The Effect of Ad Libitum Concentrate Feeding on Crib-Biting Behavior in the Horse

by

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Abstract

Previous research indicates cribbing behavior in horses increases when horses were fed concentrate meals. This study used 10 mature cribbing geldings to investigate effects of ad libitum concentrate feeding on cribbing behavior. Horses were randomly assigned to either ad libitum feeding (n=5) or control (n=5) groups and were maintained on Bermuda grass (*Cynodon dactylon*) pasture and free choice hay. Each horse received a baseline ration of 1.8 kg of a commercially available pelleted concentrate twice daily at the start of the study (d 0). Control horses remained on this amount throughout the study. Feed for ad libitum horses was increased to approximately 3.6 kg concentrate four times daily and maintained at this amount for 102 d. Ad libitum horses were then fed 0.9 kg concentrate four times daily (d 103-136) and finally returned to baseline ration (d 137-170). Numbers of crib bites, crib bouts and duration of crib bouts were recorded for all horses during six 24 h observation periods (d 0, 28, 66, 102, 136 and 170). Data were analyzed as a repeated measures design. A significant treatment by observation day interaction was revealed for crib bites ($P > 0.01$), total crib bouts ($P > 0.001$) and bout duration ($P > 0.01$). Preplanned contrasts showed that control horses performed an average of 2012 ± 495 more crib bites ($P > 0.01$), 3.9 ± 1.6 more crib bouts ($P > 0.01$) and spent 13988 ± 2922 s more time cribbing ($P > 0.001$) than ad libitum fed horses during the ad libitum feeding period. When ad libitum fed horses were fed normal feed amounts four times daily (d 103-136), their total crib bites, total crib bouts and duration of crib bouts were not significantly different from control horses. Also, no significant residual effect of ad libitum feeding on cribbing behavior was found when ad libitum fed horses were returned to baseline feeding levels (d 137-170). It is not clear from this study whether the decrease in cribbing behavior seen in the ad libitum fed horses was the result of additional feed or a change in other factors that accompany concentrate feed delivery. Additionally, ad libitum feeding cannot be considered a viable method to reduce cribbing behavior because of possible negative effects, such as obesity, of this feeding regimen on horse health and usefulness.

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I. INTRODUCTION

Cribbing is an oral stereotyped behavior pattern performed by domesticated horses which appears to be absent in wild horses. Cribbing typically involves the horse pressing its upper incisor teeth onto a horizontal surface, flexing the neck and leaning backwards with or without emitting a characteristic grunting noise. The behavior results in premature erosion of the upper incisors of the horse as well as property damage due to pulling on fences and other fixed objects. The negative stigma associated with cribbing and the resulting property damage often leads to the sale, euthanasia, or slaughter of horses that display the behavior.

Because it is considered an undesirable stable vice, horse owners and researchers have explored a wide variety of methods to prevent or punish the behavior. Acupuncture (Kuussaari, 1983), surgery (Delacalle et al., 2002), taste deterrents, opioid antagonists (Dodman et al., 1987), shock collars (McGreevy and Nicol, 1998a), and most commonly, cribbing collars, meant to punish and prevent neck flexion, have been utilized with variable results.

Once animals develop stereotypic behaviors, the behavior becomes difficult to reduce or reverse. It appears that as crib-biting behavior develops it may become increasingly disconnected from the original eliciting stimulus, which could result in performance of the behavior in response to stimuli that increase general arousal, such as delivery of concentrate feeds, and it is well documented that concentrate feed delivery causes an increase in cribbing behavior (Kusunose, 1992; Brown et al., 2007). However, it may be more likely that feed delivery serves to positively reinforce the behavior since a 12 hour shift in feeding schedule caused a shift in times of peak cribbing frequency to coincide with the altered feeding schedule (Brown et al., 2007).

II. LITERATURE REVIEW

A. *Definition and Prevalence of Cribbing*

Stereotypies are invariant, repetitive behaviors, which have no apparent function and are performed at a higher than normal rate (Broom and Kennedy, 1993; Dantzer, 1986). These behaviors are performed more frequently with anticipation, e.g., feed delivery, release from stall confinement, or increased stress (Kiley-Worthington, 1983; Mason, 1991). Stereotyped behaviors have been reported in many species and include a wide variety of behaviors, such as pacing and licking in captive giraffes (Bashaw et al., 2001), rumination (regurgitation and reingestion) in captive lowland gorillas (Lukas, 1999) bar-biting and sham chewing in sows (Rushen, 1984) and tongue rolling in cows (Wiepkema et al., 1987).

In horses, stereotypic behaviors can be classified as oral or locomotor in nature (Dodman et al., 2005). Locomotor stereotypies include weaving (a lateral rocking movement of the head, neck and forelimbs), pawing (repetitively striking the ground with a forefoot), and head bobbing (a repetitive up and down movement of the head) (Kiley-Worthington, 1983; Mills et al., 2005). Oral stereotypies include cribbing, wind sucking, and wood chewing, which involves the use of incisors to remove pieces of wood, which are not swallowed (Dodman et al., 2005; Mills et al., 2005). The occurrence of any of these behaviors is thought to reduce the performance of the animal (Kiley-Worthington, 1983), either because the animal expends energy to perform the behavior or the behavior is injurious to the animal (Houpt and McDonnell, 1993; McGreevy et al., 2001).

Before progressing with a review of cribbing, some clarification about terminology must be made. Historically, crib-biting, wind-sucking and aerophagia are used synonymously (Hayes, 1968; McGreevy et al., 1995b). Crib-biting involves the placement of the upper incisors on a horizontal surface, which is often preceded by licking of the surface (McGreevy et al., 1995b). The horse then flexes the ventral neck muscles and rocks backwards, causing the larynx to retract caudally. Air then passes through the cricopharynx and into the cranial esophagus, which is thought to be the cause of the characteristic grunting noise (Lebelt et al., 1998; McGreevy et al.,

1995b). Wind-sucking is defined in a similar manner, except the wind-sucking horse does not place its incisors on a fixed surface (Hayes, 1968). The fate of the air that passes into the cranial esophagus is a source of much confusion among scientists and laymen, with many believing these behaviors have a component of aerophagia, or swallowing air (Hayes, 1968; Houpt 1986; Dodman et al., 1987). However, endoscopic studies of cribbing horses performed by McGreevy et al. (1995b) showed that little to no air passes on to the stomach. Instead the majority of air returns to the pharynx before being expelled.

Cribbing has been observed in domestic and captive equines, but does not appear to be present in free-ranging, wild horses. Dodman et al. (2005) recently reported on the prevalence of stereotypic behaviors, including cribbing, in formerly feral mustangs. Data collected on 243 mustangs, found only six (2.4%) displayed some form of stereotypic behavior and three (1.2%) were known to crib (Dodman et al., 2005). Cribbing has been reported in 2.1-13.3% of domestic horses, depending on breed, location, use and management (Albright et al., 2009; Bachmann et al., 2003b; Luescher et al., 1998; McGreevy et al., 1995c; Mills et al., 2005; Vecchiotti and Galanti, 1986; Wickens and Heleski, 2010). Horses may spend anywhere from 10.4-64.7% of their day cribbing (Bachmann et al., 2003b; Nicol et al., 2002). It is important to note that these values are generally determined by scan samples, which may not offer an accurate representation of the daily time budget spent cribbing.

B. *Adverse Effects*

Crib-biting may seem like nothing more than an annoyance for horse owners, however there are adverse effects associated with performance of the behavior. Repeated stress placed on incisor teeth inevitably leads to premature erosion. Excessive erosion could lead to difficulty grasping feedstuffs or dropping food from the mouth (Fraser, 1992). It has been suggested that tooth wear could cause food to be poorly masticated, resulting in decreased digestibility of feed (McGreevy et al., 2001), but this is unlikely as cribbing causes damage to incisors and not molars, which are responsible for mastication. Cribbing horses often are thought of as unthrifty or "hard keepers" (Hayes, 1968). McGreevy et al. (2001) determined that cribbing horses displayed a trend for less weight gain compared to horses that did not perform the behavior, however their study was too short to make accurate conclusions about weight change in long-term cribbing horses. McGreevy et al. (2001) did point out that the horses in their study were not

regularly exercised which could have resulted in conservation of energy and weight gain that may not be seen in cribbing horses that are worked. Difficulty maintaining weight could be attributed to the propensity of cribbing horses to spend a large portion of their time budget cribbing at the expense of time eating and resting as compared to non-cribbing horses (McGreevy et al., 2001).

Due to continuous flexion when pulling, hypertrophy of neck musculature of habitual cribbers has been noted (Dodman et al., 1987). This feature could make the animal aesthetically unpleasing to owners and could affect the animal's usefulness as a riding horse. Furthermore, the pulling phase of cribbing causes significant damage to equine facilities. Cribbing can lead to loose fence posts and broken boards, as well as damage to feed and water buckets, hay rings and gates.

Anecdotal reports have suggested that cribbing horses have an increased risk of developing flatulent colic (Dodman et al., 1987). This likely stems from the erroneous belief that these animals swallow air. Archer et al. (2004; 2008) showed an apparent association between crib-biting behavior and epiploic foramen entrapment, a type of colic. The retrospective study found 68% of horses (13 of 19) that presented for epiploic foramen entrapment had a history of cribbing (Archer et al., 2004). It was hypothesized that cribbing causes a negative intra-abdominal pressure, which results in the development of epiploic foramen entrapment. Conversely, they could not rule out the possibility that cribbing and epiploic foramen entrapment were the result of the same predisposing factors.

Often cribbing horses are sold, slaughtered or euthanized, despite still being useful. In part, this is the result of the behavior being associated with medical problems and facility damage. It is also likely due to the belief that the behavior is contagious among horses, which is held by 46% of horse owners (McBride and Long, 2001). McBride and Long (2001) found that 32% of riding schools would not allow a horse displaying a stereotypic behavior on the property. Furthermore, many owners believe cribbing decreases a horse's value by as much as 45% (Prince 1987; McBride and Long, 2001).

C. *Prevention*

The adverse effects associated with cribbing have led horse owners and researchers to explore a wide variety of methods to prevent or punish cribbing. Of surveyed owners that allow

stereotypic horses on their property, 74% will attempt to physically prevent the behavior (McBride and Long, 2001). There are anecdotal reports of cribbing prevention by housing horses in specially designed stalls with rolling bars or no ledges, yet after three years in these stalls the animals resumed the behavior upon removal from the stalls (Hayes, 1968; McGreevy and Nicol, 1998a). Another method of preventing the incisor placement involved in the cribbing behavior is the use of a bucket muzzle, however this method may also interfere with prehension of food (McGreevy and Nicol, 1998a).

Prevention and punishment of the pressing phase of cribbing has been attempted and includes taste deterrents painted on cribbing substrates, shock collars and electric fencing. Electronic shock collars developed for dog training can be used to punish the act of pressing the incisors on the cribbing substrate (Houpt and McDonnell, 1993). The shock must be applied after pressing has occurred, but before neck flexion in order to be most effective (McGreevy and Nicol, 1998a). Use of shock collars requires constant observation by owners, and results are inconsistent and transient. Only 15% (9 of 60) of cribbing horses were considered "cured" of the behavior after treatment with a shock collar and one third of those eventually required further treatment with a shock collar to remain non-cribbing (McGreevy and Nicol, 1998a; Owen, 1982). Metal inserts between the upper incisors have been utilized to prevent cribbing, but this method could result in unthriftiness due to prevention of foraging and eating (Magner, 1903; McGreevy and Nicol, 1998a).

The neck muscles involved in the performance of cribbing include the sternomandibularis, sternothyrohyoideus and omohyoideus muscles (Delacalle et al., 2002). As early as 1872, these muscles have been manipulated surgically to prevent performance of cribbing. Segments of these muscles have been surgically removed in an attempt to alleviate the behavior, but this resulted in substantial disfigurement (Forssel, 1926). Bilateral neurectomy of the ventral branches of the spinal accessory nerves, which innervate the sternomandibularis muscle, prevent disfiguration due to myectomy (Bruere, 1966). However, transection of the nerves without transection of the muscles produced inferior results compared to neurectomy and myectomy combined (Delacalle et al., 2002; Hamm, 1977). Another surgical method to prevent cribbing is permanent buccal fistulation, which prevents the horse from keeping the mouth airtight (Karlander et al., 1965). However, the mouth is open when cribbing, so the efficacy of this procedure is debated (McGreevy and Nicol, 1998a). Acupuncture also has been investigated

as a potential treatment option (Kuussaari, 1983) but requires further investigation as to its effectiveness.

