51	24.04	34.48	28.15	49.64

Figure 2. Means for percentage of calves exhibiting walking behavior for days 1 through 5. TRAD = Traditionally weaned, INT = Interval weaned, FEN = Fence-line weaned.

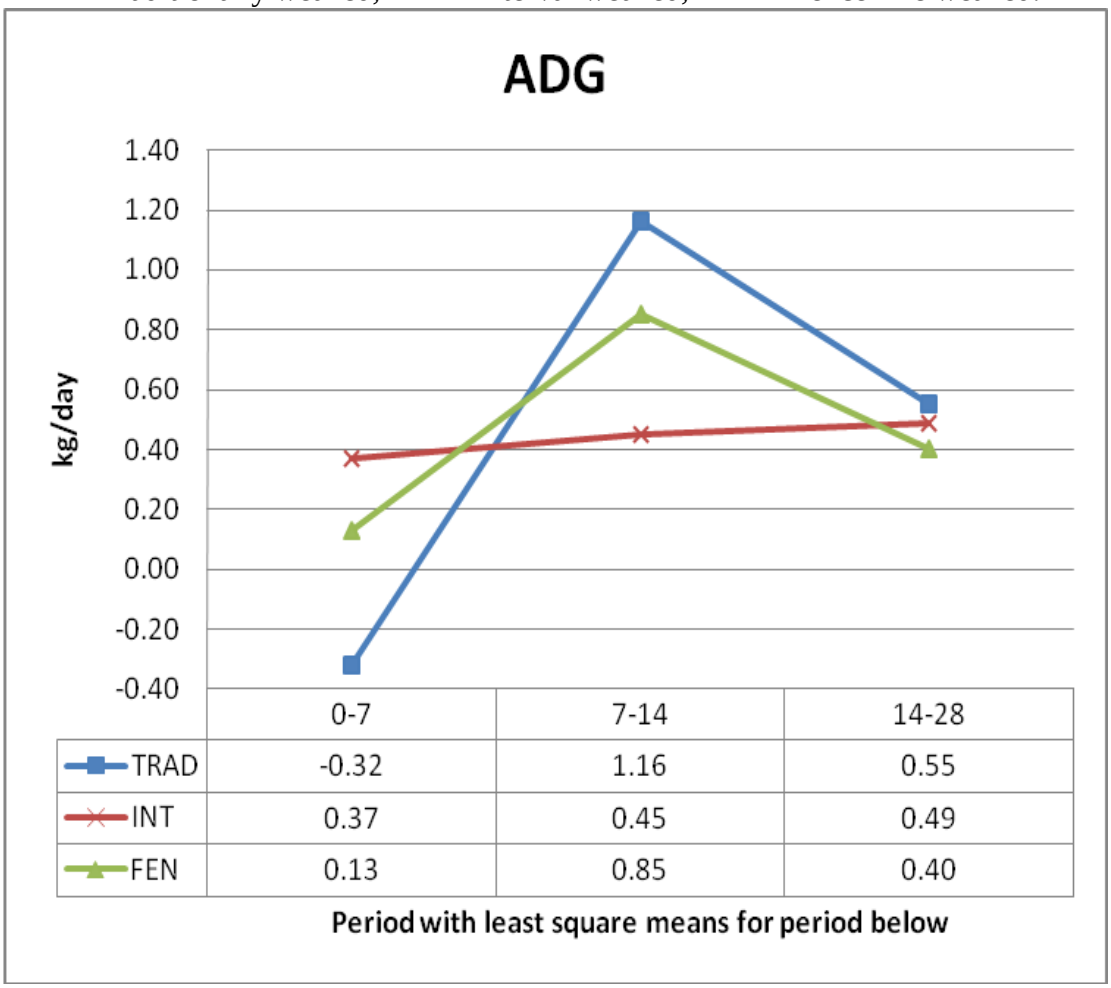


	1	2	3	4	5
TRAD	10.39	25.55	15.33	6.60	1.94
INT	2.68	4.01	3.29	3.02	0.46
FEN	10.69	8.27	3.30	1.20	0.36

Figure 3. Means for percentage of calves exhibiting lying down behavior for days 1 through 5. TRAD = Traditionally weaned, INT = Interval weaned, FEN = Fence-line weaned.

