EFFECTS OF TAIL DOCKING ON BEHAVIOR, PERFORMANCE AND HEALTH OF BEEF CATTLE RAISED IN CONFINED FEEDLOTS

By

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ABSTRACT

EFFECTS OF TAIL DOCKING ON BEHAVIOR, PERFORMANCE AND HEALTH OF BEEF CATTLE RAISED IN CONFINED FEEDLOTS

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Tail docking of feedlot cattle is a management practice used in some confined, slatted floor feedlots of the Midwestern United States. Justification for tail docking is to reduce tail injuries and their sequelae, and improve performance. Limited evidence exists to support these claims and the practice of routine tail docking is an animal welfare concern in regards to pain and loss of the tail for communication and fly avoidance. The primary objective of the research conducted for this thesis was to determine the effect of routine tail docking on performance and health parameters of feedlot cattle housed in a confined slatted floor feedlot facility and behavioral response following tail docking. Cattle were randomly assigned to 1 of 2 treatment groups; docked (DK) or control (CN). All calves received the same pre- and post-operative analgesia and DK calves had the distal two-thirds of their tail removed with pruning shears. For all performance trials, we found no significant effect of treatment on performance, carcass, morbidity, mortality or lameness. Tail injuries persisted among 60-76% of cattle that were not tail docked. Behavior studies demonstrated increased fly avoidance activity and signs of acute pain in DK calves. We were unable to identify a performance or health advantage to tail docking, and we observed signs of compromised welfare in feedlot cattle following tail docking. However, tail tip injuries persisted in cattle raised in slatted floor facilities. Because routine tail docking of cattle housed in confined, slatted floor facilities does not appear to improve performance and cattle welfare is compromised, alternative solutions to reduce the incidence of tail tip injury should be considered.

I dedicate this work to my previous written work's editors – there are many, but to name a few, my mother, Cecilia, my sisters – Alicia and Liz, my husband, Phil, and friend, Nicolle. While writing has always been a feared task for me, you have all helped to improve my writing ability with kind words and thoughtful criticisms. Thank you!

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

KEY TO ABBREVIATIONS

AABP	American Association of Bovine Practitioners
ADG	Average daily gain
ASPCA	American Society for the Prevention of Cruelty to Animals
AVMA	American Veterinary Medical Association
BCTRC	Beef Cattle Teaching and Research Center
BW	Body weight
CAB	Certified Angus Beef
CN	Control (sham treatment group)
CS	Corn silage
CVMA	Canadian Veterinary Medical Association
D	Day
DGS	Distillers grains plus solubles
DK	Docked (experimental treatment group)
DM	Dry matter
DMI	Dry matter intake
DOF	Days on feed
G:F	Gain to feed ratio, feed efficiency
GLM	General linear mixed model
H	Hour
HCW	Hot carcass weight
HMC	High moisture corn
HSUS	Humane Society of the United States
KPH	Kidney, pelvic, heart fat
LB	Lying bout
LBDUR	Lying bout duration
LM	Longissimus muscle
MOT	Motion index
MSU	Michigan State University
NMC	National Mastitis Council

NMPF	National Milk Producers Federation
OP	Other pain related behaviors
RFS	Rear foot stomp
RUM	Rumination
RV	Rear end (of calf) visible
SAS	Statistical Analysis System
STEP	Step counts
TLT	Total lying time
TST	Total standing time
TT	Tail twitch
TW	Tail wag

CHAPTER 1

LITERATURE REVIEW

INTRODUCTION

The issue

Tail docking is a routine management practice done in the beef and dairy industries using various methods that remove a portion of the tail. The most common method for tail docking in dairy cattle is through use of an elastrator band (AVMA, 2013b), while for cattle in confined feedlot settings, they are either tail banded like dairy cattle, or docked mechanically with a tool, such as pruning shears (Miller, 2010). Intended benefits of tail docking in dairy cattle are increased worker comfort and improved udder health and hygiene (Schreiner and Ruegg, 2002a). In the beef industry, tail docking is considered a prophylaxis for tail tip injury that develops while cattle are fed in confined slatted floor facilities. In turn, with reduction in tail tip injuries, producers report a reduction in morbidity and mortality and improved performance (Miller, 2010). There is significant amount of research on the impacts of tail docking in dairy cattle, most of which shows little benefit and points towards potential welfare issues. Although tail docking in feedlot cattle is practiced in response to a real problem observed in cattle raised in confined slatted floor facilities, it is done without scientific evidence for or against its utility. Welfare concerns lie in existence of tail tip injuries of feedlot cattle raised in confinement, however, response to this problem through use of tail docking is also a welfare concern. Tail docking feedlot cattle may compromise cattle welfare on the basis of acute and/or chronic pain, reduction in ability to avoid flies, and loss of a communication tool. Further understanding of whether these effects exist in feedlot cattle need to be investigated and addressed appropriately.

TAIL DOCKING IN CATTLE

Dairy cattle tail docking

The practice of tail docking in dairy cattle started in the United States of America (USA) with intentions to improve comfort for milking personnel and enhance udder cleanliness and milk hygiene (Stull et al., 2002). Concern over tail docking as an animal welfare issue and its usefulness triggered research to understand the effect of tail docking in dairy cattle.

Multiple studies were conducted on dairy cattle to understand how tail docking impacted behavior, physiology, cleanliness and milk hygiene. Primiparous dairy heifers were tail banded prior to parturition and showed no behavior changes other than an increase in eating in the days after tail banding, though this effect returned to normal after banded tails were fully removed (Eicher et al., 2000). Researchers also saw no change in cortisol response to banding the tail or complete tail removal. Since tail docking also occurs in young pre-weaned calves, Eicher and Dailey (2002) studied the effects of fly avoidance and acute pain response in calves. They observed signs of discomfort for 2 weeks following docking, an increase in fly avoidance behaviors directed toward the rear of the calf and an increased fly burden. Behavioral and physiologic effects were studied by Schreiner and Ruegg (2002a) in pre-weaned calves and primiparous heifers prior to parturition. They found an overall increased restlessness in older pre-weaned calves after banding but no significant behavioral or immunological response to tail banding or tail atrophy. A study on lactating mixed parity Holstein cows showed no changes in feeding or milk production but did reveal signs of mild discomfort in tail banded cows, as evidenced by less tail shaking and more tail pressing (Tom et al., 2002). While a lack of or minimal pain response was apparent in these studies, Eicher et al. (2001) observed an increase in fly avoidance behavior of docked cows and increased fly burden as well. Cows scored for cleanliness were found cleaner on the rear quarters, but udder cleanliness scores were not different between docked and undocked dairy cows (Eicher et al., 2001). A look at cow hygiene and milk quality across 1250 cows from 8 farms in Wisconsin found no significant advantage to tail docking dairy cows (Schreiner and Ruegg, 2002b).

Dairy employee health and comfort are also reasons some farms choose to dock tails in dairy cattle. In regards to dairy employee health, a study of leptospirosis antibody titers in farm personnel found that titers were not related to tail docking and that risk likely came through other routes of exposure on the farm (Mackintosh et al., 1982). A survey of 113 dairy farms by Fulwider et al. (2008) found that many producers were adamant regarding the need for tail docking based on worker comfort, which, next to udder health, was the second most common reason cited for tail docking. Worker comfort is allegedly impaired during udder preparation of the milking procedure of undocked cows (Schreiner and Ruegg, 2002b). However, alternative methods exist that help to avoid problems that arise from the tail while milking, such as a correctly designed butt plate in parallel parlors, tail shaving (Stull et al., 2002), or using clamps to secure tails during milking. Also, if milking personnel object to tail contact with their face, the use of eye protection may be useful.

Thorough evaluation of dairy cattle tail docking literature has led to the conclusion that tail docking is an unnecessary practice in the dairy industry and its routine use is discouraged (Stull et al., 2002; von Keyserlingk et al., 2009). Dairy cattle show minimal adverse behavioral responses to tail docking; however, no apparent health benefits to the cow or for improving milk quality exist. Furthermore, tail docking is considered detrimental to cow welfare through loss of an important method of fly avoidance. The tail does not appear to pose a health risk to humans as measured by increased exposure to leptospirosis or reduced milk quality. A remaining possible benefit to tail docking is to improve worker comfort; however, this is something that can be addressed through alternative facility design or improved hygiene on farm.

Tail docking in feedlot cattle

Current research on effects of tail docking in feedlot cattle

Justification for tail docking in confined, slatted floor feedlot cattle of the Midwest is to reduce tail injuries and their sequelae and improve performance (Miller, 2010) but limited evidence exists to support these claims. Further insight into the effects of tail tip injury in cattle can be gathered through looking at case control studies of cattle with and without tail tip injury. No studies to date have studied the impact of tail docking in feedlot cattle. One case control study in Denmark surveyed herds via questionnaire that were identified to either have a problem with tail tip necrosis or not, and then compared them for certain production, health and housing outcomes (Madsen and Nielsen, 1985). They found that in comparing weight gain and final slaughter weight, herds were not different. Another survey of farms by Drolia et al. (1990) was done comparing slatted farms with a low or high incidence of tail tip necrosis. They found no difference in initial or final weights of cattle. Additionally, there was no difference in morbidity related to lameness or respiratory disease, or mortality from respiratory disease. These case control studies do not assess tail docking, but simply compare cattle with no or low incidence of tail tip necrosis to those with some incidence of tail tip necrosis.

Tail tip necrosis: Justification for tail docking

Tail tip injury occurs in confined cattle, likely from trauma, which can become a severe purulent-necrotic wound referred to as tail tip necrosis (Buczek et al., 1984; Madsen and Nielsen, 1985). Tail tip necrosis can ascend into the spinal column resulting in paresis. Infection may also result in bacteremia and infections at other sites in the body. In a study on confined feedlot cattle in Nebraska that reported 1% tail tip necrosis based on pulling and treating, two calves with tail tip necrosis were severely lame and found lesions in the lungs, stifle joint, sacral spine and tail (Thomson et al., 2009).

Tail tip necrosis occurrence in feedlot cattle is related to two main environmental factors, the flooring type and stocking density (Madsen and Nielsen, 1985; Drolia et al., 1990; Drolia et al., 1991; Schrader et al., 2001). In Canada, an examination of tails at slaughter from cattle raised on slatted and solid floors found that 34.5% of tails were injured and 3.4% had a laceration or infection (Drolia et al., 1991). A case control study by Drolia et al. (1990) found that tail tip necrosis only occurred in slatted floor barns and not in solid floor barns. In their comparison of farms with low and high incidence of tail tip necrosis, farms with high incidence of tail tip necrosis had more cattle with abnormal motor patterns when standing up and lying down and were kept at a higher stocking density compared to the low incidence farms. Schrader et al. (2001) compared tail tip necrosis and injury in fattening bulls raised on slatted floors, slatted floors with prophylactic tail docking, and deep straw bedded farms. The frequency of tail tip necrosis was highest in bulls on slats and was found to increase as weight of bulls increased, but only in bulls on slats and on slats with prophylactic docking, and not on straw bedded floors. The effect of increased weight was greater in the warmer months. In this study, prophylactic tail docking, that removed 3.5 cm of the tail, significantly reduced but did not eliminate tail tip injury or necrosis.

Slatted floors: A risk factor for tail tip necrosis

Slatted floor facilities are beneficial from the standpoint of improved manure and runoff management, reduced labor, protection of animals from the elements, less fecal accumulation on the hide, and excellent cattle performance, especially in cold/high moisture climates such as the

Great Lakes Region of the USA (Midwest Plan Services, 1987; Rust, 2005). In contrast, detriments to slatted floor facilities include increased incidence of lameness (Westerath et al., 2007; Graunke et al., 2011), increased risk for disease spread through close confinement, and increased incidence of tail tip injuries (Madsen and Nielsen, 1985; Drolia et al., 1990; Drolia et al., 1991; Schrader et al., 2001). The incidence of tail tip injury has been shown to increase on slatted floors compared to deep bedding packs (Madsen and Nielsen, 1985; Schrader et al., 2001) and on slatted floor compared to solid floor systems (Drolia et al., 1990; Drolia et al., 1991). Many researchers have correlated slatted floors to an increased risk of lameness in feedlot cattle (Westerath et al., 2007; Graunke et al., 2011). An investigation of health status in finishing beef cattle of 29 farms found that bedding use was associated with a 33% reduction in culling risk compared to slatted pens (Cerchiaro et al., 2005). Sundrum and Rubelowski (2001) surveyed 50 farms and found that farms that raised bulls on slatted floors reported greater losses than manure-packed housing. These types of confinement facilities are not recommended for Holstein cattle since they are not well adapted to them (Rust, 2005). From a cattle health and welfare perspective, these detriments provide support for the need to investigate alternative housing and/or flooring options.

Alternatives to tail docking in confined feedlots

There is concern over the welfare of confined feedlot cattle on slatted floors, and some studies have looked into alternative housing options to address these concerns. Alternatives generally consist of increasing space allowance, changing the floor design and/or improving the softness of the floor. Some alternative floor surfaces that have been studied include rubberized floors, perforated concrete floors, and flooring bedded with straw or packed manure. In a study on cattle with a mean live weight of 516 kg, a space allowance on slatted floors of 3 m^2 per animal was the recommended minimum space allowance to avoid adversely affecting cattle welfare (Hickey et al., 2003). In this study, they found that cattle on slatted floors greatly reduced lying time at low space allowances (< 2 m^2), showed compromised *in-vitro* interferon-γ response at low space allowance (< 2 m^2), and when given more space (> 2 m^2) found a significant increase in carcass gain and improved feed efficiency. Another study on finishing bulls on slats showed that increased space allowance did not result in dirtier cattle and that the trampling of pen mates was less likely (Gygax et al., 2007b). In an investigation of finishing bulls on 17 farms, leg lesions and joint swelling were reduced in cattle raised on rubber coated slats and straw compared to fully slatted concrete floors (Westerath et al., 2007). In another study, yearling bulls were kept on slatted concrete floors, fully slatted rubber covered floors, or a partial rubber covered floor with slats and observed at various time periods over 1 year (Platz et al., 2007). When given a choice, they found that bulls preferred rubber coated flooring over concrete and when housed on fully covered rubber flooring, bulls had less incidence of skin lesions and increased lying periods. Of bulls raised on three types of flooring, fully slatted concrete, perforated concrete, and perforated concrete coated with rubber mattress, lameness was only observed in bulls on slatted floor and daily weight gains were greater on rubber floors than slatted floors (Cozzi et al., 2013). In comparing the floor types, perforated floors were no different from slatted floors, but rubber floors showed an advantage for cattle welfare with improvements in lying behavior, with fewer slipping events, decreased lying duration, and greater confidence of transitions between lying and standing. This is in agreement with a study by Gygax et al. (2007a) that saw a decrease in slipping and falling events and reduced abnormal standing and lying in bulls raised on rubber compared to concrete.

In summary, it appears that softer flooring surfaces and decreased stocking density would improve welfare of cattle without compromising production and management benefits of confined facilities. The benefits of improved flooring surfaces and decreased stocking densities have yet to be explored for their use in reducing tail tip injury, and thus the need for tail docking.