Oral inserts that impinge on the soft palate, metal inserts between the incisors and surgery raise welfare concerns, as these procedures are painful and unnecessary. Furthermore, the risks from surgery and general anesthesia, such as myopathies, neuropathies, and trauma during recovery, seem to outweigh any potential benefits of these procedures.

Studies investigating the role of beta-endorphins in the development of cribbing and other stereotyped behaviors have led to administration of opiod antagonists to stop the behavior. Dodman et al. (1987) found that one-time intravenous or intramuscular administration of an opioid antagonist, such as naloxone, nalmefene and diprenorphine, would eliminate the behavior for anywhere from 20 minutes to four hours. If these drugs were administered as an infusion, cribbing could be halted for as long as a week. Animals resumed cribbing once infusions were discontinued, and throughout administration some adverse effects were observed, including sedation. Continuous administration of injectable medications is not practical for horse owners due to cost and time constraints. Additionally, whether these pharmaceuticals work by making the behavior less rewarding, by inducing sedation, or by eliminating frustration caused by environmental shortcomings is unclear (McGreevy and Nicol, 1998a).

Environmental enrichment has been used in other species to diminish performance of stereotypic behaviors, but this only proved effective for as long as the enrichment remained novel to the animals (Kiley-Worthington, 1983). Furthermore, too much enrichment also can result in performance of stereotypic behaviors. In chimpanzees, boredom (low stimulation) and excitement (high stimulation) resulted in displays of stereotypic behaviors (Kiley-Worthington, 1983). Oral operant demand systems have been suggested as a method of cribbing prevention in horses (Houpt, 1982; Winskill et al., 1995). Small amounts of the animal's daily concentrate ration are released when the horse activates a trigger or moves a device holding the food. These systems cause alterations in the daily time budget, including an increase in foraging behavior, however, these studies did not utilize stereotypic horses. Additionally, exhaustion of the food may cause frustration making it likely the animal will resume performance of the stereotypic behavior.

A survey of owners found that 40% of farms allowing stereotypic horses on property kept these horses isolated from other animals (McBride and Long, 2001), presumably to prevent non-

stereotypic animals from learning the stereotypic behavior. However, social isolation has been reported to induce a stress response in horses (Alexander et al., 1988; Bagshaw et al., 1994; Lansade et al., 2008), and stereotypic behaviors seem to occur with greater frequency under stressful conditions (Mason, 1991). Horses and other animals allowed social contact with conspecifics have been shown to have a lower prevalence of abnormal behavior (Redbo, 1990; McGreevy et al., 1995a; Bachmann et al., 2003a).

Perhaps the most common method of cribbing prevention is the use of a cribbing collar or strap. This device punishes and prevents neck flexion (Hayes, 1968). In general, the collar consists of a leather strap with or without a hinged, metal curve to allow room for the trachea. Many modifications of the basic design exist, including metal spikes and leather spurs that are meant to increase discomfort when the neck is flexed (Owen, 1982). The collar is placed around the neck at the throatlatch and is tightened to the point where neck flexion cannot be performed. Many animals will adapt to the constriction and then resume cribbing, causing the collar to be further tightened, which eventually could lead to trauma (Hatchen, 1995). Use of a cribbing collar has been shown to induce a stress response (McBride and Cuddleford, 2001), however this was determined by measurement of cortisol concentrations, which often yield contradictory results. Additionally, while the cribbing collar initially may reduce performance of the behavior, horses have been shown to crib at higher than normal frequencies once the device is removed (McGreevy and Nicol, 1998b).

Attempts to prevent performance of cribbing in established crib-biting horses are often transient or unsuccessful. Thwarted horses may develop the ability to crib on the bodies of conspecifics or their own limbs (McGreevy and Nicol, 1998a). The ingenuity of horses in satisfying their drive to crib-bite prevails over most attempts to prevent or punish the behavior. Furthermore, should performance of cribbing be a response to some as yet unknown underlying cause, prevention could be considered detrimental and inhumane.

D. *Causes*

In horses (Bachmann et al., 2003b), as with other animals, development of stereotypic behaviors is thought to be a result of stress. A genetic predisposition to an increased susceptibility to stress might explain why stereotypic behaviors are not seen in all domestic horses. Mason (1991) suggests that stereotypic behaviors function to reduce the stress caused by

intense management and unnatural environments, but experimental prevention of stereotypic behaviors in other species showed no evidence that performance of stereotypic behaviors resulted in reduced stress (Schouten et al., 1991; Terlouw et al., 1991; Wurbel and Stauffacher, 1996). Because cortisol concentrations are normally elevated during stress (Larsson et al., 1979), McGreevy and Nicol (1998c) proposed that cribbing horses should exhibit lower cortisol concentrations should cribbing function to reduce stress. Instead, they found that cortisol concentrations fell within the normal range for all horses used in their study. Cribbing horses had higher baseline cortisol concentrations compared to non-cribbing horses, however a significant increase in cortisol concentration was seen when cribbing horses were prevented from cribbing and eating. They suggest cribbing horses may have even higher cortisol concentrations when cribbing behavior develops, and cortisol concentrations would gradually decrease with time spent performing the behavior. Additional studies have been performed to determine differences of behavioral and physiologic indicators of stress, including cortisol concentrations and heart rate, in stereotypic and normal horses at baseline and in the presence of an acute stressor (Bachmann et al., 2003a; Lebelt et al., 1998; Pell and McGreevy, 1999; Minero et al., 1999). Results of these studies are often contradicting, preventing definitive interpretation of results. McGreevy and Nicol (1998a) are careful to point out that prevention of stereotypic behaviors may be stressful, even though their performance does not function to reduce stress, and a rise in physiologic stress parameters would be anticipated with prevention of these behaviors.

Multiple surveys and epidemiological studies have been conducted which identified several management factors such as decreased turn out, decreased amounts of forage, increased amounts of concentrates and increased social isolation, that may be associated with an increased risk of developing crib-biting behavior. For example, diets high in concentrates and low in forage are related to the performance of abnormal behaviors. A prospective study found Thoroughbred foals were four times more likely to develop cribbing behavior if fed concentrates at weaning (Waters et al., 2002). Weaning is known to be stressful for young horses (McCall et al., 1985), and the way weaning is accomplished may factor in development of stereotypies. Parker et al. (2008) determined that natural weaning, which occurs at an older foal age than is typical in many management situations and at the discretion of the mare, resulted in a decreased risk of developing stereotypic behaviors. Two-thirds of horses unnaturally weaned that eventually develop crib-biting behavior did so within one month of weaning, with a median age

of onset being 20 weeks (Waters et al., 2002). Of the foals used in this study, 70% were weaned between four and six months of age, while only 2% were weaned at greater than eight months of age.

Studies have found that as time spent inside a stall decreases, performance of stereotypic behaviors, including cribbing, decreases (McGreevy et al., 1995a; Wickens and Heleski, 2010). Parker et al. (2008) reported weaned foals kept on grass pasture were less likely to develop abnormal behavior than those kept in stalls. However, placing established adult crib-biting horses on pasture does not completely extinguish performance of the behavior. This could be interpreted to mean that crib-biting is not the result of frustrated foraging behavior or could simply indicate the behavior becomes habitual with no apparent cause for performance.

In addition to pasture access, social contact with other horses has been shown to reduce the probability of cribbing behavior (Bachmann et al., 2003b; Wickens and Heleski, 2010) while isolation often results in increased risk of developing abnormal behaviors as a response to social deprivation (Mills et al., 2005). Visser et al. (2008) found that 22% of 2-year-old horses housed in isolation displayed crib-biting behavior compared to no stereotypic behaviors in horses that were paired. Horses are herd animals, so lack of social contact can be expected to elicit a stress response. If cribbing does function to reduce stress, the results of the above studies would not be entirely unexpected.

Intensive management, or any environment different from that to which an animal is adapted, could result in redirected behaviors. Wild horses spend 60-70% of their time grazing low quality forage (Henderson, 2007), whereas nutritional advances have led to the feeding of high concentrate, low forage diets in domesticated horses. The decreased amount of time it takes a horse to consume a concentrate diet compared to continuous grazing or hay consumption would not adequately satisfy their natural drive to forage. Abnormal behaviors might then serve to satisfy their drive to perform innate behaviors. This has led some to suggest that the presence of stereotypic behaviors is the result of a sub-optimal environment (Mason, 1991). A survey performed by Dodman et al. (2005) found that 2.4% of captive mustangs performed stereotypic behaviors, with 1.2% being crib-biting horses. This percentage is significantly lower than in studies reporting prevalence of crib-biting in domestic horse populations, indicating that crib-biting is not simply a redirected foraging behavior because formerly feral horses would be expected to possess a strong foraging drive. Schoenecker and Heller (2000) found that wild-

caught bank voles (*Clethrionomys glareolus*) placed in sub-optimal environments rarely display the stereotypic behaviors seen in their progeny placed in the same environments. It seems that younger animals are more influenced by their environment than older animals and that captive conditions are more likely to result in development of stereotypic behaviors in younger animals (Dodman et al., 2005). Another possibility is the existence of a critical period when these animals are young. Older, wild caught animals went through the critical period prior to capture and were therefore unaffected by the change to a stressful environment. Their offspring would be exposed to the stressful environment during that critical period, resulting in stereotypic behaviors.

Heritability of stereotyped behaviors, including cribbing, is highly debated especially since the behavior seems to occur more commonly in some breeds compared to others. A survey of horse owners revealed that 25% believed stereotyped behaviors to be inherited (McBride and Long, 2001). A pedigree study of crib-biting horses revealed that 8 of 14 cribbing horses had one or more relatives that also displayed the behavior (Vecchiotti and Galanti, 1986). It was further established that the behavior appeared more frequently in these family lines than in the general population. More recent studies have found stereotypies occur more frequently in Thoroughbred horses, which seems to further support the hypothesis of heritability of stereotypies (Bachmann et al., 2003b), but this also could be explained by exposure to stressful environments, i.e. the racetrack. Owner surveys found that 13.3% had witnessed dam and foal pairs performing stereotypic behaviors together (McBride and Long, 2001). However, the dam and foal pairs would be subject to the same management strategies, so it is unclear whether displays of stereotypies are the result of surroundings or genetics. While heritability of the actual behavior is less likely, other genetic factors, such as an increased susceptibility to stress (Luescher et al., 1991), may contribute to the development of stereotypic behaviors.

Many horse owners believe cribbing is learned by watching other cribbing horses. A survey of stable owners found that 46% believed abnormal behaviors were learned, and 40% would isolate stereotypic animals to prevent others from adopting these behaviors (McBride and Long, 2001). Albright et al. (2009) found that almost 49% of owners believed crib-biting to be learned by observation. According to a survey performed by Wickens and Heleski (2010), 7% of owners reported that a previously normal animal began cribbing after the arrival of another crib-biting horse. Some researchers suggest that foals learn to crib by watching their dams, and, as

such, foals of crib-biting mares should be removed from the dam as soon as possible (Kiley-Worthington, 1983). Furthermore, exposure to stereotypic adult animals results in development of the behavior in young animals more commonly than in other adult animals (Houpt, 1986; Houpt and McDonnell, 1993). Despite these findings, researchers have found no evidence to suggest that horses are capable of learning a task by observing a more experienced individual perform the task (Baer et al., 1983). During research performed by Clegg et al. (2008), non-stereotypic animals that were housed in contact with animals performing stereotypies did not begin performing abnormal behaviors. Luescher et al. (1991) suggest animals that begin performing the behavior after exposure to a stereotypic animal were pre-disposed or already near the threshold of expressing that behavior. This is known as social facilitation, defined as expression of a latent, pre-established behavior after exposure to another individual performing the behavior (Mills et al., 2005).