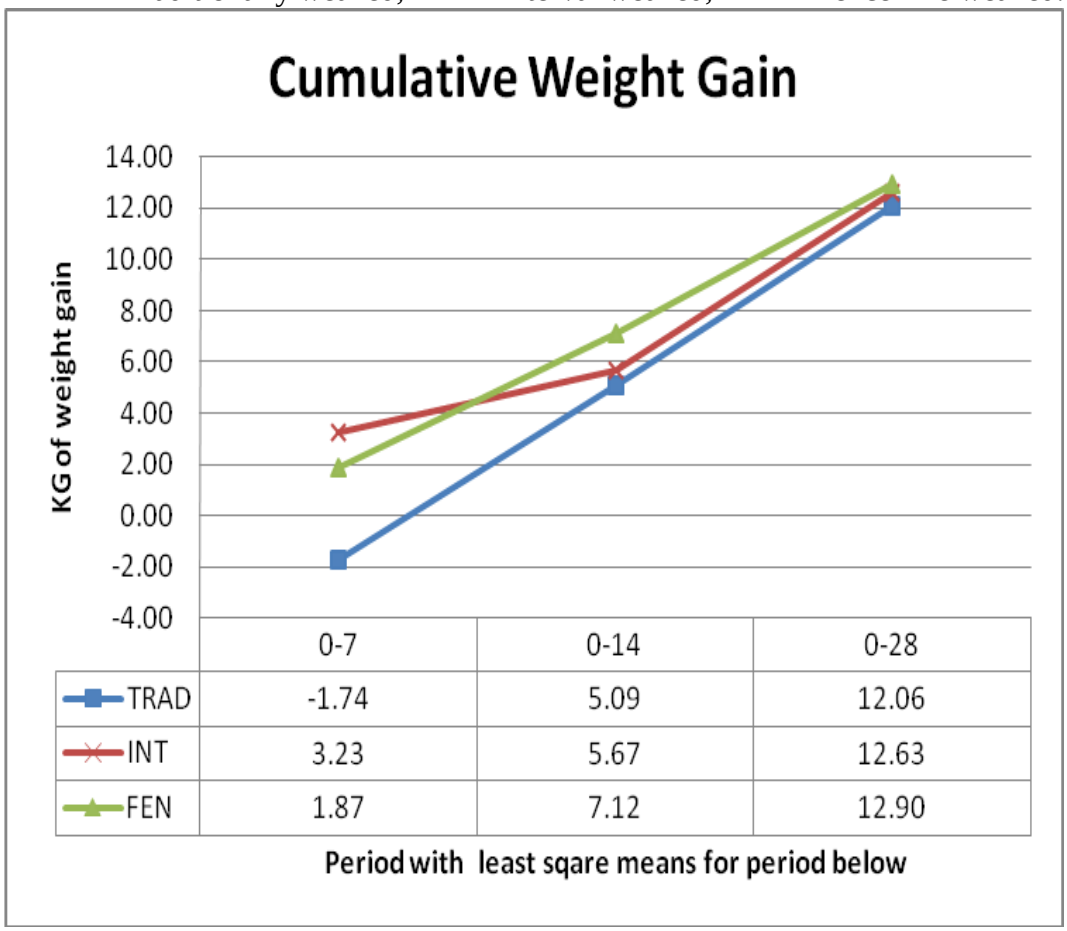
	1	2	3	4	5
TRAD	0.19	5.36	13.70	14.17	0.06
INT	5.97	15.55	12.91	20.15	0.16
FEN	5.36	17.98	16.50	33.80	3.58

Figure 4. Least square means for average daily gain (ADG) of calves for each period. TRAD = Traditionally weaned, INT = Interval weaned, FEN = Fence-line weaned.



	0-7	7-14	14-28
TRAD	-0.32	1.16	0.55
INT	0.37	0.45	0.49
FEN	0.13	0.85	0.40

Figure 5. Least square means for cumulative weight gain of calves for each period. TRAD = Traditionally weaned, INT = Interval weaned, FEN = Fence-line weaned.



	0-7	0-14	0-28
TRAD	-1.74	5.09	12.06
INT	3.23	5.67	12.63
FEN	1.87	7.12	12.90