TAIL DOCKING – A WELFARE CONCERN

Tail docking in cattle raises concern from the aspect of animal welfare due to the possibility of pain, both acute (Schreiner and Ruegg, 2002; Tom et al., 2002) and chronic (Eicher et al., 2006), increased fly burden from a shortened tail (Eicher et al., 2001; Eicher and Dailey, 2002) and loss of a method for communication between cattle (Kiley-Worthington, 1975). Many professional associations and industry groups have addressed the topic of tail docking. Based on current literature, the American Veterinary Medical Association (AVMA), the American Association of Bovine Practitioners (AABP), the Canadian Veterinary Medical Association (CVMA), the National Mastitis Council (NMC), and the National Milk Producer's Federation (NMPF) all have position statements that oppose the routine tail docking of dairy cattle (AABP, 2010; AVMA, 2013a; CVMA, 2010; NMC, 2011; NMPF; 2012). The AVMA and NMPF further specify that tail docking occur when tail docking is therapeutic, and if done, the AVMA believes tail docking must be performed by a licensed veterinarian. It is important to note that these decisions are based on research surrounding tail docking in dairy cattle only. Routine tail docking in finishing beef cattle is prohibited in Denmark, Germany, the Netherlands, Norway, Sweden, Switzerland, and the United Kingdom (AVMA, 2013b; Schrader et al., 2001). In contrast, the USA and Canada have no legislation regarding tail docking in dairy or beef cattle (AVMA, 2013b). However, state legislation in California recently amended Senate Bill 135 that now bans tail docking of cattle (both beef and dairy) unless necessary as a medical treatment, and must be performed by a licensed veterinarian (California Legislative Council, 2009). Rhode Island also banned tail docking of cattle unless needed for therapeutic reasons and stated it must be performed by a licensed veterinarian (AVMA, 2013c). Beginning in 2018, Ohio will only permit tail docking when medically necessary and only by a licensed veterinarian (AVMA, 2013c). An attempt was made in Colorado to ban tail docking without use of anesthesia in dairy cattle, but the bill has not yet made it through the legislative process (Ourcoloradonews.com, 2013). The state of New York also has a bill under consideration that, if passed, would prohibit tail docking in cattle (New York State Assembly, 2013).

In the USA, much of the push for change in legislation to ban tail docking, like in California, comes from animal rights groups like the Humane Society of the United States (HSUS), the American Society for the Prevention of Cruelty to Animals (ASPCA), and a myriad of others. In addition, consumer concern regarding the care of farm animals is growing as media outlets bring animal care issues to light. Regardless of these groups' agendas and goals, they ultimately demand attention to areas of animal welfare that might have previously been overlooked or ignored or were not addressed in a timely manner. For example, the National Milk Producers Federation (NMPF) Dairy Farmers Assuring Responsible Management program now recommends tail docking be phased out by 2022 (NMPF, 2012). Information regarding the lack of benefit to tail docking has existed since the early 2000s, so a recommendation such as that of the NMPF appears weak, especially when expected changes on farm would likely require minimal input and take a short amount of time to implement. While some dairy producers have voluntarily ceased tail docking, an industry wide change has been slow to occur. Therefore, activist groups have worked towards banning tail docking.

The delay in effective industry-wide action causes the industry to appear unconcerned with animal welfare. The efficacy of legislation versus passive industry resolution is debatable. However, if industry were to take action sooner than activist groups, they might avoid forced change through legislation. In terms of feedlot cattle raised in confinement, some welfare issues exist in regards to tail health and flooring. In light of these issues, it is important for the industry to move towards finding an appropriate resolution to improve cattle welfare while maintaining a sustainable business model.

SUMMARY

Feedlot cattle raised in confinement, especially on slatted floors are at increased risk for developing tail tip injury and necrosis. Risk factors associated with developing tail tip injury are evident and alternatives exist to reduce this risk. However, feedlots perform tail docking prophylaxis to eliminate this problem instead, without evidence for its utility. In addition, the tail docking procedure is an animal welfare concern from the standpoint of cattle pain and inability to perform natural behaviors. Minimal research exists regarding the practice of tail docking as a prophylactic method to prevent tail tip injuries and its effect on cattle performance, health or behavior. In dairy cattle, available literature on tail docking does not justify its practice, as it provides no benefit to the animal and compromises cattle welfare. These conclusions can be cautiously applied to feedlot cattle tail docking, but distinct differences exist between the environment, management, tail docking procedure and types of animals on dairy farms compared to feedlots. Research is needed to identify the effect of tail docking on the behavior, health and performance of feedlot cattle raised in a confined, slatted floor feedlot facility.

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CHAPTER 2

EFFECTS OF TAIL DOCKING ON HEALTH AND PERFORMANCE OF BEEF CATTLE IN CONFINED, SLATTED FLOOR FEEDLOTS

ABSTRACT

Tail docking of feedlot cattle is a management practice used in some confined, slatted floor feedlots of the Midwestern United States. Justification for tail docking in these management systems is to reduce tail injuries and their sequelae and improve performance, but limited evidence exists to support these claims. The primary objective of this study was to determine the effect of tail docking on performance, carcass traits, and health parameters of feedlot cattle following tail docking of animals raised in slatted floor feedlots. Three separate trials were performed. Trial 1 consisted of 140 Angus-cross (370-kg) yearling steers that spent 144 – 160 DOF. Trial 2 consisted of 137 Angus-cross (255-kg) weaned steers that spent 232 DOF. Trial 3 consisted of 103 Holstein steers that weighed 370 kg at start of trial and spent 185 – 232 DOF. Cattle were randomly assigned to 1 of 2 treatment groups; docked (DK) or control (CN). All steers received an epidural following surgical preparation of the sacrococcygeal area and post-operative intravenous flunixin meglumine. Approximately two-thirds of the tail of DK calves was removed and an elastrator band was placed near the tail tip for hemostasis. Performance parameters collected included daily gain, final weight, feed intake, and feed efficiency. Carcass data included HCW, subcutaneous fat thickness, LM area, KPH percent, marbling, USDA yield grade, and USDA quality grade. Morbidity, mortality, incidence of lameness and incidence of tail lesions were recorded. Across all three trials, there was no significant effect ($P < 0.05$) of treatment on performance parameters, carcass traits, or health parameters. In all three trials, tail tip injuries occurred in 60-76% of undocked (CN) calves,

developed from living in the slatted floor environment, compared to 100% of docked calves, whose injuries were a result of the tail docking procedure.

We were unable to identify a performance or significant health advantage to tail docking. However, tail tip injuries still occur in cattle raised in slatted floor facilities. Because of the animal welfare issues associated with tail docking and tail injuries, we recommend pursuing alternative solutions to reducing the incidence of tail tip injury in feedlot cattle housed in confined slatted barn facilities.

INTRODUCTION

Tail docking is a management practice that occurs in areas of the Midwestern United States in confined, slatted floor feedlots. A survey of Michigan producers found that 50% of slatted floor farms routinely dock tails of cattle in order to reduce tail tip injuries and lameness and improve performance (Miller, 2010).

Tail tip injury occurs in confined cattle likely from trauma, which can lead to severe inflammation and infection, causing tail tip necrosis (Madsen and Nielsen, 1985). Tails examined at slaughter from cattle raised on slatted and solid floors found 34.5% of tails were injured (Drolia et al., 1991). A study on confined feedlot cattle in Nebraska reported that 1% were pulled and treated for tail tip necrosis (Thomson et al., 2009). In this study, necropsy of two severely lame calves (from a group of 80,000 cattle) found a common bacterial pathogen present in the tail, sacral spine, lungs and stifle joint. Spread of infection to the joint and spine are possible causes for lameness in calves with tail tip injury.

No studies to date have directly looked at the impact of tail docking in feedlot cattle. Some work has looked at the impact of tail injuries in confined feedlots. A case control study in

Denmark identified herds that either had a problem with tail tip necrosis or not, and then compared them for various production, health and housing outcomes (Madsen and Nielsen, 1985). They found that in comparing weight gain and final slaughter weight, herds were not different. Drolia et al. (1990) surveyed farms in Canada and compared slatted farms with a low or high rate of tail tip necrosis. They found no difference in initial or final weights of cattle, morbidity related to lameness or respiratory disease, or mortality from respiratory disease.

The objective of our study was to compare performance, morbidity and mortality between docked and undocked cattle housed in a confined, slatted floor feedlot. We hypothesize that no performance or health differences exist between docked and undocked cattle raised in this type of system.

MATERIALS AND METHODS

This study consisted of three separate trials. All trials were approved by the Michigan State University (MSU) Institutional Animal Care and Use Committee.

Housing, animals, processing, diet and treatment allocation

All trials were conducted at the MSU Beef Cattle Teaching and Research Center (BCTRC). Calves were housed at a stocking density of 2.1 m^2 per calf in a confined, open-sided, slatted floor feedlot facility and each pen area consisted of a fully slatted, concrete floor.

Trial 1. This trial was conducted beginning in fall of 2009. One hundred forty Angus-cross steers with an initial BW of 370 ± 28.4 kg were acquired from the MSU Experiment Stations (Lake City and Chatham, MI) and MSU Purebred Beef Center (East Lansing, MI). Calves arrived 45 d (n = 122 calves) and 29 d (n = 18 calves) prior to d 0 of the trial and were on trial for either 144 d (n = 68 calves) or 160 d (n = 69 calves). After arrival, calves were rested 24 hours and then processed. During processing, calves were weighed, received an identification bangle tag and a low frequency radio frequency identification tag, dewormed with injectable doramectin, (Dectomax, Zoetis Animal Health, Florham Park, NJ), implanted with a growth promotant that contained 80 mg trenbolone acetate and 16 mg estradiol (Revalor-IS, Merck Animal Health, Summit, NJ), and vaccinated with a 4-way modified live virus vaccine (BoviShield Gold 5, Zoetis Animal Health) that included bovine viral diarrhea virus (Type 1 and 2), bovine herpes virus-1, bovine respiratory syncytial virus and parainfluenza-3, a killed clostridial bacterin that contained 8 clostridial antigens, including *Clostridium tetani* (Covexin-8, Merck Animal Health), and a bacterin against *Histophilus somnus* (Somubac, Zoetis Animal Health). Calves were stratified by farm of origin, blocked by arrival BW, and then randomly assigned to a pen (n = 7 calves/pen). Pens were randomly assigned to a treatment group: docked (DK, n = 10 pens) or control (CN, n = 10 pens). Feed was delivered once daily between 0500-0700 h and consisted of 45% high moisture corn (HMC), 30% modified distillers grains plus solubles (DGS), 10% corn silage (CS), and 4% protein-mineral supplement (DM basis).

Trial 2. Trial 2 began in fall of 2010. One hundred thirty-seven calves with an initial BW of 255 ± 27.2 kg were sourced from MSU Experiment Stations (Lake City and Chatham, MI) and MSU Purebred Beef Research Farm (East Lansing, MI) and processed at MSU BCTRC. All calves arrived at MSU BCTRC 26 d prior to start of trial and were on trial for 232 days. Upon arrival, all calves were allowed to rest for 24 hours prior to processing. Calves were processed in the exact same fashion as trial 1, except they were not vaccinated against *Histophilus somnus,* and they were implanted with a growth promotant from a different manufacturer but contained the same components (Component TE-IS, Elanco, Greenfield, IN). Calves were stratified by farm of origin, blocked by arrival BW, and randomly assigned to a pen (n = 6 or 7 calves/pen).

Pens were randomly assigned to a treatment group, DK (n = 10 pens) or CN (n = 10 pens). The diet and feeding routine was the same as described for trial 1.

Trial 3. Trial 3 began in spring of 2012. One hundred two Holstein steers with an initial BW of 370 ± 29.1 kg were sourced from 3 different backgrounders in Kentucky. Calves arrived to MSU BCTRC 8 d prior to the start of the trial and remained on trial for 185 (n = 52 calves) to 213 d (n = 50 calves). Upon arrival, calves were allowed to rest for 24 hours prior to processing. Calves were weighed and processed the exact same way as trial 2. Calves were stratified by source, blocked by weight, and randomly assigned to a pen (n = 14 calves/pen). Pens were randomly allocated to 1 of 2 treatment groups (n = 8 pens total): CN (n = 4 pens) and DK (n = 4 pens). During the study period, calves were fed a diet of 73% CS, 24.5% HMC, and 2.5% protein-mineral supplement (DM basis). Calves were fed once daily between 0500-0700 h.

Experimental procedures

In trial 1, experimental procedure began after cattle were acclimated to their new environment for 29 d (n = 18 calves) or 45 d (n = 122 calves). In trial 2, calves were acclimated for 26 days while in trial 3 the acclimation period was 8 days.

Procedures were performed in the MSU BCTRC cattle handling facility where calves were restrained in a hydraulic chute (Silencer, Moly Manufacturing, Inc., Lorraine, KS). Calves in DK group had their tail heads prepared aseptically to receive caudal epidural anesthesia. Hair was shaved in a 10 cm^2 area surrounding the sacrococcygeal area. The area was aseptically prepared using 4 separate 1% betadine scrubs, followed by application of 70% isopropyl alcohol and sprayed with 1% betadine solution. Five milliliters of 2% lidocaine hydrochloride (LidoJect, Butler Schein Animal Health, Dublin, OH) was injected into the epidural space using a 4 cm 18 gauge needle. Epidural effectiveness was evaluated by lack of tail tone. Approximately 25 cm distal from the tail head, a circumferential area measuring 15 cm in length was prepared aseptically using the same procedure as described above. The tail was held horizontally by project personnel to keep it from coming in contact with the chute environment or caudal end of the calf. The distal two-thirds of the tail was removed at the aseptically prepared site using commercially available tree limb pruning shears. Between calves, the shears were rinsed in water and then placed in a bucket containing 2% chlorhexidine disinfectant. To control hemorrhage, an elastrator band was immediately placed 1 cm above the distal end of the remaining tail. For post-operative analgesia, each calf was administered 1 ml/45 kg of flunixin meglumine (50 mg/ml) (FlunixiJect, Bimeda-MTC Animal Health Inc., Cambridge, ON, CAN) intravenously in the jugular vein using a 4 cm 18 gauge needle. Flunixin meglumine was used in an extra-label manner for pain control in accordance with guidelines set forth in the Animal Medicinal Drug Use Clarification Act (AMDUCA) (FDA, 1994). The CN calves (sham treatment) received all of the above procedures except for removal of the tail.

Outcome variables measured

Performance data. Body weight, feed delivery, and feed refusal data were collected at 28 d (range = 25 – 32 d) intervals to calculate first weigh period daily DMI (First DMI), cumulative daily DMI (Overall DMI), first weigh period daily G:F (First G:F), cumulative daily G:F (Overall G:F), first weigh period ADG (First ADG) and cumulative ADG (Overall ADG).

Health data. Each weigh day, tails were examined and given a numeric score of 0 – 3 based on presence and severity of tail tip injury (Table 2.1). The score system was modified from the tail tip injury score rubric described by Drolia et al. (1991). The same research personnel scored the tails each time (LKK) using our modified score system (Appendix). Pens were observed at least twice daily by farm personnel for signs of morbidity or lameness and treated according to farm protocol. Adverse health and lameness events were recorded.

Table 2.1. Description of tail tip injury score system used to score tails at monthly intervals.