Willard et al. (1977) found that horses fed only concentrates had significantly lower cecal pH and spent significant amounts of time wood chewing compared to those fed hay diets. Wood chewing behavior decreased when the cecum of horses was infused with sodium carbonate (Willard et al., 1977). More recent studies found lower fecal pH in horses fed increasing proportions of concentrate diets (Johnson et al., 1998). Those horses with lower fecal pH also performed more abnormal oral behaviors, not including crib-biting, compared to horses on hay diets. Concentrate diets were then supplemented with virginiamycin, an antibiotic that suppresses lactic acid production in the hindgut, and performance of abnormal behaviors decreased. A more recent study found that virginiamycin supplementation had no effect on the performance of cribbing suggesting hindgut acidosis may not be involved in maintenance of the behavior in established cribbing horses (Freire et al., 2008).

Evidence for a relationship between cribbing and foregut acidosis or irritation also has been found. Gastric ulceration could be the result of feed deprivation because it allows for greater exposure of gastric mucosa to acidic conditions. Horses fasted for 24 hours were found to have a greater degree of gastric ulceration compared to those that were given hay (Murray and Eichorn, 1996). Compared to hay, consumption of sweet feed caused increased amounts of gastrin to be released, which resulted in prolonged gastric acid secretion (Smyth et al., 1989). Bicarbonate in saliva and buffering ability of feed appear to facilitate neutralization of gastric acidity. Salivation in horses is a result of chewing or other forms of oral stimulation (Alexander

and Hickson, 1970). Compared to a forage diet, concentrates require less time to consume. This led Nicol (1999) to suggest that cribbing is a functional behavior, which serves to increase saliva flow and protect against gastric irritation. Moeller et al. (2008) found that cribbing horses produced similar saliva weights overall compared to non-cribbing horses, but had less saliva at the initial sampling time than non cribbers. When cribbing was prevented, decreased saliva production was observed (Moeller et al., 2008). Nicol et al. (2002) performed endoscopic exams on foals and found that 60% of cribbing foals suffer from gastric ulceration, compared with only 20% of non-cribbing foals. Cribbing foals also had greater degree of ulceration and inflammation than non-cribbing foals. Addition of antacid to the foals' diets resulted in decreased cribbing behavior as well as improvement in the condition of the gastric mucosa. Based on these findings some have suggested that cribbing and colic are the result of altered gastrointestinal physiology, instead of one being the causative agent of the other. Cribbing behavior would manifest in response to anything that results in visceral pain, which would include gastric ulceration (Mills et al., 2005). However, personal observations revealed that known cribbing horses hospitalized for colic did not crib until the colic resolved.

It appears that as stereotypic behaviors, including crib-biting, develop they become increasingly disconnected from the original eliciting stimulus (Kiley-Worthington, 1983; Mason, 1993; Ridley and Baker, 1982). This disconnect could be the result of habituation or possibly self-reinforcement of the behavior due to the release of beta-endorphins. It has been suggested that endogenous opioid release facilitates and reinforces stereotypic behaviors (Dodman et al., 1987; Gillham et al., 1994) and administration of opioid antagonists has resulted in decreased performance of cribbing (Dodman et al., 1987). However, studies seeking to determine plasma beta-endorphin concentrations in cribbing and non-cribbing horses have yielded conflicting results (Gillham et al., 1994; Lebelt et al., 1998; Pell and McGreevy, 1999).

Feed delivery may function either to elicit or to positively reinforce cribbing behavior. Cribbing frequency increases in the horses before and after feeding (Brown et al., 2007; Kusunose, 1992). Shifting feeding from a 06:00 h and 18:00 h feeding schedule to a 00:00 h and 12:00 h schedule causes a shift in times of peak cribbing frequency to coincide with the altered feeding schedule (Brown et al., 2007). This research cannot clearly identify whether cribbing is a response to the feed delivery or the result of restricted feeding. Survey studies found that offering feed four times daily was positively correlated with performance of stereotypic

behaviors (Bachmann et al., 2003a). Increasing meal frequency while maintaining the amount of feed given caused a decrease in other stereotypic behaviors such as stall-walking and wood-chewing, however this study did not report on crib-biting as a separate activity (Cooper et al., 2005). Use of foraging devices have been shown to prolong consumption of concentrate feeds (Winskill et al., 1995), however further studies would be needed to determine what effect, if any, this would have on cribbing behavior.

The objective of the present study was to determine effects of ad libitum concentrate feeding on crib-biting activity. Based on studies that found an increase in cribbing frequency associated with consumption of concentrate feed (McGreevy et al., 1995b) and delivery of concentrate rations (Brown et al., 2007), we hypothesized that crib-biting could increase in response to ad libitum feeding of concentrates. Conversely, if delivery of concentrate feeds positively reinforces cribbing behavior, flooding the horse with concentrates could reduce the reinforcing value of these feeds in which case a decrease in cribbing frequency could be expected. Additionally, if crib-biting is a result of frustrated foraging behavior (Mason, 1991), ad libitum feeding would reduce this frustration decreasing cribbing behavior Because horses used in this study were routinely maintained on pasture with free choice hay for at least 24 months prior to the start of the study, we did not expect to see a decrease in cribbing frequency due to reducing foraging frustration.

III. MATERIALS AND METHODS

A. *Animals and Observations*

Horses used in this experiment were maintained at the Auburn University Horse Unit according to a protocol that had been approved by the Institutional Animal Care and Use Committee. This study used 10 mature geldings of Thoroughbred or Quarter Horse breeding with a history of cribbing for at least 24 months prior to the start of the study. Horses were randomly assigned to either ad libitum feeding (n=5) or control (n=5) groups. The horses were maintained on adjoining Bermuda grass (*Cynodon dactylon*) pastures and offered free choice Bermuda grass hay, water and trace mineralized salt. Horses were subjected to their routine exercise regimen for the duration of the study. The study lasted from June to December of 2007.

For 60 days prior to the start of the study, all horses received a baseline ration of 1.8 kg of a commercially available pelleted concentrate fed twice daily (Compete, Nutrena, Minneapolis, MN 55440, USA; 14% CP, 7% fat, 8% CF, 28% starch, 6% sugar). Control horses remained on this amount throughout the study. Feed for ad libitum horses was gradually increased over a two week period to approximately 3.6 kg concentrate delivered four times daily, for a total of approximately 14.4 kg concentrate per horse per day. Ad libitum horses remained on the ad libitum feeding schedule for 102 days. For 33 days following the ad libitum feeding period (d 103-136) ad libitum horses were fed 0.9 kg of concentrate four times daily, which represented their baseline amount of concentrate divided among the four feed delivery times. During the final 33 days (d 137-170), ad libitum horses were returned to baseline concentrate ration of 1.8 kg twice daily. Table 1 shows the frequency of feeding and the amount of feed delivered for both control and ad libitum horses throughout the study.

Table 1. Feeding frequency and amount of feed delivered per horse for control and ad libitum horses

DAY	CONTROL	AD LIBITUM
-60-0	1.8 kg twice daily	1.8 kg twice daily
1-102	1.8 kg twice daily	3.6 kg four times daily
103-136	1.8 kg twice daily	0.9 kg four times daily
137-170	1.8 kg twice daily	1.8 kg twice daily

Concentrate feed was delivered at approximately 07:00 and 17:00 h for both the ad libitum and control horses. When being fed four times daily, concentrate feed was delivered to the ad libitum group at approximately 12:00 and 00:00 h in addition to their normal times. Feed was divided between rubber tub feeders in each pasture (seven feed tubs for each group of five horses) and horses were free to move among the feed tubs during concentrate feed consumption throughout the day.

Cribbing stations were constructed in each pasture and were readily visible to the observation area, which was approximately 10 m and 15 m away for the control and ad libitum groups respectively. The cribbing stations were constructed of pine boards, each measuring approximately 5 X 15 cm and 4.9 m in length. The boards were attached at each end to 15 cm diameter wooden posts at a height of approximately 1.1 m. Electric fencing was placed at the top of the pasture fence to prevent performance of cribbing on locations other than the cribbing stations or the metal hay rings. The metal hay ring in the control pasture was approximately 20 m away from the observation area, and the metal hay ring in the ad libitum pasture was approximately 25 m from the observation area. Horses were allowed to acclimate to their pastures for two weeks before any observations were started.

Observations were made at day 0 and day 170 when all horses were fed 1.8 kg of concentrate feed twice daily. Observations of horses during ad libitum feeding periods occurred at day 28, 66, and 102. Observations also were performed on day 136, when ad libitum horses were receiving 0.9 kg concentrate four times daily. All six observational periods (d 0, 28, 66, 102, 136, and 170) lasted a full 24 hours.

During observational periods, number of crib bites, number of crib bouts and duration of crib bouts were recorded. A crib bite was defined as the placement of the horses' incisors on a surface with an attempt to pull back. A crib bout began with the first crib bite after some other

activity and ended when the horse stopped cribbing and began a new activity. Night-time observations were facilitated by scheduling observations during periods of the full moon and by attaching 15 cm chemiluminescence "glow" sticks (Coleman Illumistick Light Stick, The Coleman Co., Inc., Wichita, Kansas, USA) to a plastic identification neck collar worn by each horse. Horses readily accepted and seemed to ignore the glow sticks, which hung at their throatlatches. Pen lights were turned on briefly when recording data, but otherwise artificial lighting was not used in night-time observations.

B. *Statistical Analysis of the Experiment*

One control horse was removed from the study at d 75 due to a lameness problem. Number of crib bites, crib bouts and duration of crib bouts for each horse at the baseline (d 0) observation period was included as a covariate to adjust each group to a common starting point and to reduce residual variation. A q-q plot of the residuals (SAS Inst., Inc. Cary, North Carolina, USA) was used to check for normality of the data, and no major departures from normality were observed for number of crib bites or crib bout duration. One observation was identified as an outlier during this procedure and excluded from the final analyses. These data were analyzed using the MIXED procedure (SAS Inst. Inc., Cary, North Carolina, USA) for repeated measures using horse as subject and observation day as the repeated variable. Number of crib bouts was analyzed as a Poisson distribution using the GLIMMIX procedure (SAS INST., Inc. Cary, North Carolina, USA) for repeated measures using horse as subject and observation day as the repeated variable. Pre-planned contrasts were used to test differences in crib bites, bouts and bout durations for control vs. ad libitum horses during the ad libitum feeding period (d 1-102.) The first contrast averaged values obtained on d 28, 66 and 102 to compare control and ad libitum horses to determine if ad libitum feeding affected cribbing behavior. A second contrast compared the cribbing behavior in the control and ad libitum horses when ad libitum horses were fed 0.9 kg concentrate four times daily (d 103-136). This contrast utilized behavioral data collected on d 136 and was intended to differentiate effects due to either feed amount or the four times daily feed delivery schedule. A final contrast compared cribbing behavior in control and ad libitum horses when ad libitum horses were returned to the basal diet (1.8 kg concentrate twice daily; d 137-170). This contrast was designed to determine if there were any residual effects from the ad libitum feeding period.

IV. RESULTS AND DISCUSSION

A. *Results*

Total bout duration for each horse was used to determine the percentage of the daily time budget used to perform cribbing behavior throughout the study**.** Control horses displayed consistent amounts of time spent cribbing throughout the study (Figure 1). For control horses, percentage of daily time budget spent cribbing ranged from 8-44%. With the exception of one horse (Falcon) which spent a large portion of the day alternating between hay consumption and cribbing on the metal hay ring, the control horses spent an average of approximately 17% of their day on cribbing activity. Figure 2 shows the percentage of time spent cribbing for ad libitum fed horses. Ad libitum horses began the project with a slightly lower portion of their daily time budget devoted to cribbing (6-32%). Ad libitum fed horses showed a significant decrease in the amount of time spent cribbing during the ad libitum feeding periods (d 28-102) with two of the horses (Dutch and Flashy) spending little to no time cribbing during d 66 and 102. Gradual increases are seen in the amount of time spent cribbing as the ad libitum fed horses are returned to baseline feeding levels (d 136 and 170).

Figure 1. Percentage of daily time budget spent cribbing for control horses

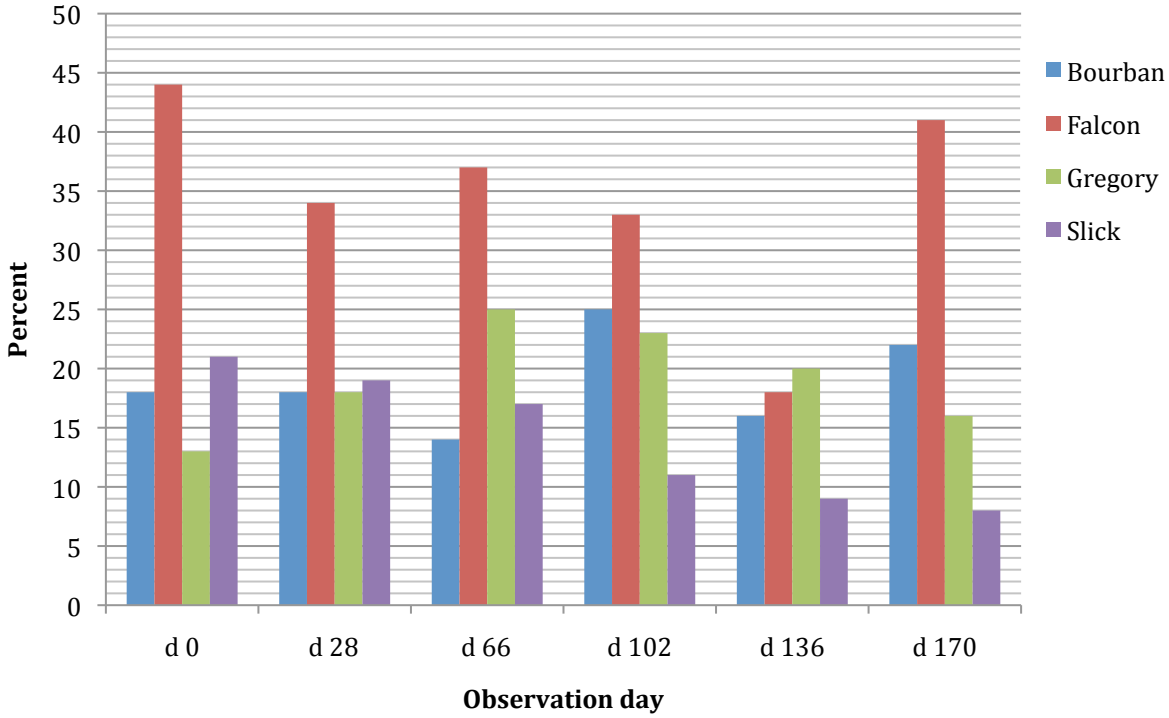
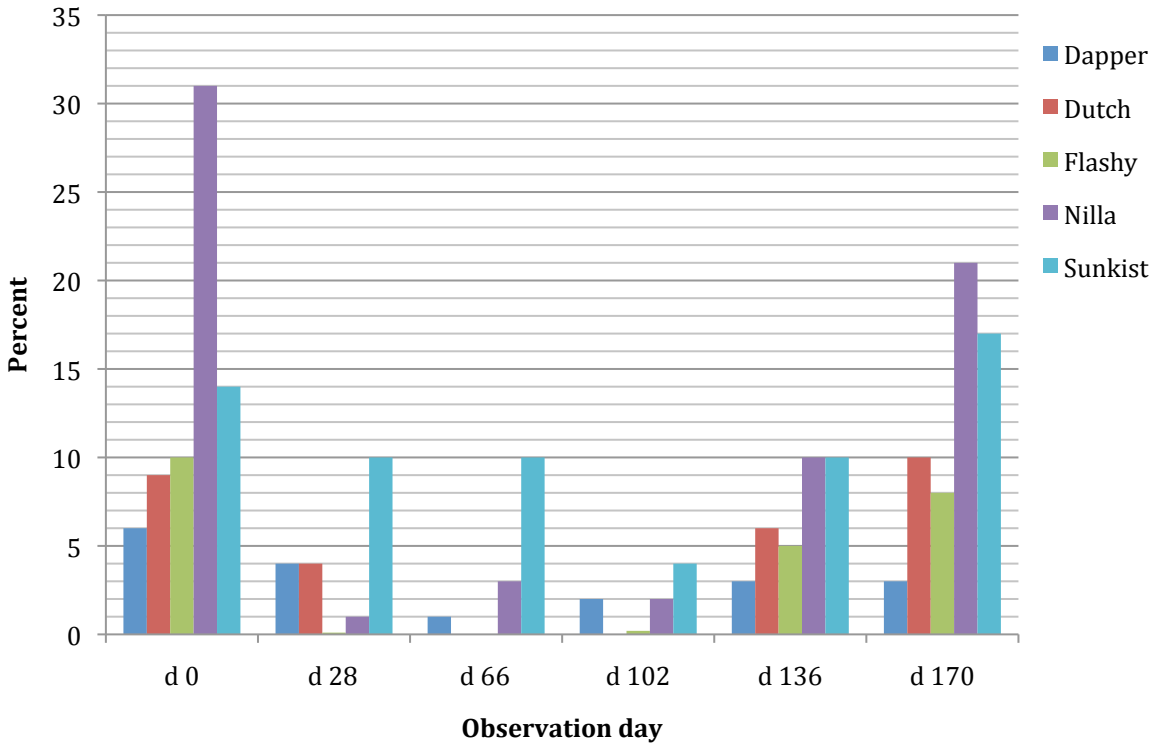


Figure 2. Percentage of daily time budget spent cribbing for ad libitum horses



Figures 3, 4, and 5 show mean bout duration, number of crib bites and number of crib bouts for control horses at each observation day and illustrate the relative consistency of cribbing behavior of the individual control horses during the study period. Mean bout duration, number of crib bites and number of crib bouts for ad libitum fed horses at each obsevation day can be found in the appendix (Appendices 4, 5 and 6, p. liv).

Figure 3. Mean bout duration (s) for control horses at each observation day

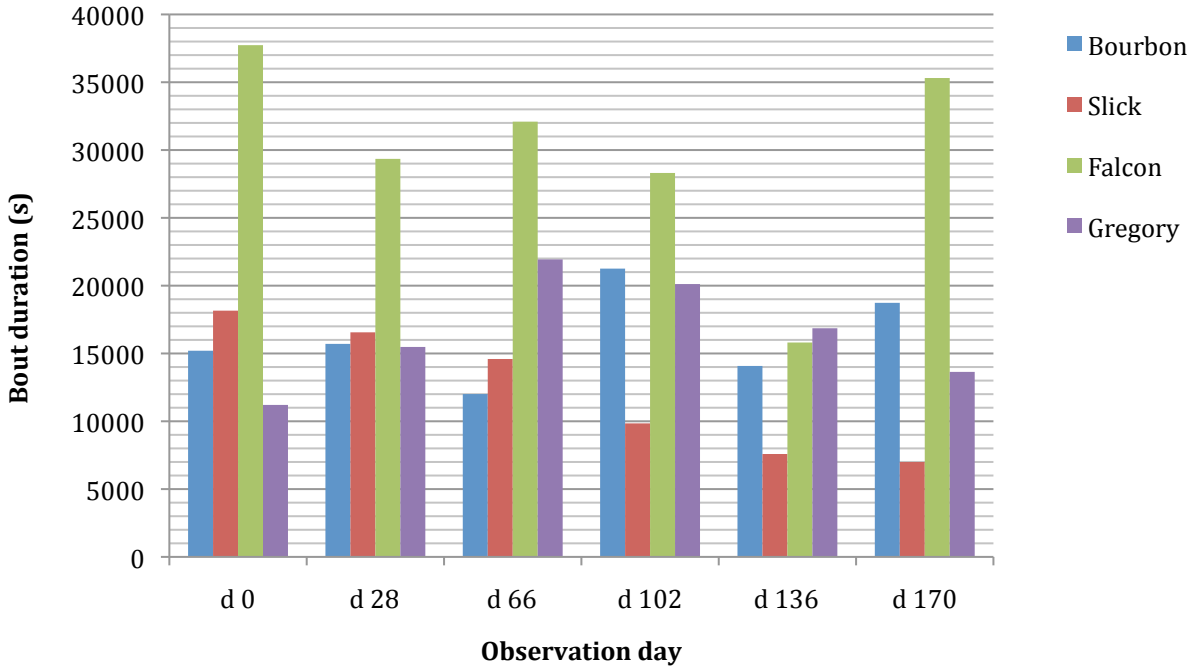


Figure 4. Number of crib bites for control horses at each observation day

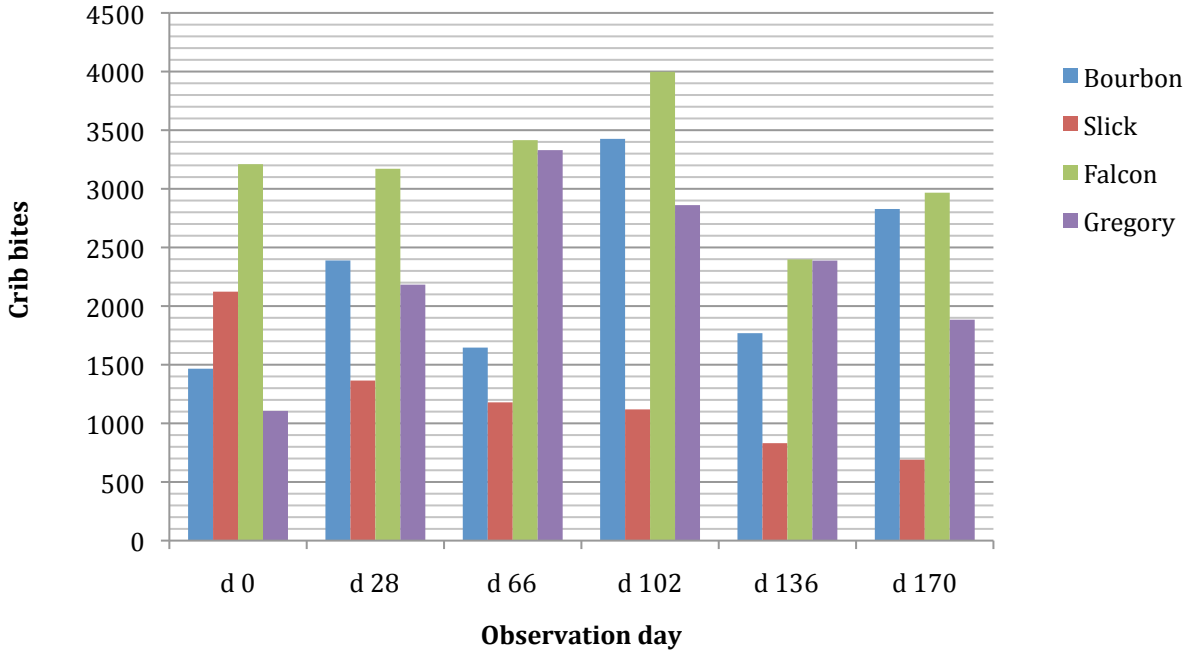
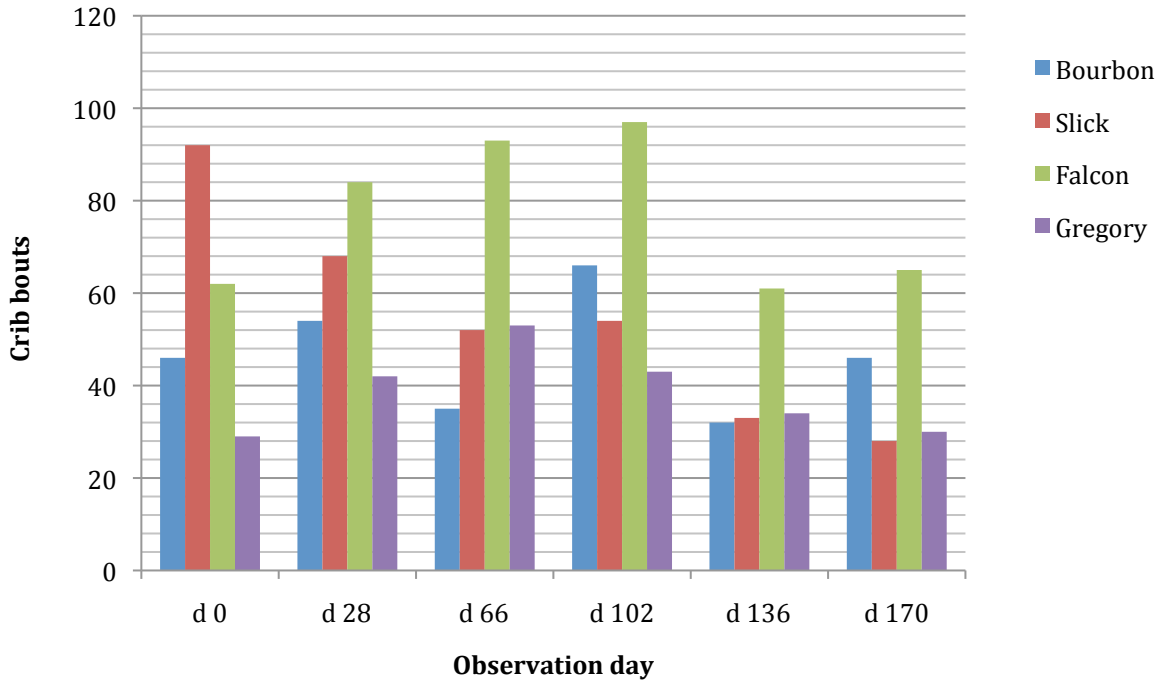


Figure 5. Number of crib bouts for control horses at each observation day



Mean bout duration, number of crib bites and number of crib bouts were calculated for control and ad libitum horses during the baseline feeding period (Figures 6, 7, and 8). During

baseline feeding, similar levels and times of cribbing frequency are seen for both control and ad libitum fed horses. Peaks are seen around feed delivery as well as around times of high activity on the farm.