Score	Description
0	No gross lesion visible
1	Mild injury to tail – < 5 cm involvement of tail injury, no sign of gross infection or hemorrhage
2	Moderate injury to tail tip – open wound, infected, extending < 10 cm length of tail and/or if small tip of necrosis
3	Severe tail injury – open, active infection, suppurative to necrotic involvement of tail

Carcass data. For trial 1 and 2, carcass data were collected by trained personnel and included HCW, dressing percent, subcutaneous fat thickness, LM area, KPH percent, marbling, USDA yield grade, and USDA quality grade. Percent certified Angus beef (CAB) and percent choice (CHOICE) were calculated based on reported yield and quality grade. Trial 3 carcass data were not included in the analysis due to incomplete data collection at slaughter.

Statistical analysis

All variables were tested for normality using the univariate procedure of SAS (SAS Inst. Inc., Cary, NC) through assessing for linearity of the probability plots and evaluating the Shapiro-Wilk test. Tests of linearity and homogeneity were done for all variables using the general linear model (GLM) procedure of SAS (Cary, NC) through a plot of residuals. All variables were found to have normal distribution of variance and normal linearity and homogeneity. Statistical analysis was performed with the linear mixed model of SAS (SAS Inst. Inc., Cary, NC) with pen as the experimental unit. Trial (1, 2, or 3) and treatment group (docked or control) were considered the fixed effects. Variables were reported out as least squares means and then compared using the Student’s t-test. Comparisons among treatment groups were considered statistically significant when $P < 0.05$. The initial BW variable was tested with the t-test procedure of SAS. Morbidity, mortality, and lameness were statistically analyzed using Chi-square test in Excel (Microsoft Excel, Redmond, WA). Tail lesions were reported descriptively.

RESULTS

Performance data

Three calves did not complete the study from trial 1 and 1 calf did not complete the study from trial 2 for reasons related to severe morbidity or death. In trial 3, 9 calves did not complete the trial due to severe morbidity or death. These deaths were not related to the presence of tail tip necrosis or as a result of tail docking. Data from all calves were included in the analysis up to the point of their removal from the trial.

Within each trial, initial BW was not statistically different across treatment groups ($P = 0.536$, Table 2.2). There was no significant effect ($P < 0.05$) of treatment on First ADG, Overall ADG, First G:F, Overall G:F, final BW, First DMI, or Overall DMI (Table 2.2). While the effect of trial was significant for all performance variables, there was no interaction of trial and treatment group (trial*txgroup) identified for any of the performance parameters ($P < 0.05$).

Carcass data

There was no significant effect of treatment on HCW, dressing percent, subcutaneous fat thickness, KPH, USDA yield grade, marbling, USDA quality grade, percent CAB or CHOICE (Table 2.3). However, an interaction (trial*treatment) was present for LM. In trial 1, CN cattle had numerically larger LM compared to DK, and it was the reverse for trial 2. This converse relationship may indicate that LM interaction is either simply due to chance or an inconsistent effect of treatment on LM.

Table 2.2. Performance parameters of docked and control cattle on slatted floors in three trials.

Item	Trial [1]	Treatment groups Control	Docked	SEM	*P*
Number of cattle	1	70	70		
	2	69	68		
	3	51	52		
DOF[2]	1	144 / 160	144 / 160		
	2	232	232		
	3	185 / 213	185 / 213		
Initial BW, kg	1	369.8	369.1	9.2	0.9587
	2	244.5	264.8	9.3	0.1447
	3	404.8	403.5	20.3	0.9677
Final BW, kg	1	611.7	611.4	9.1	0.9259
	2	584.6	599.7	9.9	0.2872
	3	651.9	665.9	14.5	0.4971
First[3] ADG, kg/d	1	1.52	1.53	0.16	0.8936
	2	0.41	0.34	0.08	0.5863
	3	0.90	0.88	0.11	0.9108
Overall ADG, kg/d	1	1.51	1.51	0.029	0.9357
	2	1.47	1.44	0.031	0.6192
	3	1.33	1.40	0.045	0.2736
First[3] DMI, kg/d	1	8.90	8.94	0.20	0.9044
	2	4.68	4.88	0.21	0.5274
	3	10.30	10.26	0.31	0.9181
Overall DMI, kg/d	1	10.36	10.31	0.16	0.8117
	2	8.56	8.70	0.18	0.5798
	3	11.05	11.34	0.26	0.4280
First[3] G:F	1	0.171	0.172	0.012	0.9252
	2	0.086	0.072	0.012	0.4266
	3	0.087	0.085	0.018	0.9359
Overall G:F	1	0.146	0.147	0.0030	0.9382
	2	0.173	0.167	0.0032	0.2191
	3	0.113	0.116	0.0047	0.5697

[1]Trials: Trial 1 = 2009 backgrounded Angus-based steers, Trial 2 = 2010 weaned Angus-based calves, Trial 3 = 2012 backgrounded Holstein steers.

[2]Trial 1 DOF = 144 d (n = 68) and DOF = 160 d (n = 69); Trial 2 DOF = 232 (n = 137); Trial 3 DOF = 185 d (n = 52) and DOF = 213 d (n = 50).

[3]First weigh period: Trial 1 = 29 d, Trial = 25 d, Trial 3 = 32 d.

Table 2.3. Carcass parameters of control and docked cattle on slatted floors in three trials.

Item	Trial [1]	Treatment groups Control	Docked	SEM	*P*
Number of carcasses	1	68	69		
	2	62	56		
HCW, kg	1	384.3	383.4	6.1	0.9220
	2	357.3	366.1	6.7	0.3534
Dressing %	1	62.8	62.7	0.26	0.7470
	2	61.1	61.1	0.29	0.9021
Fat thickness, cm	1	1.33	1.40	0.06	0.4354
	2	1.35	1.27	0.06	0.3869
LM, cm^2	1	86.7	84.8	0.9	0.1419
	2	80.2	82.6	1.0	0.0983
KPH[2], %	1	1.90	1.92	0.038	0.7423
	2	2.10	2.04	0.041	0.2958
Calc. yield grade	1	3.10	3.26	0.076	0.1676
	2	3.25	3.12	0.083	0.2617
Marbling[3]	1	573.6	578.0	12.4	0.8026
	2	568.8	561.4	13.5	0.7029
Quality grade[4]	1	18.80	19.04	0.16	0.3053
	2	19.13	19.04	0.18	0.7078
Certified Angus Beef, %	1	26.4	24.3	6.24	0.8098
	2	32.3	33.9	6.78	0.8642
Choice, %	1	76.7	79.8	5.05	0.6673
	2	87.0	80.4	5.48	0.3951

[1]Trials: Trial 1 = 2009 backgrounded Angus-cross steers, Trial 2 = 2010 weaned Angus-cross calves, Trial 3 = 2012 backgrounded Holstein steers.

[2]Kidney, pelvic and heart fat as percent of total body weight.

[3]Marbling scores: 500 = small; 600 = modest.

[4]USDA quality grades: 18 = select; 19 = choice.

Health data – morbidity, mortality, lameness and tail tip injuries

There was no significant difference ($P < 0.05$) in morbidity between CN and DK calves from trial 1, 2, or 3 (trial 1, $P = 0.1221$; trial 2, $P = 0.808$; trial 3, $P = 0.167$). Likewise, incidence of lameness did not differ between treatment groups for any of the 3 trials (trial 1, $P = 0.0517$; trial 2, $P = 0.683$; trial 3, $P = 0.366$). Mortality rate did not differ between DK and CN cattle for any of the 3 trials (trial 1, $P = 0.5595$; trial 2, $P = 0.3191$; trial 3, $P = 0.3151$).

At the start of each trial, DK cattle all had tail lesions from the experimental procedure, though these tails all healed by the completion of each trial (Figure 2.1, 2.2, and 2.3). The duration of time to heal lesions created by tail docking varied between trials; trial 1 calves had all healed by 158 d, trial 2 by 193 d, and trial 3 by 144 d after tail docking procedure was performed (Figure 2.1, 2.2, and 2.3). Control cattle developed tail injuries at variable rates over time (Figure 2.1, 2.2, and 2.3). The incidence of tail injuries that developed in undocked cattle while on trial with a tail injury score of 1 or greater ranged from 60.2 – 76.0% (trial 1 = 60.2%; trial 2 = 61.8%; and trial 3 = 76.0%), and for a score of 2 or greater incidence ranged from 36.8 – 53.7% (trial 1 = 37.7%, trial 2 = 36.8%; trial 3 = 53.7%). In comparison, 100% of docked cattle from each trial developed a tail injury score of 1 or greater (due to tail docking procedure), and for a score of 2 or greater incidence ranged from 1.5% to 81.1% (trial 1 = 32.4%; trial 2 = 1.5%; trial 3 = 81.1%). as a result of the tail docking procedure. In CN cattle of trial 1 and 3, there was a varying level of tail injuries present from early on in the trial, whereas in trial 2, cattle did not start to develop tail tip injuries until 81 d (Figure 2.1, 2.2, and 2.3).

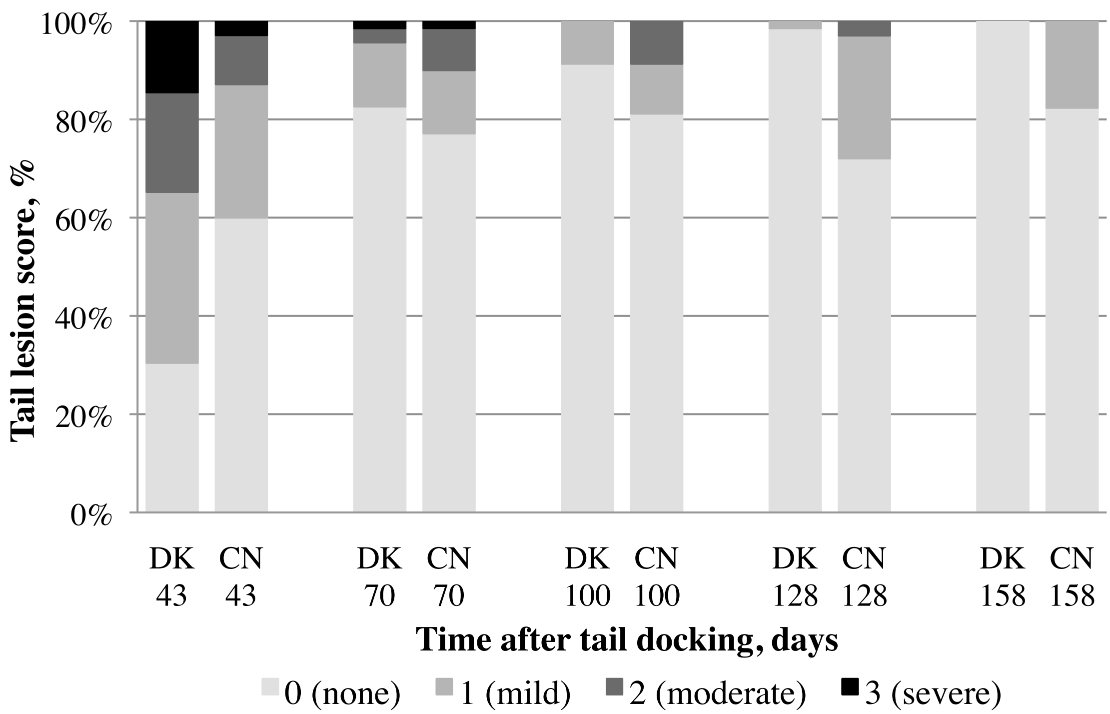

Figure 2.1. Trial 1 docked (DK) and control (CN) cattle tail tip injury scores by percent of total for each weigh period.

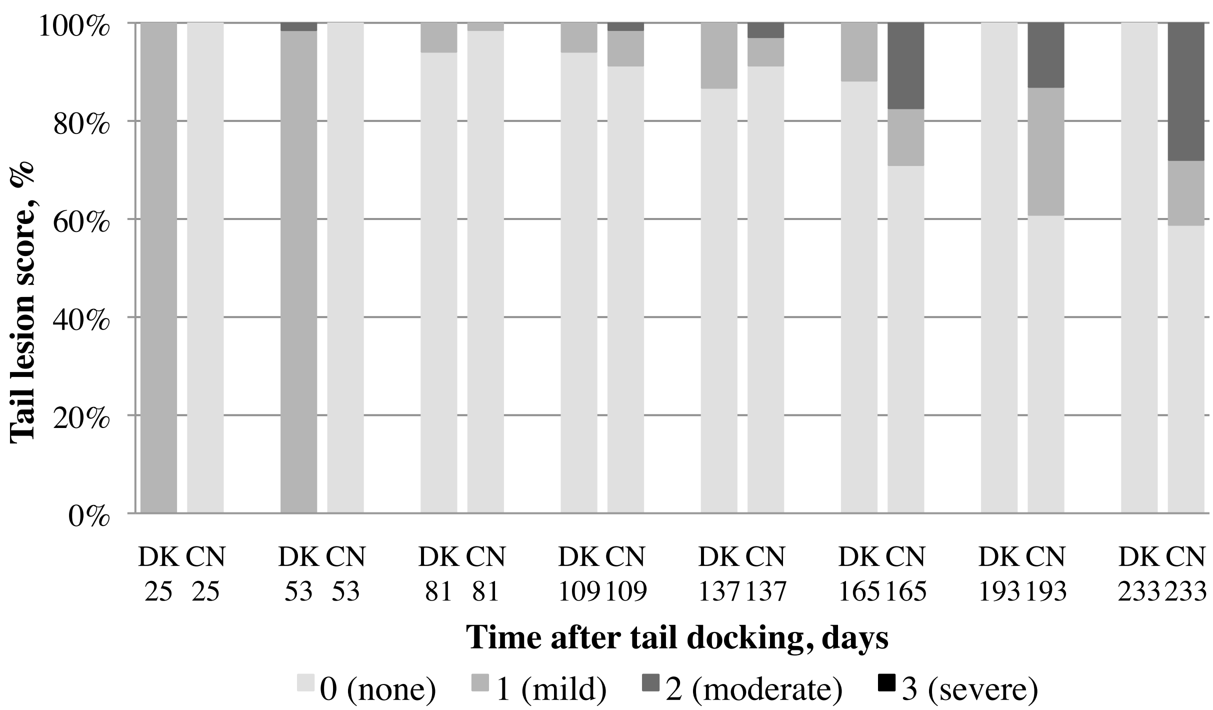

Figure 2.2. Trial 2 docked (DK) and control (CN) cattle tail tip injury scores by percent of total for each weigh period.