Figure 6. Mean number of crib bites for control and ad libitum horses during baseline observations (d 0)

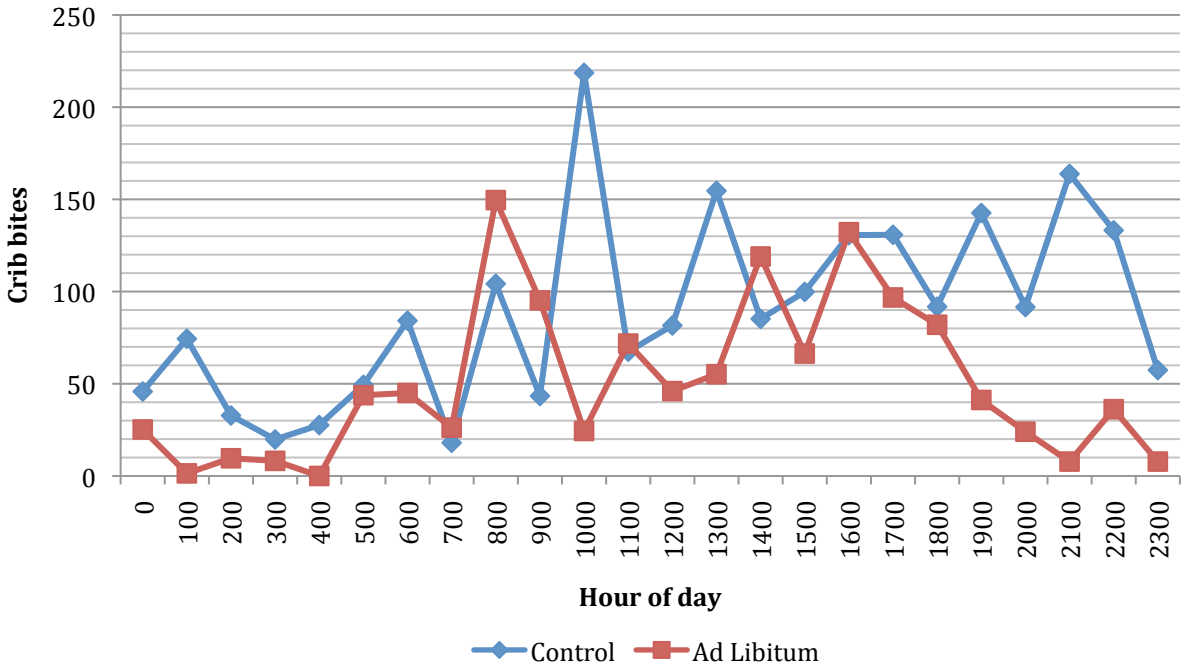


Figure 7. Mean bout duration (s) for control and ad libitum horses during baseline observations (d 0)

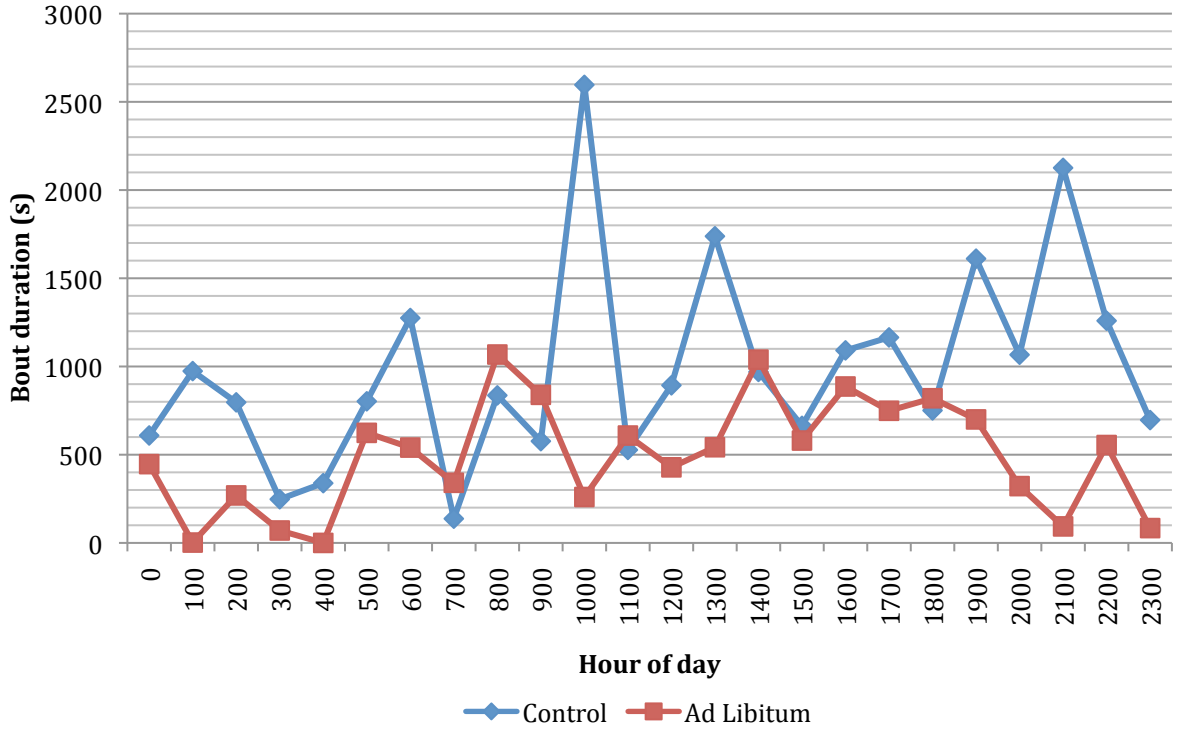
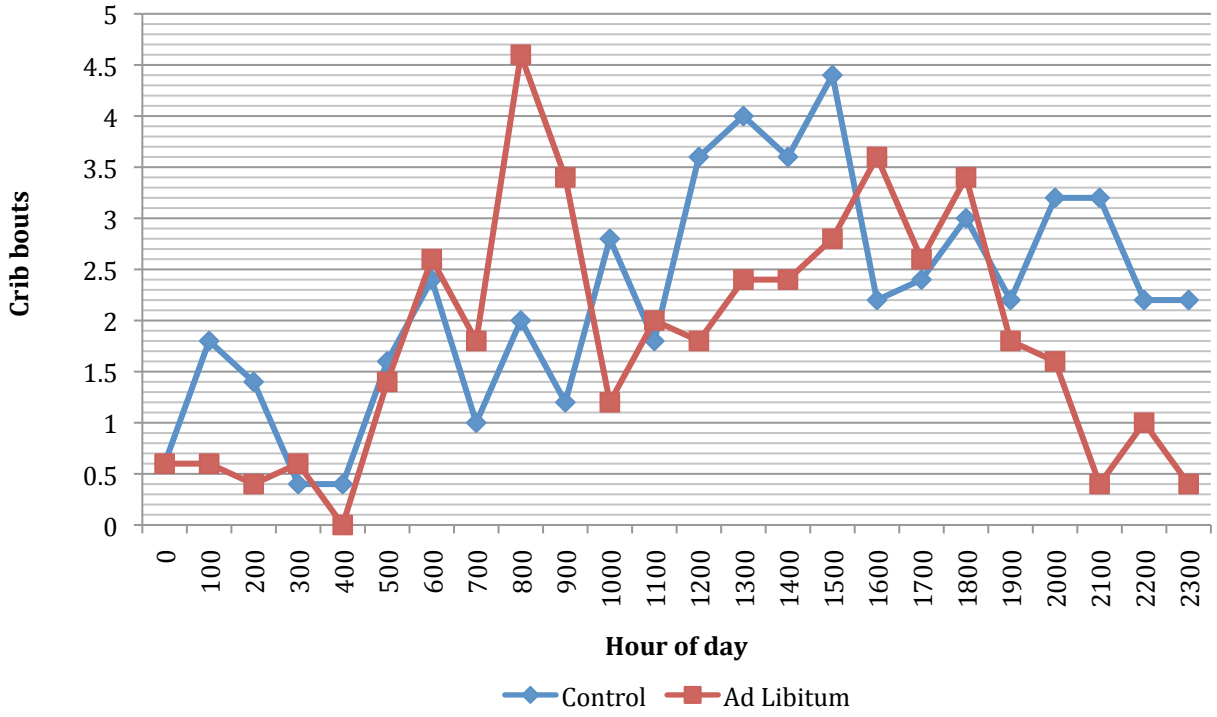


Figure 8. Mean number of crib bouts for control and ad libitum horses during baseline observations (d 0)



Figures 9, 10 and 11 show mean bout duration, number of crib bites and number of crib bouts during the ad libitum feeding period (d 1-102). During ad libitum feeding periods, peaks in cribbing activity in the ad libitum fed horses are seen immediately before and after concentrate feed delivery times (approximately 07:00, 12:00, 18:00 and 23:00 h). Figure 10 illustrates that the peaks in cribbing activity seen in the ad libitum horses at 12:00 and 23:00 h are not mirrored in the control horses. Peaks seen in the control horses coincide with their normal feeding times (07:00 and 18:00 h) and their overall cribbing frequency remains higher throughout the day than the ad libitum fed horses.

Figure 9. Mean bout duration (s) for control and ad libitum horses during ad libitum feeding (d 1-102)

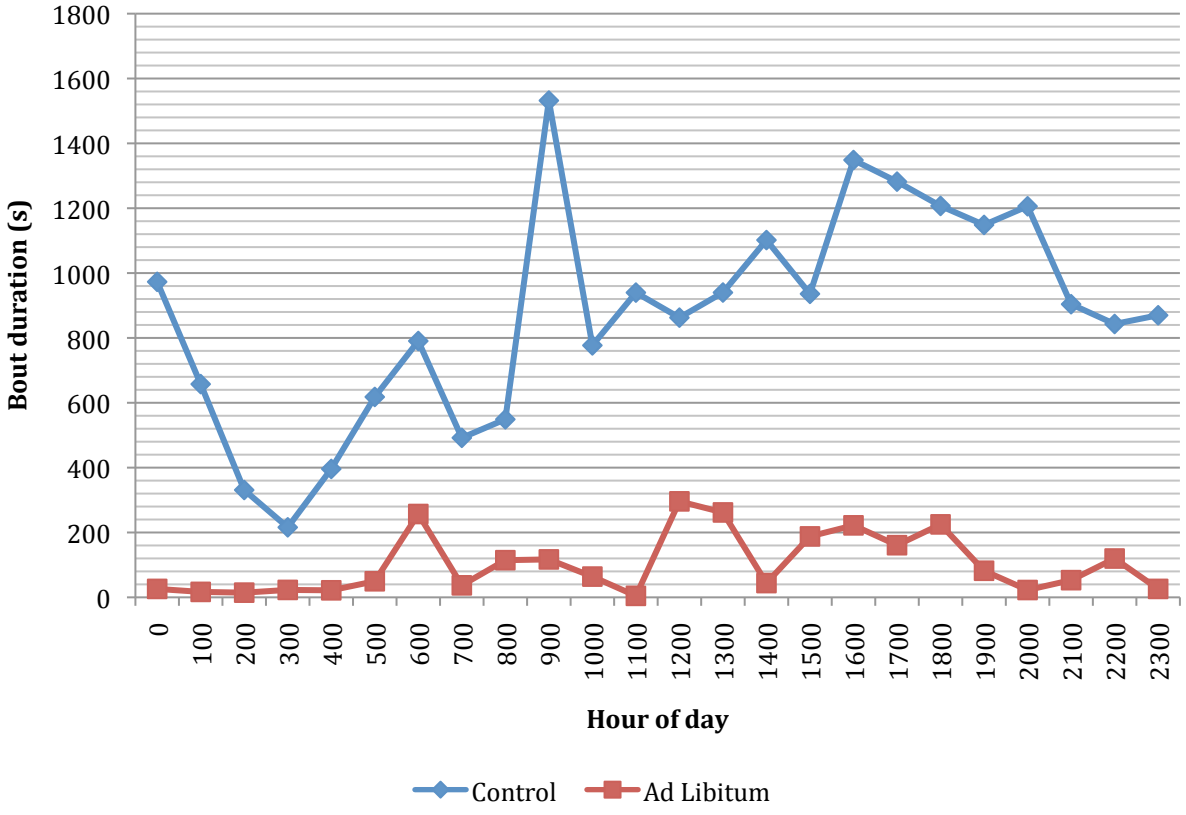


Figure 10. Mean number of crib bites for control and ad libitum horses during ad libitum feeding (d 1-102)

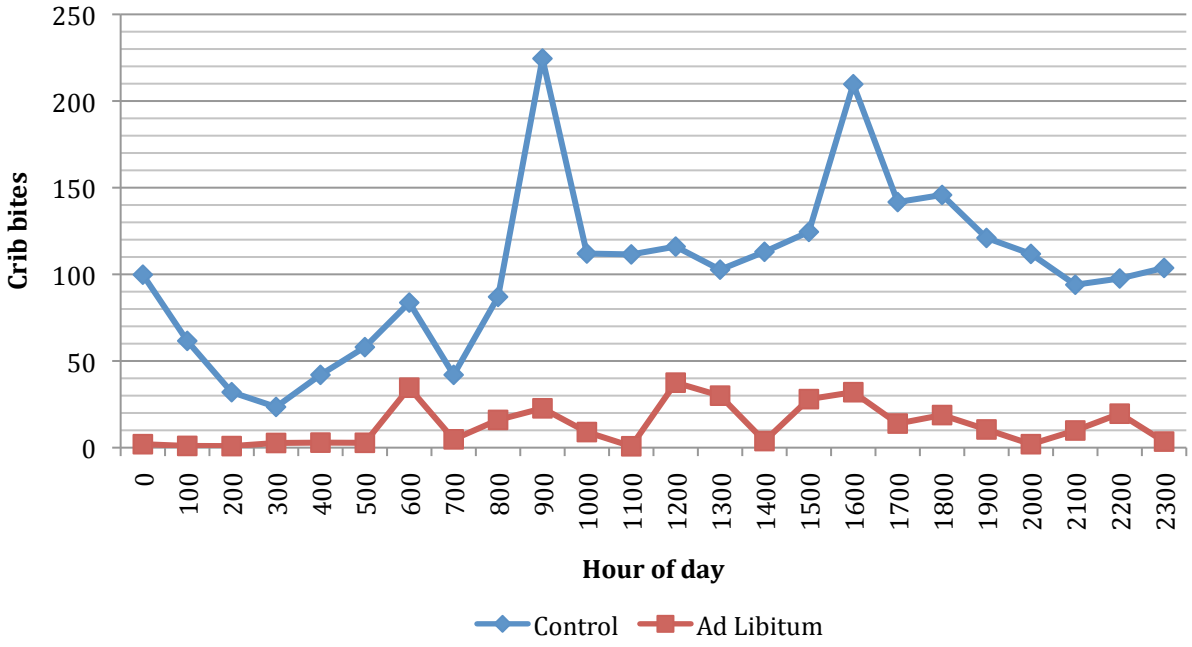
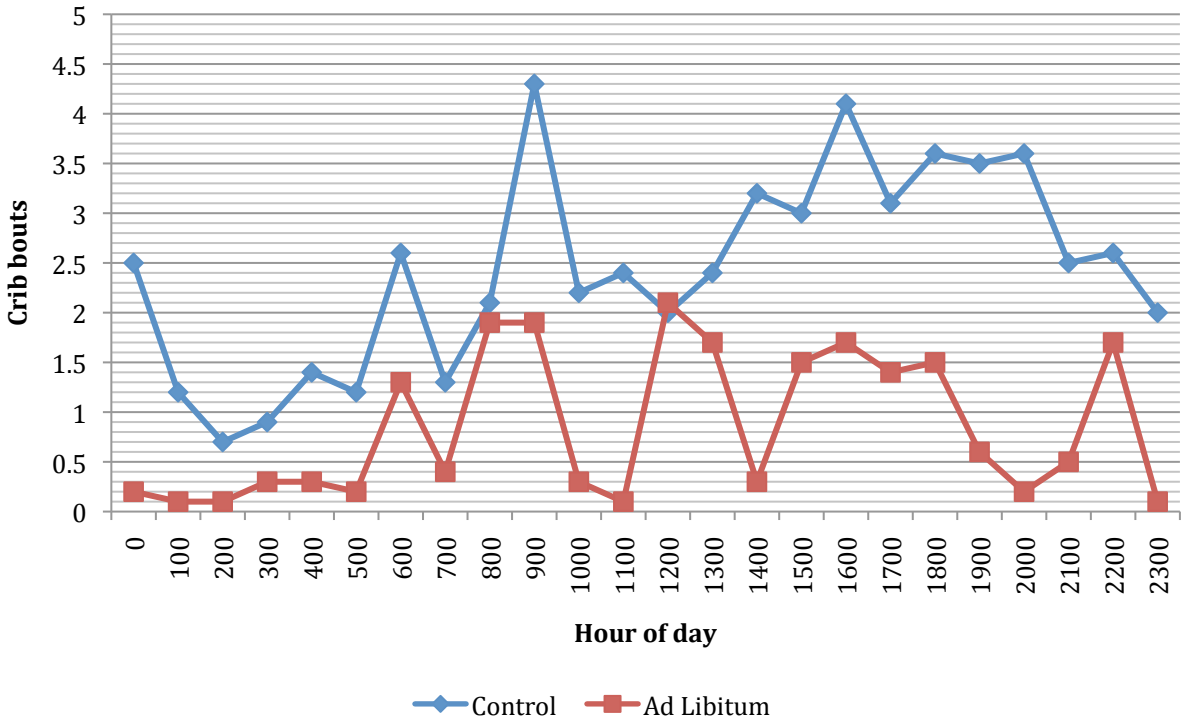


Figure 11. Mean number of crib bouts for control and ad libitum horses during ad libitum feeding (d 1-102)



Figures 12, 13 and 14 show mean bout duration, number of crib bites and number of crib bouts for control and ad libitum fed horses when concentrate feed for the ad libitum fed horses was reduced to 0.9 kg of concentrate delivered four times daily (d 136). During this time, peaks in cribbing activity in the ad libitum fed horses are still evident immediately before and after concentrate feed delivery times (approximately 07:00, 12:00, 18:00 and 23:00 h). These figures show increases in the cribbing frequency of ad libitum fed horses during this period compared to the ad libitum feeding period. Peaks seen in the control horses coincide with their normal feeding times (07:00 and 18:00 h) and their overall cribbing frequency remains higher throughout the day than the ad libitum fed horses.

Figure 12. Mean bout duration (s) for control and ad libitum horses when ad libitum horses were fed 0.9 kg concentrate four times daily (d 103-136)

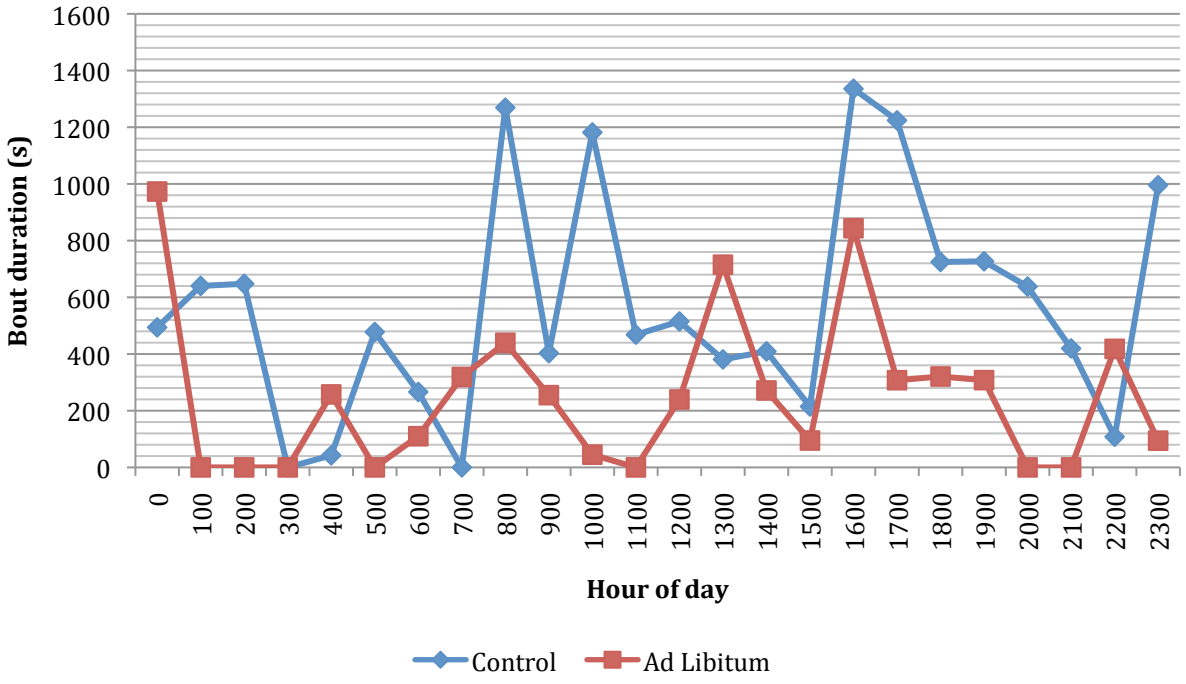


Figure 13. Mean number of crib bites for control and ad libitum horses when ad libitum horses were fed 0.9 kg concentrate four times daily (d 103-136)