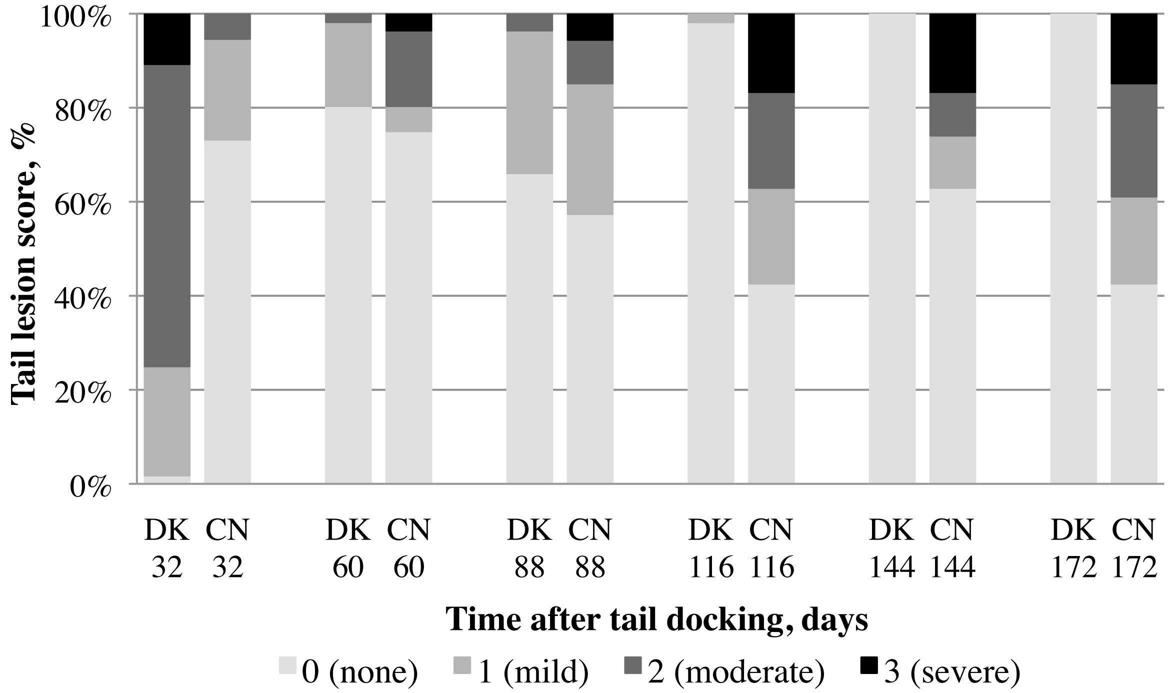

Figure 2.3. Trial 3 docked (DK) and control (CN) cattle tail tip injury scores by percent of total for each weigh period.

DISCUSSION

In this study, we observed no significant difference in performance parameters, health events, or carcass quality between tail docked and undocked cattle raised in our confined slatted floor facility. The studies were performed over 3 separate trials, on cattle from different backgrounds, during different seasons of the year. Cattle were housed at a stocking density of 2.1 m^2, which is within the range of 1.7 – 2.3 m^2 for finishing beef cattle on slatted floors, as recommended in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (Federation of Animal Science Society, 2010). Our study was designed to represent how the tail docking intervention may impact confined feedlot cattle raised on slatted floor facilities.

To our knowledge, this is the first controlled experimental study looking at the effect of tail docking on performance, health and carcass traits of feedlot cattle. Our findings are consistent with the case control study by Madsen and Nielsen (1985) which found no difference in weight gain and final weight at slaughter of cattle from herds with evidence of tail tip necrosis when compared to those without tail tip necrosis. Performance studies following tail docking have been conducted in young dairy replacement heifers. Tom et al. (2002) monitored 36 7-17 day old Holstein calves for 3 weeks following rubber ring or hot iron docking, and found no significant differences in milk intake and weight gain between docked and undocked calves. Another study monitored weekly bodyweight on 56 heifers for 6 months following tail docking and was unable to identify any significant differences between docked and undocked heifers (Matthews et al., 1995).

We observed a lack of treatment effect amongst all the trials; however, we did observe an effect of trial. This trial effect was likely due to the differences in cattle backgrounds, breeds, and ages of calves upon arrival to the feedlot. For example, final weights of cattle may have varied due to various factors such as breed differences (Holsteins versus Angus based breeds) and days on feed. Similarly, other growth variables like ADG and G:F may be affected by the backgrounding of calves prior to arrival, initial arrival weight, or change in environment (pasture to feedlot), to name a few.

In all of the three trials performed, we did not find that tail docking reduced the incidence of overall morbidity, lameness-related morbidity, or mortality in docked cattle reared in a slatted floor facility. A survey of Michigan feedlot producers by Miller (2010) found that major rationales for tail docking in feedlot cattle on slats are to reduce morbidity, specifically lameness, and to reduce mortality. The possibility of cattle becoming lame due to tail injury is plausible. In a Nebraska case report, tail tip injury and infection preceded severe lameness in two calves (Thomson et al., 2009). Our average tail tip injury rate is similar to a report on feedlot bulls that found 5.8-30% affected with only tail lesions, and some of these bulls had inflammation observed in scrotum, muscle, hind leg joints and thoracic cavity (Buczek et al., 1984). While there is a possibility that tail tip necrosis may be an etiology for specific animals' lameness, identifying pathogenesis of lameness was not the focus of our study.

Since it is established that slatted facilities are known to increase risk of lameness and culling in feedlot cattle (Drolia et al., 1991), it is possible that producers subjectively associate tail tip injuries with lameness or early culling. Drolia et al. (1991) surveyed southern Ontario feedlot producers and compared farms that identified themselves to have a problem with tail tip necrosis with those that did not. They were unable to identify a causal relationship between tail tip necrosis and lameness; greater lameness on a farm could result from tail tip necrosis or cause tail tip necrosis, or both could be the result of another factor, such as floor type or stocking density. The incidence of tail tip injury was shown to increase on slatted floors compared to deep litter packs (Madsen and Nielsen, 1985; Schrader et al., 2001) and on slatted floor compared to solid floor systems (Drolia et al., 1990; Drolia et al., 1991). Many researchers have correlated slatted floors to an increased risk of lameness in feedlot cattle (Westerath et al., 2007; Graunke et al., 2011). An investigation of health status in finishing beef cattle of 29 farms found that bedding use was associated with a 33% reduction in culling risk compared to slatted pens (Cerchiaro et al., 2005). Sundrum and Rubelowski (2001) surveyed 50 farms and found that farms that raised bulls on slatted floors reported greater losses than deep-litter housing.

Regardless of the practice of tail docking, some feedlot producers might expect to see higher levels of lameness and mortality in general when raising cattle in slatted floor feedlots.

In the current study, cattle were housed at a stocking density of 2.1 m^2 per animal and 60 – 76% of undocked cattle were observed to have a lesion at some points. This is comparable to other studies that identified tail tip injury occurred in 5-30% (Buczek et al., 1984) and 34.5% (Drolia et al., 1991) of feedlot cattle. Slatted floors (Madsen and Nielsen, 1985; Drolia et al., 1990; Drolia et al., 1991; Schrader et al., 2001), high stocking densities (Drolia et al., 1990, Schrader et al., 2001) and large body weight of animals on slats (Schrader et al., 2001) are all previously identified risk factors for tail tip injury. Madsen and Nielsen (1985) identified tail tramping as one reason for tail tip injury to occur. In a study on space allowance and cleanliness, Swiss bulls with an average start weight of 339 kg were housed at different space allowances (2.5, 3, 3.5 and 4 m^2) and observed for various behaviors (Gygax et al., 2007). They found that bulls were less likely to get stepped on and were more spread out from each other at higher space allowances; the recommended space allowance was determined to be 4 m^2. The study also concluded that cattle were cleaner at higher space allowances, and therefore the self-cleaning effect of slats was not lost. Our cattle weights are similar to the previous study, so it is reasonable to assume that some of our cattle may have experienced tail injury from tail tramping and that their risk was increased at our stocking density of 2.1 m^2.

In itself, the creation of tail injuries in all of the docked cattle is considered detrimental to cattle welfare as it is acutely painful, has potential for chronic pain, and the open wound may become infected and lead to sequelae. In fact, in our study up to 81% of docked cattle had post-surgical infections of tail tips while on trial. In contrast, as many as 76% of undocked cattle developed tail tip injuries by the end of the feeding period, and up to 54% developed infected and/or necrotic tail tips while on trial. It is evident that undocked cattle develop significant levels of tail tip injury when raised in the slatted floor feedlot, which may lead to tail infection and/or necrosis. Likewise, the practice of tail docking guarantees that cattle will have a tail lesion, which similarly has the potential to develop severe detrimental consequences such as tail infection.

While our study showed no apparent performance or health benefit to tail docking, tail tip injury persisted in our undocked cattle raised on confined slatted flooring. This in itself is concerning from an animal welfare perspective. Because of the lack of apparent performance or health benefit beyond eliminating tail tip injuries and the probable compromise of animal welfare through the tail docking procedure (which results in injury for all animals receiving the procedure), alternative solutions to address the issue of tail tip injuries should be sought. Alternative solutions such as decreased stocking density and softer flooring may prove beneficial by reducing the risk of tail injuries from occurring in confined slatted barn facilities. Additionally, these improvements in housing conditions have been shown to improve cattle welfare, and therefore are recommended regardless of the possible reduction in tail tip injury.

APPENDIX

Appendix – Tail tip injury and necrosis score system – Michigan

Table 2.4. Description of tail tip injury score system used to score tails at monthly intervals

Score	Description
0	No gross lesion visible
1	Mild injury to tail < 5 cm involvement of tail injury, no sign of gross infection or hemorrhage
2	Moderate injury to tail tip – open wound, infected, extending < 10 cm length of tail or if small tip of necrosis
3	Severe tail injury – open, active infection, suppurative to necrotic involvement of tail


Figure 2.4. Score 1


Figure 2.5. Score 2


Figure 2.6. Score 3

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CHAPTER 3

EFFECTS OF TAIL DOCKING ON BEHAVIOR OF CONFINED FEEDLOT CATTLE

ABSTRACT

Tail tip injuries occur in some feedlot cattle housed in slatted barn facilities typically found in the Midwestern United States. The practice of tail docking cattle upon entry into these feedlot facilities was initiated to prevent tail injuries. Tail docking is a welfare concern from the standpoint that an important method of fly avoidance is removed and the tail docking procedure is painful. The primary objective of this study was to describe the behavioral responses of feedlot cattle following tail docking. Thirty-six heifers were randomly assigned to 1 of 2 treatment groups; docked (DK) or control (CN). All calves received an epidural following surgical preparation of the sacrococcygeal area and post-operative intravenous flunixin meglumine. A portion of the tail of DK calves was removed using pruning shears. An elastrator band was placed near the tail tip for hemostasis and tail tips were sprayed with fly spray. IceQube™ accelerometers collected step counts (STEP), motion index (MOT), standing time, lying time, lying bouts, and lying bout duration on d -4 – 13. Direct observation of cattle behavior was performed on d 0, 1, and 2. MOT and STEP were significantly elevated in the DK calves ($P < 0.05$) on d 0 – 13 for both variables (except d 12 for MOT, ($P = 0.0567$)). Docked cattle performed rear foot stomp behavior more ($P < 0.001$) than controls on d 0, 1 and 2. In the 48-72 hours following tail docking, DK calves had increased lying bouts ($P < 0.01$) and reduced lying bout durations ($P < 0.001$). On d 0, DK calves twitched tails more ($P < 0.05$) and ruminated less ($P < 0.001$). Observed behavioral changes suggest that calves were uncomfortable following tail docking, which may be related to pain associated with tail docking and/or compensatory activity to avoid flies. We identified behavior changes that suggest a compromised welfare state for tail

docked feedlot cattle and recommend that alternative strategies to reduce tail tip injury be explored.

INTRODUCTION

Tail docking of feedlot cattle is a management practice of the Midwestern United States that amputates a portion of the tail for health reasons as either calves or yearlings. A recent Michigan survey found that 50% of slatted floor farms routinely dock tails of yearling cattle upon entry to the feedlot with the rationale that this practice will reduce tail tip injury, reduce lameness, and improve performance (Miller, 2010).

Tail injuries increase risk for secondary complications such as tail infections, bacteremia, ascending myelitis and paresis. Tail tip necrosis, an acute, purulent lesion, is the most severe form of tail tip injury (Madsen and Nielsen, 1985; Drolia et al., 1991). Bovine tails from solid and slatted floors were examined at slaughter and 34.5% of tails were found to be injured (Drolia et al., 1991) with most of the tail tip necrosis present in cattle housed on slatted floors (Madsen and Nielsen, 1985; Drolia et al., 1990; Schrader et al., 2001).

Tail docking raises potential animal welfare concerns. Tail docking limits communication via the tail and removes an important method for fly avoidance (Kiley-Worthington, 1976). Lastly, the tail docking procedure is likely an acutely painful process with the possibility of chronic pain developing at the amputation site. Behavior and thermographic image changes similar to those found in humans who experience phantom limb pain were found in docked dairy cattle (Eicher et al., 2006). Many studies have examined the behavioral effect of tail banding with rubber rings on dairy cattle (Eicher et al., 2000; Eicher et al., 2001; Eicher and Dailey, 2002; Schreiner and Ruegg, 2002; Tom et al., 2002). There is no research on the behavioral response of feedlot cattle to tail docking via amputation.

The objective of our study was to describe the behavioral response of feedlot cattle after tail docking, which may have implications for welfare. Our null hypothesis states that we will not observe behavioral differences between docked and undocked cattle raised in a confined, bedded pack feedlot.

MATERIALS AND METHODS

The Michigan State University Institutional Animal Care and Use Committee approved this study. All cattle were owned by Michigan State University and the studies were conducted at the Michigan State University Beef Cattle Teaching and Research Center (BCTRC) located in East Lansing, MI.

Sample Size Calculation

The sample size required to detect at least a 70 step count difference was calculated by use of the following equation:

$$n = 2\left(\frac{\left[Z_{\alpha} - Z_{\beta}\right]^2 \sigma^2}{\left[\mu_1 - \mu_2\right]^2}\right)$$

Where n is the sample size per treatment group, Z_{α} is the standard normal value for the desired confidence level (95% [i.e., 1.96]), Z_{β} is the standard normal value required for a power of 80%, σ^2 is the *a priori* estimate of the population variance (70 step counts), μ_1 is the *a priori* estimate of the mean for the calves with docked tails (1250 step counts) and μ_2 is the *a priori* estimate for control calves (1320 step counts) (Dohoo et al., 2003). Using this calculation, the initial sample size was calculated to be 15 calves per group.

Animals, Housing and Processing

Animals and Housing. Thirty-six crossbred beef heifers with average initial BW of 323 ± 17.0 kg were sourced from Kentucky and housed at Michigan State University BCTRC in an open-sided, covered, bedded pack feedlot. Calves were housed at a stocking density of 2.1 m^2 / animal and the entire pen area consisted of fully slatted concrete floors.

Processing. Calves were allowed to rest for 48 hours after arrival. After 48 hours, the calves were processed whereby they received a low radio-frequency identification (RFID) ear tag, plastic bangle ear tag, injectable doramectin anthelmintic (Dectomax, Zoetis Animal Health, Florham Park, NJ), weight measurement, and were vaccinated with a modified-live virus vaccine (BoviShield Gold 5, Zoetis Animal Health) for bovine respiratory disease, including bovine viral diarrhea virus, parainfluenza-3, bovine respiratory syncytial virus and bovine herpes virus-1 and a bacterin vaccine that covers eight clostridial pathogens, including *Clostridium tetani* (Covexin-8, Merck Animal Health, Summit, NJ). Twenty-four hours later, weight measurements were repeated and an average initial BW was calculated. All heifers were blocked by initial BW and sorted into pens of 3 animals. Calves were allowed to rest for the following 5 days to acclimate to their new environment prior to experimental procedure.