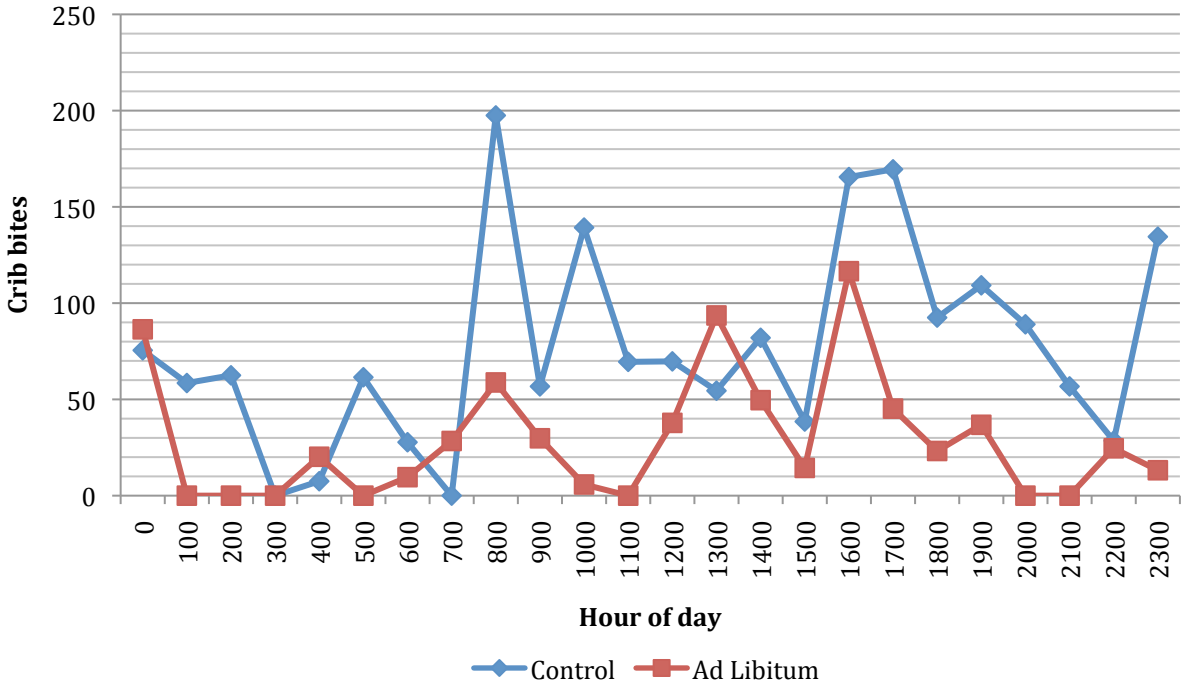
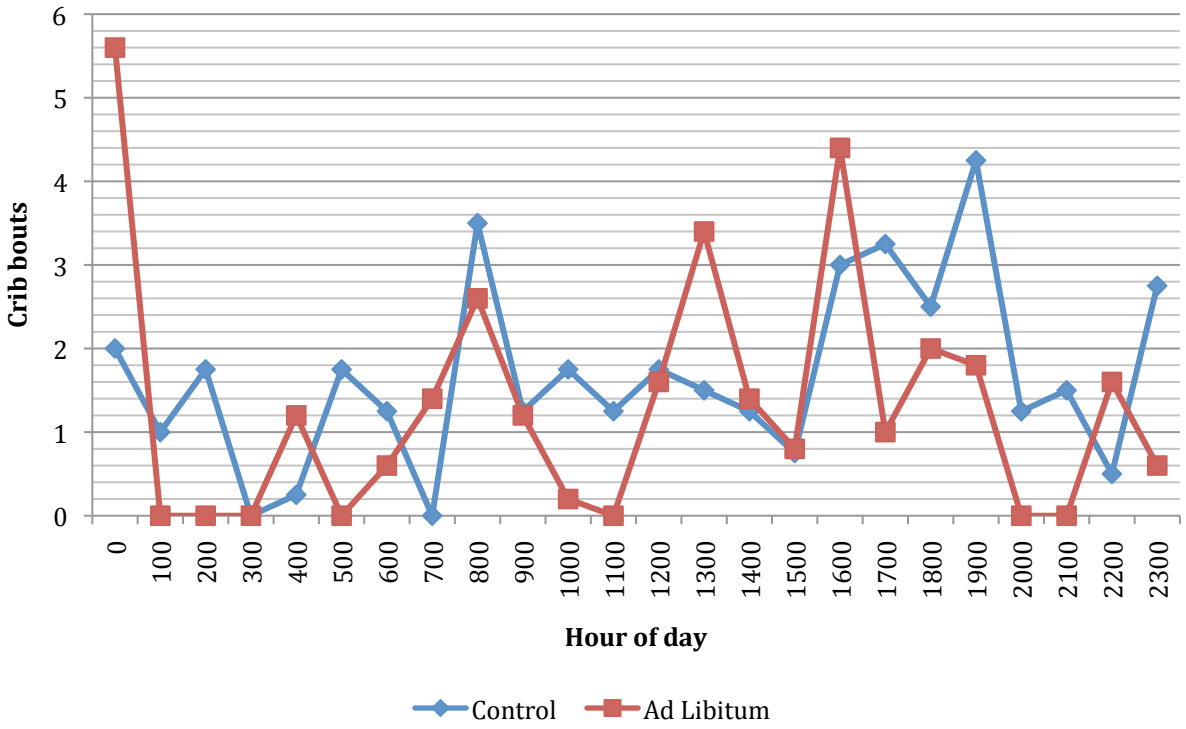


Figure 14. Mean number of crib bouts for control and ad libitum horses when ad libitum horses were fed 0.9 kg concentrate four times daily (d 103-136)



Mean bout duration, number of crib bites and number of crib bouts were calculated for control and ad libitum horses when ad libitum fed horses were returned to baseline feeding (Figures 15, 16, and 17). Similar levels and times of cribbing frequency are seen for both control and ad libitum fed horses. Peaks are seen around feed delivery as well as around times of high activity on the farm.

Figure 15. Mean bout duration (s) for control and ad libitum horses when ad libitum horses returned to baseline feeding (1.8 kg concentrate two times daily, d 137-170)

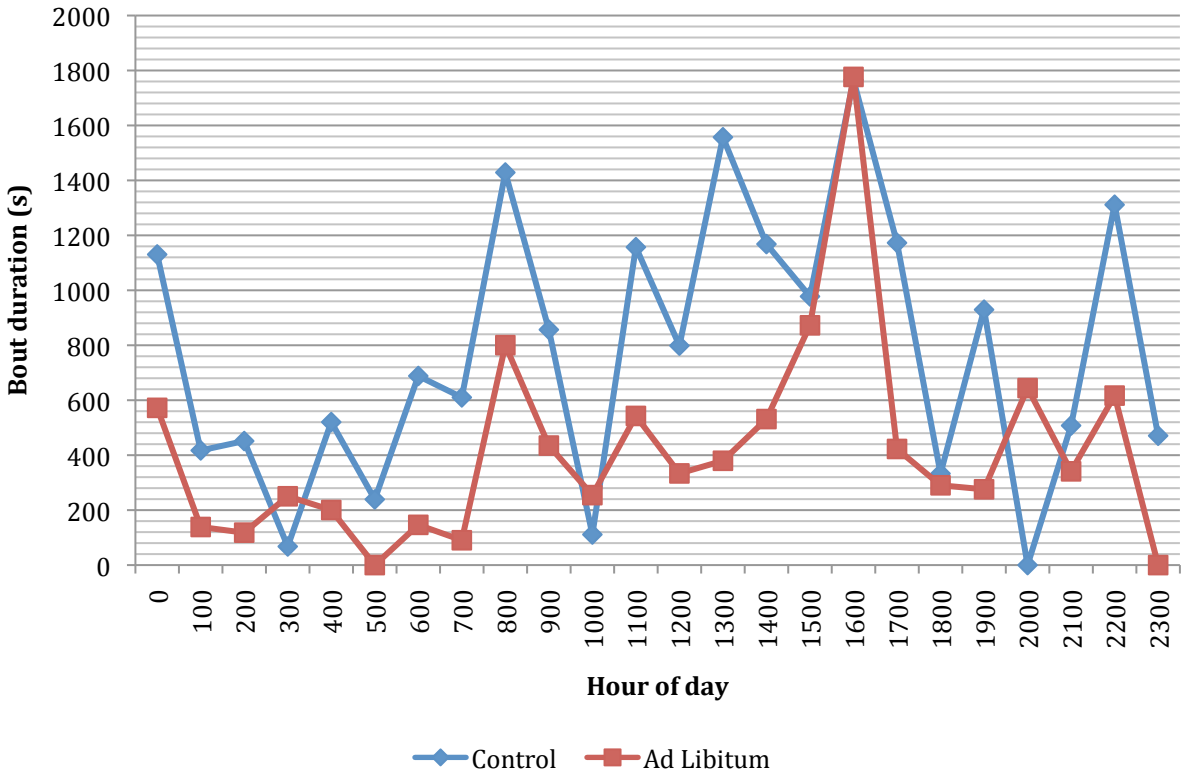


Figure 16. Mean number of crib bites for control and ad libitum horses when ad libitum horses returned to baseline feeding (1.8 kg concentrate two times daily, d 137-170)

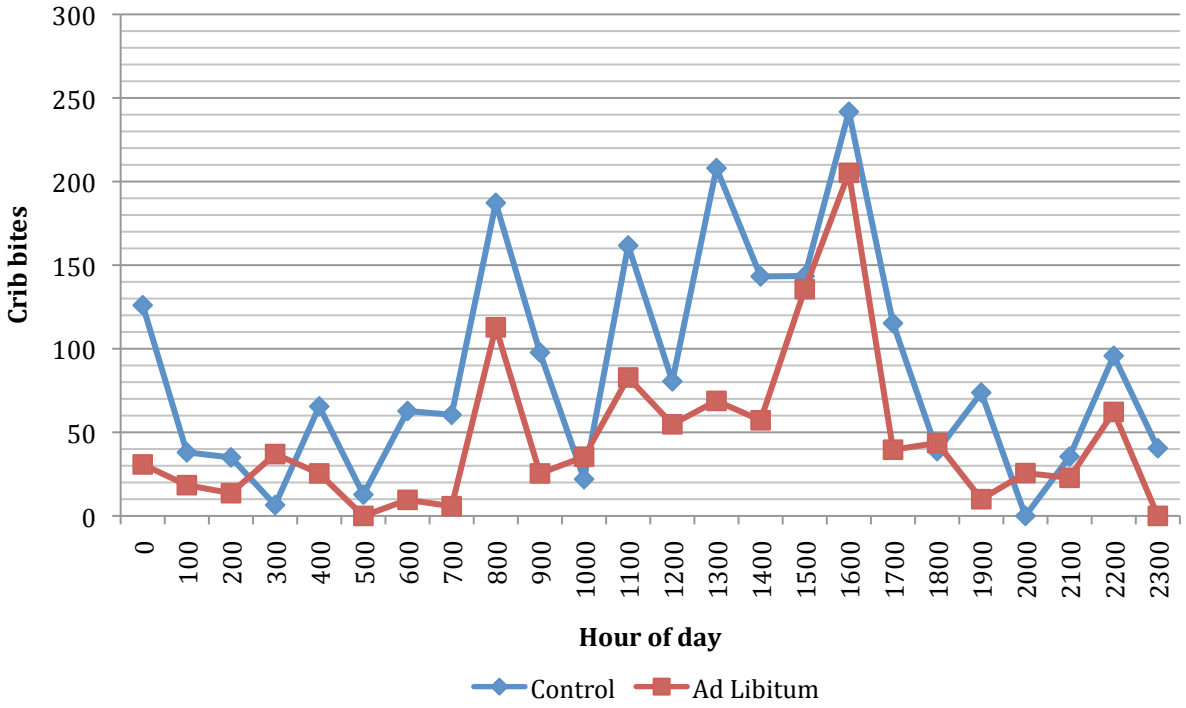
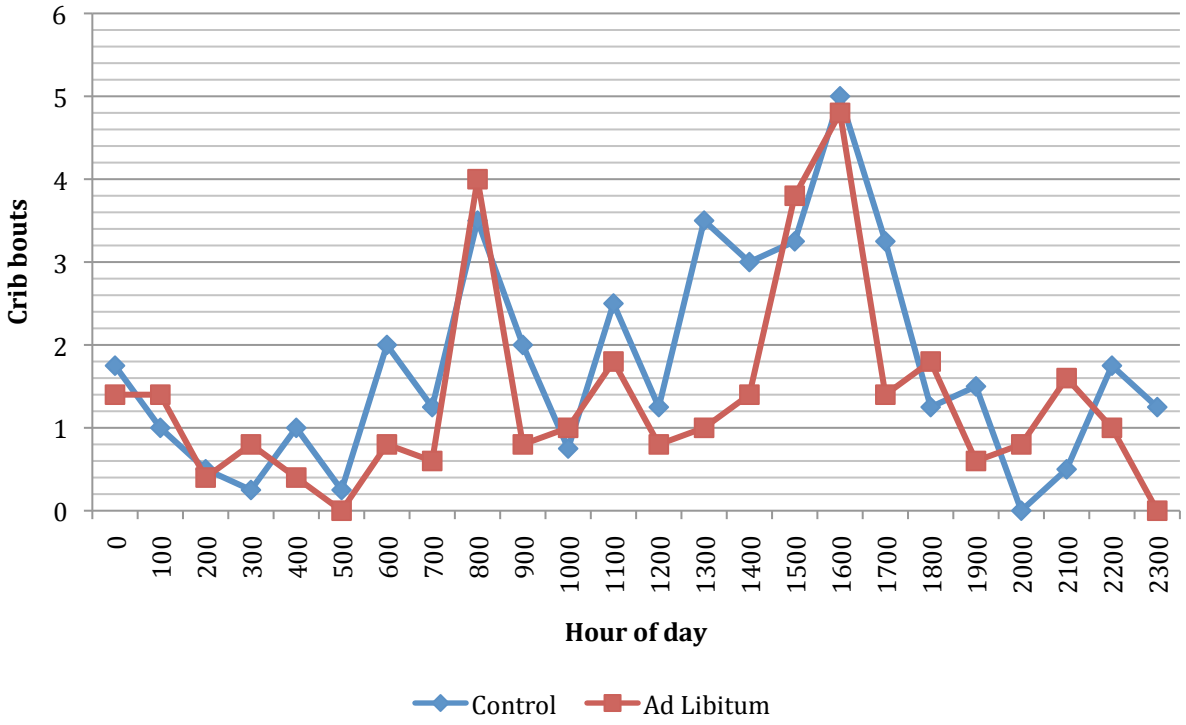