Feeding

Heifers were fed a diet of 50% hay, 20% HMC, 25% CS, and 5% protein mineral supplement (DM basis). Feed was delivered once daily between 0500 to 0700 hours.

Study Design and Experimental Procedure

Study Design. Upon arrival, calves were weighed on two consecutive days to determine arrival BW. Calves were then blocked by weight into 12 pens of 3 calves. Pens were randomly assigned by the flipping of a coin into 1 of 2 treatment groups; docked (DK) or control (CN). Six pens (3 DK and 3 CN) received treatment during the first week of the trial (replicate 1). The remaining 6 pens (replicate 2) were housed at the far end of the same barn. The treatments were repeated on replicate 2 during week 2 of the trial. Location of pens in the barn was the same for both replicates during their respective treatment periods, but specific pen locations for DK and CN treatments were swapped between replicates to control for effect of pen.

Experimental Procedure. All calves were brought through the handling facility at BCTRC and restrained in a cattle chute (Silencer, Moly Manufacturing, Inc., Lorraine, KS). All calves, regardless of treatment, received caudal epidural anesthesia. The sacrococcygeal area of all calves was shaved, surgically prepared with iodine scrub, followed by iodine solution and an alcohol rinse. The site of injection was identified by standing to the side of the calf and moving the tail up and down to find the depression of the first coccygeal space (Noordsy and Ames, 2006). A dosage of 1 mL/45 kg of 2% lidocaine hydrochloride (LidoJect, Butler Schein Animal Health, Dublin, OH) was infused into the epidural space between the last sacral vertebra and first coccygeal vertebra or first and second coccygeal vertebrae. Successful caudal epidural anesthesia was identified by lack of tail tone. For DK calves, the site of tail amputation was identified by measuring 25 cm from the base of the tail. The surgical site was shaved and prepped in a manner similar to that used on the epidural site. The distal portion of the tail was removed with commercially available pruning shears at the amputation site. One research assistant operated the pruning shears while another research assistant held the tail with a hand on each side of the surgical site. Between calves, the pruning shears were rinsed with water and then disinfected in a dilution of 2% chlorhexidine solution. After tail removal, an elastrator band was placed 1 cm proximal to the amputation site to provide hemostasis and then sprayed with a permethrin-based fly spray. The CN heifers were treated in exactly the same fashion, except the tail was not removed, an elastrator band was not placed, and tails were not sprayed with fly spray. All calves, regardless of treatment, received post-operative analgesia of 1 mg/kg of flunixin meglumine (50 mg/ml) (FlunixiJect, Bimeda-MTC Animal Health Inc., Cambridge, ON, CAN) administered intravenously in the jugular vein. Flunixin meglumine was used in an extra-label manner for pain control in accordance with guidelines set forth in the Animal Medicinal Drug Use Clarification Act (AMDUCA) (FDA, 1994).

Data collection

Accelerometer data. A random number generator (Microsoft Excel, Redmond, WA) was used to select 2 calves per pen to be fitted with IceQube accelerometers (IceRobotics Ltd., Edinburgh, UK). Three days after calves arrived accelerometers were fitted to 2 of 3 cattle per pen onto to the right hind leg between the hock and fetlock. Cattle were given 5 d (replicate 1) and 19 d (replicate 2) to acclimate to the accelerometer. When cattle were handled, date and times were recorded to ensure externally induced activity was accounted for. Step counts, motion index, standing time, lying time, and lying bouts were recorded in 15-minute blocks over d -4 through 13. Lying bout duration was recorded for each lying bout over d -4 through 13. Raw data was downloaded and edited in excel and imported into SAS (SAS Inst. Inc., Cary, NC) for statistical analysis.

Live observations. At time of experimental procedure, calves were spray painted on each side of their body in three locations – neck, shoulder, and paralumbar fossa – with a green, orange or red animal-safe spray paint (Nasco, Fort Atkinson, WI). The color was assigned to the calves after they were allocated to pens and every calf was assigned a different color so that all colors were represented in each pen. All calves were acclimated to the observer for 1 hour per day for 3 days following arrival to BCTRC. The observer (LKK) wore the same outfit (coveralls, boots, hairstyle, hat) every day during acclimation and during data collection. The same chair, clipboard, camera, bag, and water bottle were used during every day of live observations. Cattle were observed for behaviors from 0800 to 1200 and 1300 to 1700 on d 0, 1, and 2 of treatments for both replicates. The observer alternated between 2 positions whereby 3 pens were observed at once for a focal time of 1 hour. Direct observations were made using scan sampling every 15 minutes (Altmann, 1974; Mitlöhner et al., 2001). Each animal was observed for approximately 60 seconds at each sampling. A total of 44 observations (12 on d 0, 16 on d 1 and 16 on d 2) were made per calf for a grand total of 1584 observations. The sampling process involved first noting whether the heifer's hind end was visible (RV), (Table 3.1) and then taking note of whether certain behaviors were exhibited. The observer utilized an ethogram to correctly and consistently identify the behaviors (Table 3.1).

Video observations. Four video cameras (Sky9621BHD Camera, Skyway Security, Mauldin, SC) were fixed to the rafters of the barn and connected to a 4-channel standalone digital video recorder (AVerDiGi EB 1304 MD, Walnut, CA). The cameras were positioned in order to optimally view the feeding behavior of the calves. Barn lights were left on so that animals were observed performing feeding behaviors at night. The positioning of the cameras was such that 2 cameras provided video coverage on 3 pens. Therefore, 4 cameras were able to record video on all 6 pens collectively. The video data was decoded by two observers so both observers were assigned the same preliminary test video to determine inter-observer variability.

The inter-observer agreement was high (kappa = 1.0). Feeding behavior was recorded as binary and identified according to an ethogram definition (Table 3.1). Feeding behavior data was collected for each replicate using scan sampling every 15 minutes for the first 72 h following tail docking. Calves were weighed upon arrival and at 28 d to determine ADG during experimental period.

Statistical analysis

A general linear mixed model (PROC GLIMMIX) of SAS (Cary, NC) using analysis of variance (ANOVA) was used to analyze accelerometer and video recorded feeding data. The model included treatment (docked or control), day and their interaction as fixed factors with day as a repeated measure. The random factor was replicate (replicate 1 or 2 as a blocking factor) and the experimental unit was animal ID nested within the replicate. A total of 24 calves were used for accelerometer data and 36 calves for video feeding data. Accelerometer data from one animal was excluded in the pre-experiment time frame (d -4 – 0) due to detachment of the accelerometer on d -4. The accelerometer was replaced at time of experimental procedure and data was used henceforth. Of accelerometer data, standing time and lying time were converted to number of minutes, then added for each day, and reported as total daily standing time (TST) and total daily lying time (TLT) in minutes/day. Number of steps taken were added over the day and reported as steps/day (STEP). Motion index (MOT) and lying bouts (LB) were added over the day and reported as lying bouts/day and duration of lying bouts were averaged and reported as average lying bout duration/day (LBDUR).

For live observations, data were reported descriptively as well as statistically. Variables reported include tail wag (TW), rear foot stomp (RFS), tail twitch (TT), rumination (RUM) and other pain-related behaviors (OP). Statistical analysis was done through analysis of covariance

(ANCOVA) using of a generalized linear mixed model in PROC GLIMMIX of SAS (Cary, NC) using , and as a repeated measure analysis. Data were modeled as binary and reported out as the probability of observing a behavior, by day. For live observations, rear visualization (RV) (Table 3.1) was used as a covariate in the analysis. A subset of the infrequently observed live behaviors (tail press, tail lift, abnormal lying, vocalization and head-to-tail reach) commonly associated with pain (OP) were combined and reported as one outcome. The RV covariate was not included in the analysis of OP due to the diversity of the behaviors in relation to the head or rear end of cattle.

Pre-treatment days (d -4 through -1) started at 0001 and ended at 2400, for a total of 24 hours per day. Treatment day 0 started at 1001 (when all cattle returned from pens following experimental procedure) and ended at 2400 (midnight) for both accelerometer and video data, for a total of 14 hours/day. All proceeding treatment days started at 0001 and ended at 2400 the following day for a total of 24 hours/day.

The differences between DK and CN for the feeding and accelerometer variables (STEP, MOT, TST, TLT, LB and LBDUR) were assessed using Fisher's exact t-test; differences were considered significant when $P < 0.05$. The null hypothesis stated that there would be no difference in behavior response between docked and control cattle. The alternate hypothesis stated that there would be a difference in behavior response between docked and control cattle.

Table 3.1. Ethogram used for live and feeding observations of heifer cattle behavior following tail docking (Eicher and Dailey, 2002). Rear visible observation was considered as a covariate in the statistical analysis of live observations. Live and feeding observations were recorded as binary.

Item	**Definition**
Video observation	
Feeding	The calf's head is (minimum ½ length of head) over the feeder or lowered into feeder
Live observations	
Rear visible	Can see at least rear end completely or one lateral side of hindquarters and tail
Rumination	Regurgitates feed, chews, then swallows feed
Tail wag	Movement of tail greater than 45 deg from vertical, apparent effort to eliminate flies
Rear foot stomp	Forcefully raising and lowering of hind foot in one spot, not related to walking
Tail press	Tail is drawn into hind end tightly against body
Tail lift	Tail is elevated from resting position
Tail twitch	Intermittent and vigorous swinging of tail without tail slapping back to indicate fly avoidance
Vocalization	Any vocalization from animal
Abnormal lying posture	Hind leg extended abnormally while lying, with one or both hind legs extended, instead of tucked under body
Head-to-tail	Movement of head to touch or view tail, that was not to dislodge flies or to groom

RESULTS

Accelerometer data

Based on analysis of MOT, DK cattle were significantly more active ($P < 0.05$) compared to CN for all days except d 12 ($P = 0.0567$) (Figure 3.1). Similarly, DK cattle took more steps compared to CN cattle for all days ($P < 0.05$) (Figure 3.2). Prior to treatment, a significant difference existed between treatment groups on d -2 for MOT and STEP. The data set was reviewed in the four days prior to experiment and we identified 4 suspicious outliers; 2 calves from 1 pen in replicate 1 and 2 calves from 1 pen in replicate 2. Upon review of video that had captured feeding behavior, we were able to visualize estrus behavior in 2 calves from one pen of the animals we identified as outliers. The pen from replicate 2 was not visible on video as they were located away from the cameras, but it is likely that estrus behavior caused the increase in activity. After removal of data from the replicate 2 animals, there was no significant difference for either MOT or STEP on d -2.

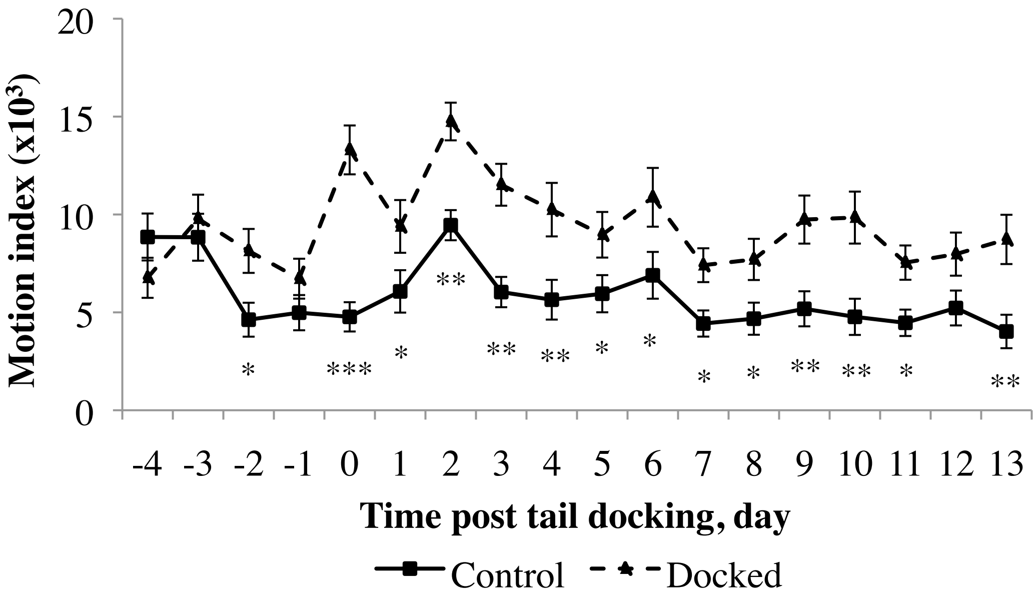

Figure 3.1. Least squares means of motion index ± SEM by day post tail docking of control and docked cattle for 4 days prior to and 14 days after docking. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

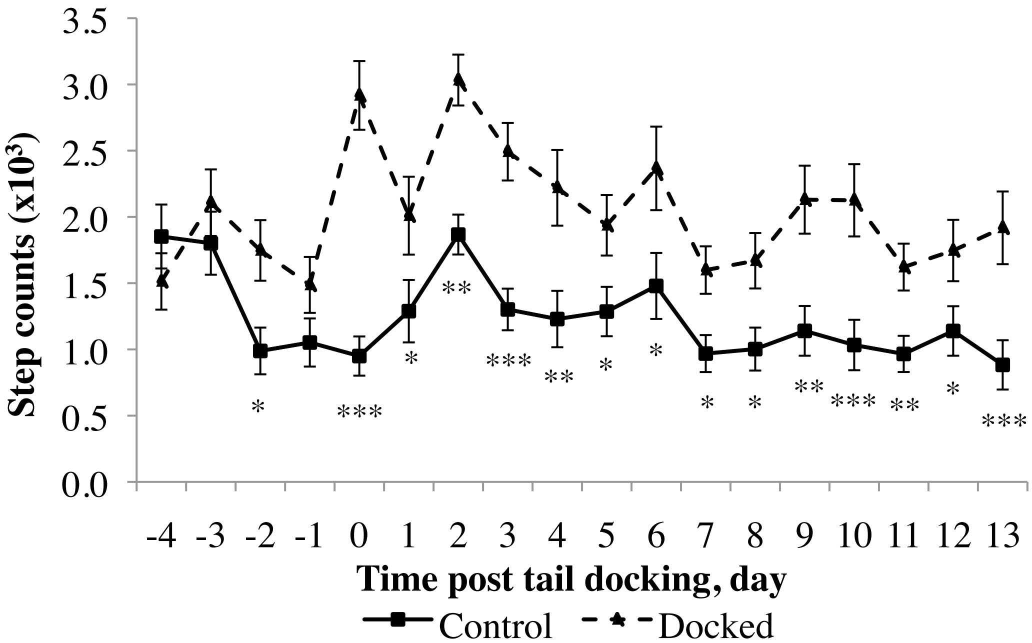

Figure 3.2. Least squares means of step counts ± SEM by day post tail docking of control and docked cattle for 4 days prior to and 14 days after docking. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Docked cattle had significantly longer TST than control cattle on d 0, 1, and 2, and also d 9 and 13 (Figure 3.3). Conversely, docked cattle had significantly shorter TLT compared to control cattle on d 0, 1, 2 and 9 (Figure 3.4). The first two full days after tail docking (day 1 and 2), docked calves spent 8.2 and 8.6 h lying per day compared to control cattle who spent 13.4 and 12.5 h lying per day, respectively. Docked cattle displayed more frequent LB than control cattle on d 0 and 1 (Figure 3.5); however, docked cattle had shorter LBDUR compared to control cattle on d 0, 1 and 2 (Figure 3.6).

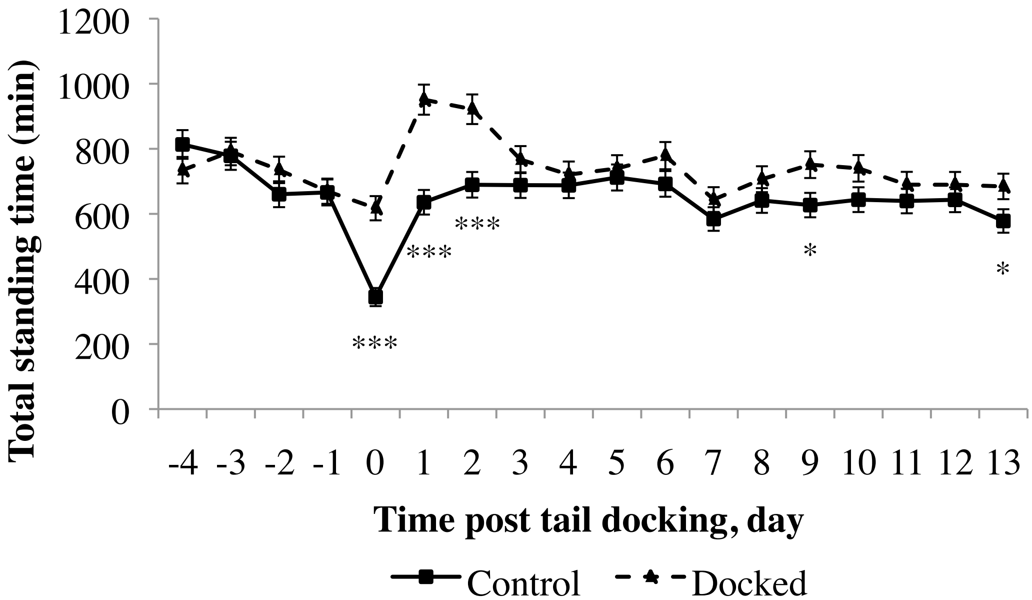

Figure 3.3. Least squares means of total standing time (minutes) ± SEM by day post tail docking in control and docked cattle for 4 days prior to and 14 days after docking. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

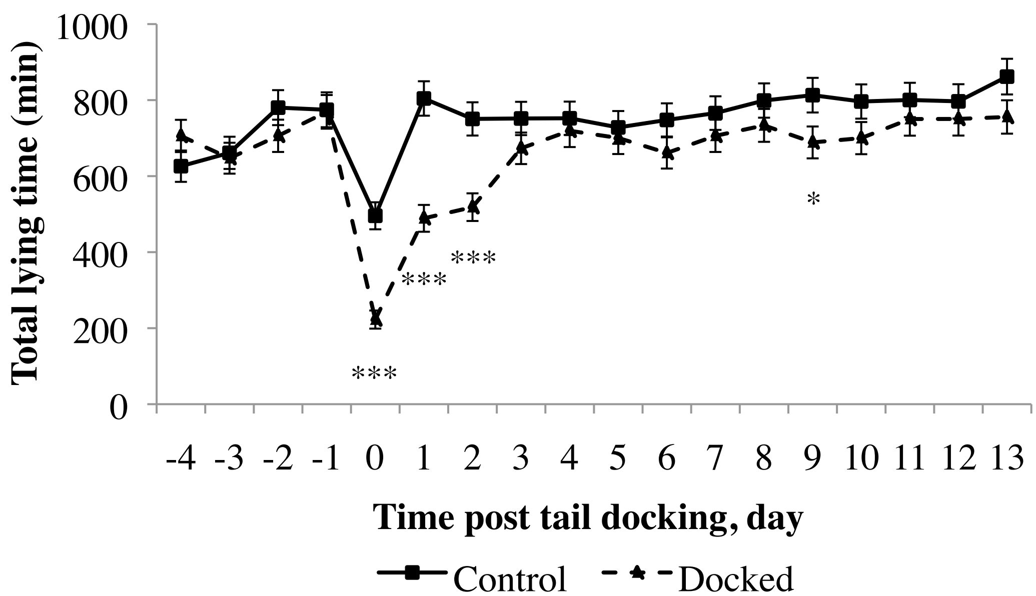

Figure 3.4. Least squares means of total lying time (min) ± SEM by day post-experiment for control and docked animals for 4 days prior to and 14 days after docking. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

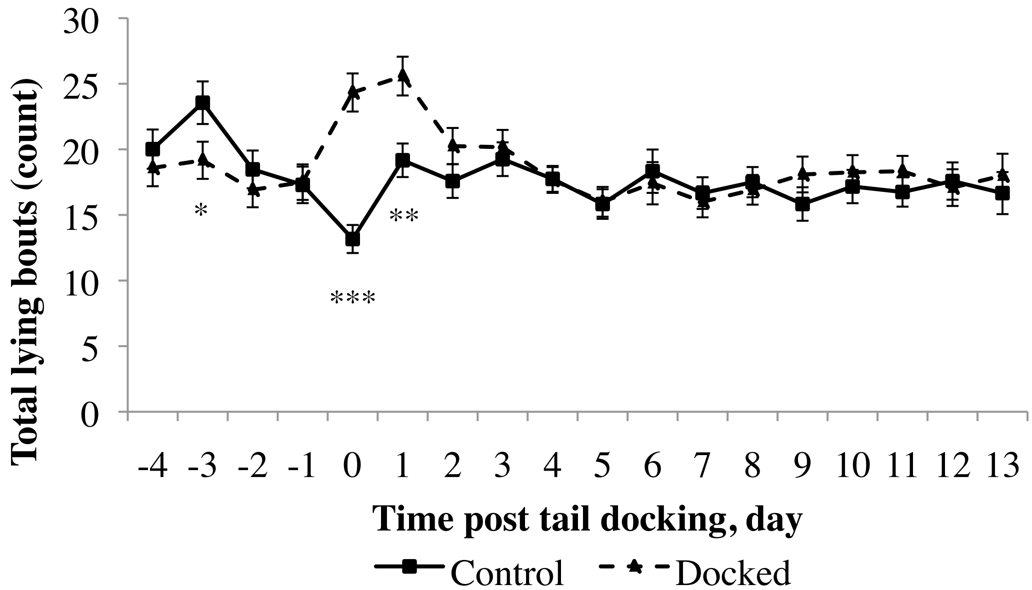

Figure 3.5. Least squares means of total number of lying bouts ± SEM by day following experimental treatment for control and docked cattle for 4 days prior to and 14 days after docking. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

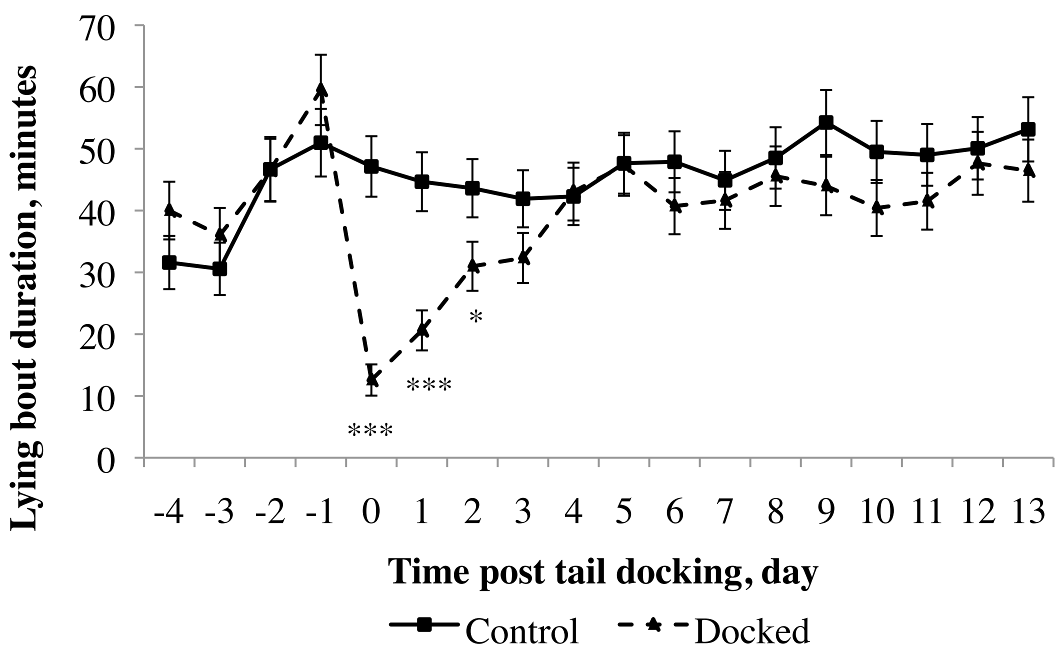

Figure 3.6. Least squares means of duration of lying bouts (min) ± SEM by day following tail docking for control and docked cattle for 4 days prior to and 14 days after docking. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Live observations data

During review of data set analysis, we noticed that inclusion of rear visualization (RV) (Table 3.1) as a covariate was significant in the analysis of live observation outputs (RFS, TW, TT, and RUM). Since RV represents the ability of the observer to visually see the rear end of a calf, behaviors that involved the tail and/or hind leg (RFS, TW, and TT) were analyzed with a confirmed visual of the rear end. One variable, RUM, was analyzed with the lack of rear visualization, as this behavior depended on the observer's ability to see the front of the animal (for cud chewing and swallowing). Other pain-related behaviors (OP), which included tail press, tail lift, head-to-tail reach, vocalization, and abnormal lying, were not analyzed for inclusion of a covariate as this inclusion of varying behaviors involved activity of both the front and rear end of the animal.

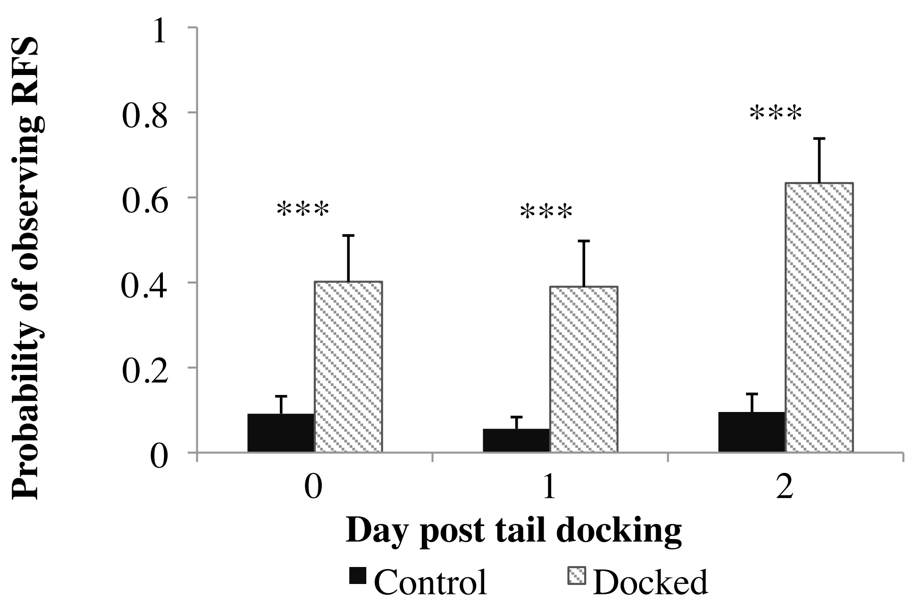

Figure 3.7. The probability of observing rear foot stomp behavior (RFS) + SEM within the defined observation period by day following tail docking in control and docked cattle. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

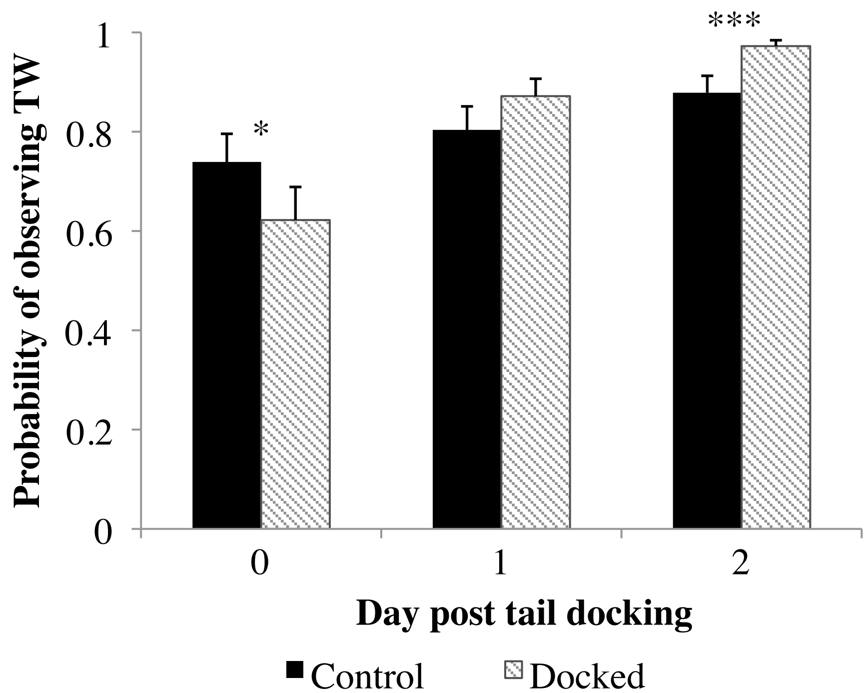

Figure 3.8. Probability of observing tail wag behavior (TW) + SEM within the defined observation period by day post tail docking in control and docked cattle. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

The probability of observing RFS was significantly higher ($P < 0.05$) for DK than CN cattle for the three days following tail docking (Figure 3.7). On d 0, the probability of observing TW was less likely for DK than CN ($P < 0.05$). No significant difference was observed between DK and CN on d 1 ($P = 0.0687$) for TW (Figure 3.8). However, by d 2, DK had a significantly higher probability of performing TW compared to CN. The probability of observing RUM was significantly lower for DK following tail docking than for CN on d 0 ($P < 0.001$) (Figure 3.9). The probability of RUM increased from d 0 to d 1, however, no significant difference was observed when compared to CN on d 1 ($P > 0.1$). Docked cattle were more likely observed performing TT compared to CN on d 0 and 1 ($P < 0.05$, $P < 0.01$ respectively) (Figure 3.10). However, the difference between DK and CN diminished by d 2 ($P = 0.972$). Other pain related behaviors (OP), including tail press, tail lift, head-to-tail reach, abnormal lying and vocalization, were observed infrequently. However, as a group, one of these behaviors was more likely to be observed in DK compared to CN calves on d 0 ($P < 0.01$) (Figure 3.11).

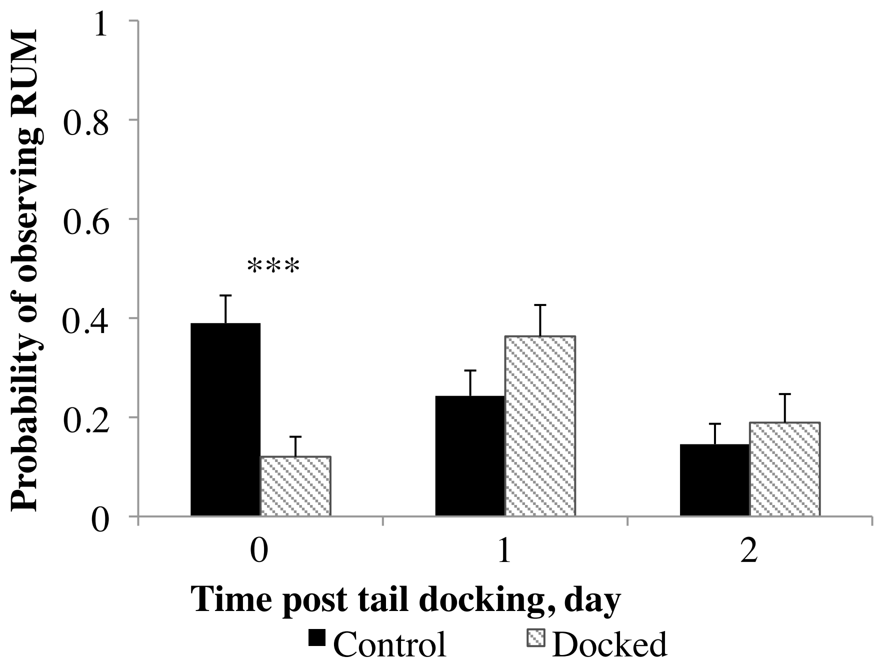

Figure 3.9. Probability of observing rumination behavior (RUM) + SEM within the defined observation period by day post tail docking in control and docked cattle. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

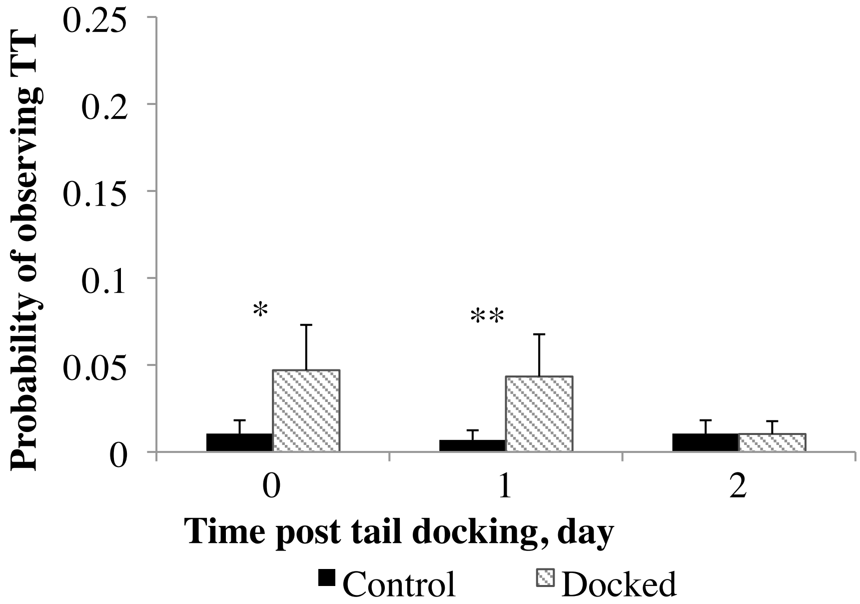

Figure 3.10. Probability of observing tail twitch behavior (TT) + SEM within the defined observation period by day post tail docking in control and docked cattle. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

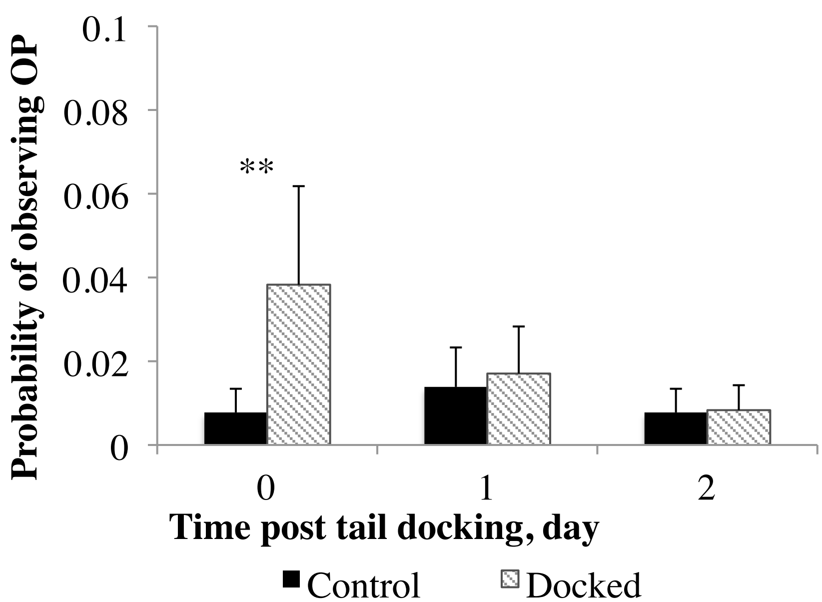

Figure 3.11. Probability of observing other pain related behaviors (OP) + SEM within the defined observation period by day post tail docking in control and docked cattle. OP includes tail press, tail lift, head-to-tail reach, abnormal lying, and vocalization behaviors. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Numerically, CN calves wagged their tails more than DK calves on d 0, while DK calves stomped their rear foot more than CN calves for days 0, 1, and 2 (Table 3.2). Control calves were nearly equal to DK calves in frequency of observations reported for tail wags on day 1 and 2 and control calves were observed to have fewer rear foot stomp behaviors on all days (Table 3.2). Docked calves had more tail twitch and head-to-tail behaviors than control calves on day 0 (Table 3.2).

Table 3.2. Total number and percent of total daily live behavior observations in feedlot heifers after tail docking.

Day 0	Control		Docked	
Item	Counts[a]	% of total[b]	Counts[a]	% of total[b]
Tail wag	187	71.4	149	52.5
Rear foot stomp	23	8.8	91	32.0
Tail twitch	1	0.4	9	3.2
Ruminating	48	18.3	22	7.8
Vocalization	1	0.4	0	0
Head-to-tail reach	0	0	7	2.5
Tail press	2	0.8	6	2.1
Tail lift	0	0	0	0
Abnormal lying	0	0	0	0
Total	262	100	284	100

Day 1	Control		Docked	
Item	Counts[a]	% of total[b]	Counts[a]	% of total[b]
Tail wag	220	75.1	223	52.8
Rear foot stomp	16	5.5	106	25.1
Tail twitch	2	0.7	12	2.8
Ruminating	48	16.4	73	17.3
Vocalization	1	0.3	3	0.7
Head-to-tail reach	0	0	0	0
Tail press	0	0	4	1.0
Tail lift	6	2.1	0	0
Abnormal lying	0	0	1	0.2
Total	293	100	422	100

Day 2	Control		Docked	
Item	Counts[a]	% of total[b]	Counts[a]	% of total[b]
Tail wag	239	76.9	250	55.3
Rear foot stomp	31	10.0	164	36.3
Tail twitch	2	0.6	3	0.7
Ruminating	36	11.6	30	6.6
Vocalization	2	0.6	1	0.2
Head-to-tail reach	0	0	0	0
Tail press	0	0	2	0.4
Tail lift	1	0.3	2	0.4
Abnormal lying	0	0	0	0
Total	311	100	452	100

[a]total number of times a behavior was observed for all animals of both replicates

[b]percent of all behaviors observed per day

Video data

Docked cattle were more likely to visit the feed bunk during 1400 – 1800 h and 1800 – 2200 h compared to CN on d 0 (1400 – 1800 h, $P < 0.05$, 1800 – 2200 h, $P < 0.01$) (Figure 3.12). Docked cattle were more likely to visit the feed bunk during 1000 – 1400 h ($P < 0.05$) and 1800 – 2200 h ($P < 0.05$) on d 1, but CN were more likely to visit the feed bunk in the evening hours of 2200 – 0200 h ($P < 0.05$) on d 1 (Figure 3.12). On d 3, DK were more likely to visit the feed bunk compared to CN during 1800 – 2200 h, however, CN were more likely to visit the feed bunk compared to DK during 2200 – 0200 h ($P < 0.01$). The only time period where DK cattle were observed eating more often was on d 0, 1, and 2 between 1800 – 2200 h. The differences found in feeding behaviors did not result, however, in any performance effect. Twenty-eight days following experimental procedure, the ADG of our calves was not significantly different between treatments (by t-test, $P = 0.170$) (unpublished data).

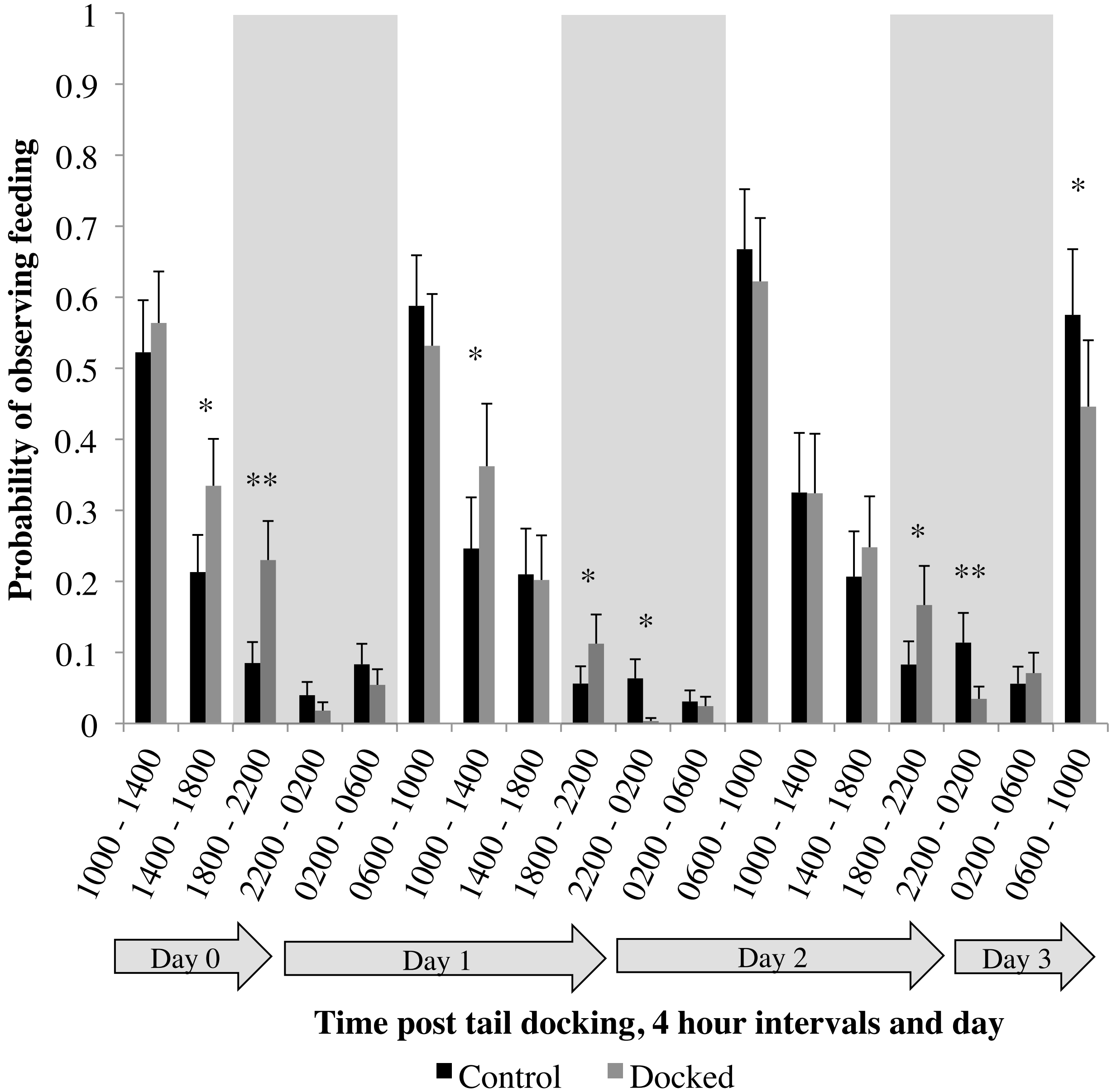

Figure 3.12. Probability of observing feeding behavior of control and docked calves by four-hour intervals post tail docking. Feeding was defined by an ethogram (Table 3.1) for accurate and consistent recording. Grey shaded areas span from 1800 – 0600 to represent the evening hours and help identify separation of days. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

DISCUSSION

In our study, we were able to detect short-term and long-term behavioral differences between tail docked and undocked heifers in a confined, bedded pack feedlot. Multiple data collection methods (video, activity monitors, and live observations) allowed for a surveillance of diverse behaviors, which showed that following tail docking heifers displayed behaviors consistent with acute pain and increased fly avoidance. This study used changes in behavior as a means to identify the affective state of cattle following a painful and physically altering procedure.

Activity level, as measured by motion index and step counts, was significantly elevated in docked calves on all 14 days following tail docking (except day 12 for motion index) when compared to control calves. There are several possible reasons for this increased activity. First, removal of the tail partly takes away ability to avoid flies, causing the calves to walk or stomp to physically move away from or dislodge flies. Our study was intentionally conducted in the summer months when fly numbers were high to specifically observe behaviors associated with fly irritation. Walking activity has been shown to be significantly increased in yearling feedlot steers under high levels of fly burden (Harvey and Launchbaugh, 1982); however, current literature does not describe a relationship between docked cattle and increased walking activity as an alternative fly avoidance behavior. Secondly, increased activity in the tail-docked heifers may be due to pain from the tail amputation procedure. Pain is another plausible explanation for altered behavior as the analgesic effects of the lidocaine epidural and flunixin meglumine may have lasted less than 8 h. Previous studies looking at walking behavior in docked dairy cattle have had mixed results. No difference in walking behavior was found between docked and undocked primiparous heifers observed for 24 h post-banding and 24 h post-docking (Eicher et al., 2000). Similarly, adult dairy cows showed no difference in walking activity when observed for 3 1-hour periods for 5 days following banding, though other significant fly avoidance behaviors (tail swings and foot stomps) were found (Eicher et al., 2001). In contrast to the dairy cow studies but similar to our findings, 3-5 week old calves that were tail banded spent a greater percent of time walking compared to control calves in the 2 h after banding which was interpreted as discomfort (Eicher and Dailey, 2002). The differences found between these previous studies suggest that young calves may be more sensitive to pain from tail docking than more mature cows. Our study differs from the adult animal experiments as these cattle were housed in box stalls or tie-stalls, therefore restricting the area in which to move and express walking behavior. Our calves were housed in a sizeable pen (616 ft^2) at a stocking density of 205 ft^2/animal, thus allowing ample room for unrestricted movement and interaction with pen mates. Thirdly, docked cattle may have expressed displacement behaviors, like visiting the feed bunk and antagonizing pen mates, because they were unable to perform normal tail behaviors. Displacement behaviors occur when animals are motivated to do two different actions, or when they are highly motivated to perform a certain behavior that they are somehow restricted from doing (Fraser, 2008). Docked cattle visited the feed bunk more often in the present study and may have accumulated more steps in the process. Also, docked calves may have paced or antagonized pen mates in response to their inability to normally move their tails. Our use of a more quantifiable and objective method to measure steps and activity levels through use of accelerometers might have provided more sensitivity in detecting differences between the groups compared with direct observations of previous studies. One other possible explanation for the described differences between studies is that our calves had their tails surgically removed, whereas other studies used banding and tails were allowed to undergo necrosis before eventually falling off or being physically removed. The necrotic tail may have served as a functional fly avoidance tool during the time it was still physically attached.

Within this period of increased activity for DK calves, an initial dramatic increase followed docking for four days, then declined gradually, but remained consistently elevated through the entire 14-day period. It may be that the initial four days after docking consisted of a pain response coupled with a fly avoidance response. Our study did not include a study group that included a prolonged pain control therefore these two effects cannot be confidently separated out at this point.

Over the 48-72 hour period post tail docking, docked calves showed an increased frequency of lying bouts, and each lying bout duration was shorter than that of control calves. In addition, total daily lying time was significantly decreased in docked calves, despite their more frequent lying bouts. Total lying time of our control calves represent typical feedlot calves, which tend to spend approximately 12 h lying per day (Robért et al., 2011; Hoffman and Self, 1973). One possible explanation for the altered lying behaviors of docked calves is that they were uncomfortable from generalized pain in the tail region and felt the need to change positions. Another possible explanation is that physical contact of the tail tip with the pen floor created or exacerbated pain causing the calf to rise. Other studies found a decrease in time spent lying in adult dairy cows that were tail banded prior to parturition (Eicher et al., 2001) and increased restlessness was observed in calves after tail banding (Schreiner and Ruegg, 2002). Similar results of increased standing time occurred in rubber ringed docked 1-week old calves (Tom et al., 2002) and following castration in beef calves compared to prior to castration (White et al., 2008).

Direct live observations of cattle have inherently low reliability due to variation in accuracy of observations within observer(s) (intra-observer reliability) and between observer(s) (inter-observer reliability). Two observers were tested on the same video footage of feeding and found to have high inter-observer reliability in this study. Only one observer performed live direct observations of the cattle after docking.

We saw an interesting interaction of tail wag behavior between the treatment groups. On day 0, control calves were more often observed to perform the tail wag behavior. Docked calves may have decreased tail wag behavior the day of docking due to 1) a loss of motor control from the epidural or 2) pain associated with movement of the tail. However, both groups of cattle had received an epidural, so response from epidural is less likely. Interestingly, by day 2 of this study, docked calves were more likely to perform the tail wag behavior, though both groups performed the tail wag behavior often. A possible explanation for this is that docked cattle were less effective in dislodging flies due to loss of the majority of their tail, and therefore responded by increasing the frequency of this now less effective fly avoidance behavior. The tail swing behavior was frequently used in cattle with intact tails, likely to dislodge flies. The rear foot stomp behavior was used significantly more by docked calves on all three days following docking and likely represents an alternative method of fly avoidance when tail swings are not effective. In a study of primiparous heifers, docked heifers significantly increased tail swings in the afternoon when flies were more abundant (Eicher et al., 2001). Eicher and Dailey (2002) studied 7 week old calves after tail banding and subsequent tail removal and found that control calves performed tail swings more frequently overall. The previous study also found that docked calves performed more fly avoidance behaviors directed toward the rear end (licking) of the calf and had numerically more foot stomps. Tom et al. (2002) found no difference in tail shake behavior between docked and control calves following tail docking using rubber ring or hot iron on d 0, 1 or 5. Fly pressure may vary across the studies depending on the season and geographical location of these studies and may account for some of the observed differences. In addition, methods of tail docking are different in dairy calves and cows compared to our cut and band approach and different behavioral responses may be triggered depending on the method used.

The decrease in observed rumination of calves on day 0 may have occurred due to pain from the tail removal process. On day 1 we saw a rebound increase in rumination of the docked calves, suggesting pain was waning. Preparturient heifers docked with rubber ring and no epidural showed a decrease in rumination up to 4 hours after banding (Schreiner and Ruegg, 2002). Tom et al. (2002) described no difference in frequency of rumination in mixed parity dairy cows that were tail banded. A decrease or absence in rumination on physical exam usually indicates pain from significant clinical diseases, such as displaced abomasum or toxic mastitis. Cows with endotoxin-induced clinical mastitis decrease rumination time immediately following endotoxin administration and increased rumination later in the day (Fitzpatrick et al., 2013). The observed decrease in rumination seen here may represent a short-lived pain response to tail removal.

Individual behaviors often associated with pain, such as abnormal lying, tail press, tail lift and vocalization, occurred infrequently and were therefore less helpful in describing behavioral response of cattle to tail docking. However, when combined into one variable representing abnormal behavior, there was an increased occurrence in docked animals that could possibly represent an acute pain response. Vocalization in animals tends to communicate painful experiences (Molony and Kent, 1997). One study showed increased vocalization in calves following tail banding (Petrie et al., 1995) while studies on tail docking in dairy cows and calves show infrequent expression of the behavior (Schreiner and Ruegg, 2002; Tom et al., 2002). Abnormal lying postures were significant elevated following three methods of castration in young calves when compared to controls (Molony et al., 1995). Anatomical location and short-term analgesia provided in the current study may account for low occurrence of these observations.

The feeding behavior video showed docked calves visited the feed bunk more often around the afternoon time frame on day 0, 1, and 2. Docked calves were likely in pain for the 48-72 hours following tail docking, as evidenced by prior description of changes in lying behaviors, tail twitch response, rumination, and tail wag behavior. An increase in feeding may occur as a displacement behavior similar to findings in studies of rats that are tail pinched and subsequently consume more sweetened milk (Rowland and Antelman, 1976). Primiparous heifers increased eating behavior after banding, and returned to normal behavior after the tails were removed 6 days later (Eicher et al., 2000). Furthermore, our results of no differences in growth are supported by a report by Grooms et al. (2009) that showed no difference in ADG or feed intake between docked and undocked confined feedlot steers. The docked calves in the current study visited the feed bunk more, but this did not result in increased weight gain from these visits.

Multiple behavior collection methods (video recording, direct observation and activity monitors) were used in this study to optimize surveillance of behaviors that may be seen following tail docking. No previous studies have used activity monitors to collect data on cattle following tail docking. Elischer and colleagues (2013) previously validated IceQube (Edinburgh, UK) activity monitors and found a high correlation between live observations, the gold standard of behavior observation, and IQ outputs. Activity monitors are useful from the aspect of minimizing labor surrounding direct behavior observation, limiting observer bias, and observer effect on the animal's behavior (Elischer et al., 2013). Two-dimensional accelerometers were successfully validated and used to detect activity changes of calves after surgical castration (White et al., 2008) and three-dimensional accelerometers proved accurate in monitoring calf behavior (Robért et al., 2009). The use of remote monitoring through use of accelerometers is thus an acceptable method for obtaining behavior data because of its accuracy and minimal human interference.

The purpose of our study was to understand the behavioral changes of feedlot cattle to tail docking following a routine tail removal procedure. We understand that analgesics may have masked some acute pain responses immediately following tail docking; however, Institutional Animal Care and Use Committee guidelines required that we provide pre-operative and post-operative analgesia. We believe that the short duration of analgesia provided resulted in close approximation of field conditions, while still operating within the requirements of a research setting. Expected duration of effect for lidocaine epidural is modest at 10-115 minutes (Coetzee, 2013). Following surgical castration in feedlot calves, flunixin meglumine and lidocaine with epinephrine caudal epidural provided 8 hours of analgesia (Currah et al., 2009). Epinephrine is known to extend the anesthesia of lidocaine. Since we did not use lidocaine with epinephrine, we expect our analgesic coverage was less than 8 hours.

Different methods can be used for tail docking cattle. We utilized the cut and band approach that is commonly used in slatted floor feedlot facilities. Other approaches used in feedlots include tail banding of yearlings on arrival or in young calves (Miller, 2010). Our results, especially those related to pain, may have been different if we had used a different procedure such as tail banding. However, it is reasonable to expect that changes in fly avoidance behaviors would be similar regardless of the tail removal procedure.

Since our study provided some degree of pain control, we can consider our results a baseline level of abnormal behavior in response to acute pain in comparison to what cattle may actually experience in the field. The behaviors of docked calves indicate a moderate degree of acute pain and prolonged irritation from fly burden associated with tail docking. Additionally, the notion of chronic pain cannot be ignored. In a study on 22-23 mo. old heifers that were docked as young calves, results showed heifers were sensitive to temperature changes in a manner similar to that of human limb amputees who experience phantom limb pain (Eicher et al., 2006). Neuromas develop following amputation of beaks in chickens, tail amputation in dogs, and tail amputation in lambs (Gentle, 1986; Gross and Carr, 1990; French and Morgan, 1992). Neuroma formation is also known to occur in other species as well. Further investigation into chronic pain development from possible neuroma or complex nerve formations in tail docked feedlot cattle is warranted.

In summary, tail docking in feedlot cattle causes behavioral changes that are consistent with increased discomfort from fly irritation and acute pain. Although routine tail docking is practiced in confined slatted floor facilities to reduce the risk of tail injuries from occurring, changes in behaviors do present an animal welfare concern. Development of alternative strategies for reducing tail injuries in slatted floor facilities would be beneficial in improving cattle welfare in these types of management facilities.

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SUMMARY

Tail docking in feedlot cattle occurs in response to a problem that the industry had identified within cattle raised in confinement on slatted floors; tail tip injury and necrosis. Tail tip injury is considered traumatic in origin and most commonly happens when cattle are lying down and are stepped on by pen mates. The risk of tail tip injury increases with higher stocking density and concrete slatted floors. Research has shown that the more confined cattle are, the more likely they are to step on each other. The hard nature of concrete floors provides minimal absorption of force in the event a pen mate steps on another's tail. In severe cases the tail becomes infected and necrotic, i.e., tail tip necrosis. This may then lead to bacteremia, and cause infection in other areas of the body, such as the joints, spine, or lungs, creating ill and/or lame cattle. It is reasonable to hypothesize that if tail tip injury and necrosis increases the risk of these sequelae; perhaps tail docking would eliminate the risk of tail tip injury and therefore improve health and performance.

Tail tip injury and necrosis are welfare issues because of the pain and discomfort associated with this condition. However, reduction in the risk of tail tip injury in some of the cattle via tail docking may reduce welfare of all cattle as well. Tail docking is an animal welfare issue, as the procedure itself is acutely painful, may result in chronic pain, and may reduce the tail's function in fly avoidance and communication. Likewise, the tail docking practice began in the beef industry without true knowledge of whether it would improve health and performance. These concerns warranted further investigation into the actual behavior, performance and health effects of tail docking in confined feedlot cattle raised on slatted floors.

The facility design of confined slatted floor barns was created with the good intentions of protection of cattle from the elements, reduced environmental impact from animal waste, reduced land use compared to outdoor feedlots, and reduced labor costs for the producer. Another benefit of raising cattle in these facilities is that the hides of finished cattle are quite clean. This is a valuable benefit to meat packers and consumers from a food safety standpoint. From the societal and environmental perspective, the confined feedlot facility has some clear advantages. From the perspective of the animal, however, there are areas of reduced health and welfare in these systems. Tail tip necrosis occurs in finishing beef cattle in these systems as a result of facility design (slats) and management (high stocking rate). The industry made a well-intentioned decision to reduce these injuries and their possible sequelae through tail docking. Our research sought to bring light to this area in order to determine performance and health effects of tail docking and how it impacted cattle welfare.

Our studies showed that routine tail docking had no effect on performance and health, but instead compromised the welfare of docked cattle raised in confined feedlots. Compromised welfare in docked cattle was demonstrated by an increase in behaviors associated with pain and fly avoidance. Additionally, the creation of a tail injury in 100% of docked cattle is considered detrimental to cattle welfare as it is acutely painful, has potential for chronic pain, and the open wound may become infected and lead to downstream sequelae. In fact, in our study up to 81% of docked cattle had an infected tail tip at some point during the feeding period. In contrast, in our study as many as 76% of undocked cattle developed tail tip injuries by the end of the feeding period, and up to 54% developed infected and/or necrotic tail tips at some point during the feeding period. It is evident that undocked cattle develop significant levels of tail tip injury when raised in the slatted floor feedlot, which may lead to tail infection and/or necrosis. Likewise, tail docking guarantees that cattle will have an injury due to the procedure and the potential to develop severe detrimental consequences such as tail infection. Perhaps, instead of addressing tail tip injury with tail amputation, which in itself may cause problems; the solution may be to reduce the identified risks associated with tail tip injury and necrosis in these facilities.

Research has identified risk factors associated with tail tip injury related to flooring type and stocking density. Concrete slatted floors and space allowance of < 2 m^2 are known to increase tail tip injury and reduce welfare of confined feedlot cattle. Recommendations for ideal stocking density of cattle in slatted facilities range from 3 m^2 to 4 m^2. This density still allows for the management benefits of confinement, but improves cattle welfare related to tail tip injury (less tail tramping) as well as other welfare areas (such as increased lying time and reduced leg lesions). Other recommendations that may reduce tail tip injury are to increase the softness of the floor, through rubber matting or bedding. Thus far, no studies have looked into the effects of alternative flooring type on tail tip injury, however, other welfare indicators, such as lameness, slipping, and lying time are all improved in cattle raised on rubber floor compared to concrete. Further research should be done looking at the impact of decreased stocking density and alternative flooring types on tail tip injury.

Alternative strategies to reduce tail tip injury and necrosis should be explored. The aim should be to identify the balance point where benefits to the animals, environment, and society are maximized. Current research points towards increased space and softness of flooring to improve cattle welfare. Further research is needed to look into the economic threshold to remain profitable when raising cattle with more space and softer flooring, while identifying the proper stocking density and flooring type that benefits the animal. Other alternatives might include a hybrid flooring design that incorporates a bedded area with slatted floors. Another approach is to sort cattle as they grow to reduce stocking density of pens. Lastly, tail alterations may provide reduced chance for tail injury. Possible approaches include tail shaving or switch trimming, with special consideration given to optimal timing (for example, on arrival or day 100 of feeding period) and frequency of shaving/trimming. Another alternative may be to dock tails therapeutically only as they are identified as injured, though the challenge of monitoring for tail injuries may require more labor costs and time. If done therapeutically, tail docking should be performed with local anesthesia and appropriate analgesia. Another option might be to dock only the tail tip, so that the tail is still long enough to avoid flies and be useful for communication, but short enough to reduce tail tip injury and necrosis. This approach would be recommended only with use of local anesthesia and appropriate analgesia. Tail tip docking is considered a last resort effort since the practice itself is acutely painful, has potential for chronic pain, may worsen fly burden, and may not actually reduce tail tip injury. Lastly, if no practical alternatives can be identified to reduce tail tip injury in confined feedlot cattle, it may be that these facilities need to be reconsidered and a new approach explored for raising cattle in confinement.