Figure 17. Mean number of crib bouts for control and ad libitum horses when ad libitum horses returned to baseline feeding (1.8 kg concentrate two times daily, d 137-170)



i. *Crib Bites*

Number of crib bites for an individual horse during a 24 h observation period ranged from 0 to 3998 bites. Mean number of crib bites for ad libitum fed and control horses are shown in Table 2. Although not statistically significant at all end points, control horses exhibited numerically greater cribbing activity than ad libitum horses at all end points. It is unclear whether this occurred due to chance or whether this indicates residual effect of ad libitum feeding which was not detectable due to lack of power. Because of the small sample size, baseline cribbing values (d 0) were included as covariates in an attempt to account for any disproportionate assignment of horses to groups. There was a significant treatment by observation day interaction ($P < 0.001$) in number of crib bites, which was expected due to the design of the experiment. In both groups of horses, differences from baseline values increased with each successive observation day during the ad libitum feeding period. Control horses increased in crib bites over the three observation days and ad libitum horses decreased in crib bites over the same days. Ad libitum fed horses increased in number of crib bites when switched to baseline amounts of feed delivered four times daily (d 103-136) and when they were returned to baseline feeding level and times (d 137-170). Number of crib bites for control horses decreased during these two observation days compared to their values during the ad libitum feeding period.

Table 2. Least square means and standard errors of total crib bites, crib bout duration, and bouts for ad libitum fed and control horses during each observation day

	Observation Day				
	Ad Libitum Feeding			0.9 kg 4X daily	1.8 kg 2X daily
	28	66	102	136	170
Control					
bites	2186 ± 353	2216 ± 353	2730 ± 365	1725 ± 365	1971 ± 365
bout duration (s)	18357 ± 2395	18876 ± 2395	18669 ± 2539	12370 ± 2539	17457 ± 2539
bouts	54.2 ± 16.6	45.9 ± 14.1	54.1 ± 17.4	33.5 ± 10.9	34.9 ± 10.9
Ad libitum					
bites	556 ± 344	305 ± 418	233 ± 344	774 ± 344	1202 ± 344
bout duration (s)	5434 ± 2331	5167 ± 2772	3355 ± 2331	8019 ± 2331	12041 ± 2331
bouts	18.7 ± 6.1	15.4 ± 5.8	7.7 ± 2.7	29.3 ± 9.3	30.9 ± 9.8

Results of pre-planned contrasts for crib bites are shown in Table 3. Contrasts comparing control and ad libitum horses during the ad libitum feeding period (d 1-102) indicate that ad libitum fed horses performed a mean of 2012 ± 495 fewer crib bites than control horses ($P < 0.004$). When the ad libitum horses were returned to the same total amount of concentrate feed as control horses divided over 4 feed delivery times (d 103-136), contrasts of crib bites for control and ad libitum fed horses showed no significant difference (952 ± 536, $P > 0.11$) between the treatments. Similarly, contrasts indicated no significant differences ($P > 0.18$) in number of crib bites between the treatments (769 ± 536) when the ad libitum fed horses were returned to baseline concentrate feeding schedule (d 137-170).

Table 3. Pre-planned contrasts for number of crib bites for ad libitum (AL) and control (C) horses for all observation days

	Estimate	Standard Error	df	t value	Pr > |t|
C vs AL d 28, 66 and 102	2012	495	7.8	4.1	0.004
C vs AL d 136	952	536	10.5	1.78	0.1
C vs AL d 170	769	536	10.5	1.44	0.2

ii. *Bout Duration*

Total crib bout durations during a 24 h observation ranged from 0 to 37734 s, and again there was a significant treatment by observation day interaction ($P > 0.01$), which was expected due to the design of the experiment. Crib bout duration for the ad libitum fed horses decreased from the beginning to the end of the ad libitum feeding period while control horses remained fairly steady in crib bout duration throughout this period (Table 2, p. 30). Bout duration of ad libitum horses increased when they were returned to baseline feed amounts delivered four times daily and when they were returned to baseline feed amounts and times. Control horses decreased in crib bout duration after the ad libitum feeding period. Contrasts of crib bout durations between control and ad libitum horses (Table 4) during the ad libitum feeding period revealed that ad libitum fed horses spent 13988 ± 2922 s less time cribbing than control horses ($P < 0.001$). Contrasts comparing crib bout duration between controls and ad libitum horses did not differ significantly when ad libitum horses were returned to the baseline amount of feed delivered four times daily ($P > 0.2$) or when they were returned to baseline feeding amount and schedule ($P > 0.1$).

Table 4. Pre-planned contrasts for crib bout duration (s) for ad libitum (AL) and control (C) horses for all observation days

	Estimate	Standard Error	df	t value	Pr > |t|
C vs AL d 28, 66 and 102	13988	2922	8.8	4.8	0.001
C vs AL d 136	4351	3571	17.4	1.2	0.2
C vs AL d 170	5416	3571	17.4	1.5	0.1

iii. *Number of Crib Bouts*

Number of crib bouts ranged from 0 to 105 during a 24 h observation period, and showed the expected treatment by observation day interaction ($P < 0.001$). Number of crib bouts for the ad libitum fed horses decreased during each observation day of the ad libitum feeding period, while control horses remained fairly steady in their crib bouts during this period. When ad libitum horses were switched to a normal amount of feed delivered four times daily and then to baseline feed amounts and delivery, their crib bouts increased (Table 2, p. 30). Control horse crib bouts decreased during these two feeding periods compared to their bouts during the ad libitum feeding period. Contrasts showed that ad libitum horses had 3.9 ± 1.6 fewer crib bouts than controls ($P > 0.01$) during observation days of the ad libitum feeding period (d 28, 66 and

102; Table 5). Contrasts comparing the number of crib bouts between ad libitum fed and control horses revealed no significant differences in the number of crib bouts after ad libitum horses were switched to normal feed amounts delivered four times daily (d 136, $P > 0.8$) or after they were returned to baseline feed amounts and times (d 170, $P > 0.8$).

Table 5. Pre-planned contrasts for number of crib bouts for ad libitum (AL) and control (C) horses for all observation days

	Estimate	Standard Error	df	t value	Pr > |t|
C vs AL d 28, 66 and 102	3.9	1.6	8.0	3.3	0.01
C vs AL d 136	1.1	0.5	11.3	0.3	0.8
C vs AL d 170	1.1	0.5	11.3	0.3	0.8

B. *Discussion*

Figures 1 and 2 (p. 18) show the percentage of the daily time budget spent cribbing for control and ad libitum fed horses. Based on baseline (d 0) values, horses in this study spent 6-44% of their daily (24 h) time budget cribbing, with control horses spending 13-44% of their time cribbing while ad libitum fed horses spent 6-30% of their time cribbing. During the ad libitum feeding period, percentage of time spent cribbing ranged from 0-10% of the day for ad libitum fed horses and 11-37% for control horses. Ad libitum horses cribbed 3-10% of the day while control horses cribbed 9-20% of the day when ad libitum horses were fed 0.9 kg concentrate feed four times daily. When returned to baseline feeding levels, control horses cribbed 8-41% of the day and versus 3-17% for ad libitum horses. Previous studies reporting on the time budget of cribbing horses have found that performance of the behavior can occupy 10.4-64.7% of the animals' time (Bachmann et al., 2003a; Nicol et al., 2002). It is important to note that these percentages are based on scan samples, and, in some cases, occur in novel environments, which may not offer accurate representations of daily activities. These previously reported time budget percentages are higher compared to d 0 values obtained during the present study. Alterations in cribbing activity may occur in response to external stimuli, e.g., diet, social structure, environment, seasonal changes, or simply sampling time, which could falsely elevate or reduce these values. Utilizing 24 h observations could serve to negate false values associated with random sampling. However, cribbing frequency may vary from day to day which may result in changes to cribbing values if a different 24 h sample was obtained. Regardless of which

sampling method is utilized, horses should be observed in areas to which they are accustomed to avoid alterations in cribbing frequency as a result of environmental changes.

Although horses were randomly assigned to treatment, baseline (d 0) values obtained in this study show that control horses displayed slightly more cribbing activity compared to ad libitum fed horses at the start of the study (Figure 6, p. 21). While this was negated in the study by utilizing the d 0 data as a covariate, it would be interesting to determine changes in cribbing frequency if control horses were offered ad libitum concentrate. Cribbing activity for individual animals in this study did fluctuate during the observation days (Figures 3, 4, and 5, p. 19 and 20). For example, cribbing activity for Bourbon alternately rises and falls throughout the study. This pattern is not seen in Slick whose cribbing behavior steadily decreased over the course of the study, or in Falcon who cribbed consistently during observation d 0, 28, 66, 102 and 170 but had a decrease in activity on d 136.

In the present study, forage availability and type were held constant by providing pasture and hay free choice, while concentrate amounts were varied. Results from the present study indicate that concentrate feed allowance does affect cribbing activity. With ad libitum concentrate, horses still performed cribbing behavior, but at a significantly reduced rate compared to control horses. It should be noted that while the ad libitum horses increased their cribbing behavior when ad libitum feeding was stopped, their cribbing behavior always remained lower than that of controls. Therefore, the significant treatment by observation day interactions observed in this study were due to changes in the magnitude of the cribbing behavior of the treatments rather than changes in ranks between control and ad libitum treatments. These changes in magnitude of cribbing behavior were anticipated if ad libitum feeding influenced cribbing because ad libitum horses were rotated off ad libitum feed delivery during the course of the experiment.

Though not reported as such, three stages of crib-biting behavior seem to emerge when reviewing causal mechanisms: the developmental stage, the maintenance stage and the ongoing stage. Each stage can be multi-factorial with a wide range of individual variation. Most research seems to agree that the developmental stage, the stage in which cribbing behavior first begins, is associated with negative, stressful stimuli such as early weaning, decreased forage, or prolonged confinement. Cribbing often is thought to be the result of frustrated and, therefore, redirected feeding behaviors. Free-ranging, feral horses spend as much as 70% of their time grazing low-

quality forage (Henderson, 2007). Research has suggested that increased turn out time and access to free choice hay may decrease the frequency of crib-biting (McGreevy et al., 1995a; Wickens and Heleski, 2010). Horses in this study were maintained on pasture and offered free choice hay and still cribbed, which seems to contradict those findings. However, the horses used were established cribbers, so it is still possible that decreased amounts of forage factored into the development but not the maintenance of the behavior.

The maintenance stage of development leads to an apparent disconnect from the original, eliciting stimulus. Continued expression of the behavior despite correction of various management factors associated with its development often is attributed to reinforcement of the behavior, i.e., concentrate feed delivery. Kusunose (1992) reported an increase in stereotypic behaviors associated with scheduled concentrate feeding times. Brown et al. (2007) found that cribbing frequency increases in the hours before and after concentrate meal delivery. Arousal and high activity levels that are often associated with delivery of daily ration were initially seen in the ad libitum fed horses during ad libitum feeding periods, but over time the horses seemed to develop a blasé attitude towards feed delivery. It is possible that ad libitum feeding thwarts the positive reinforcement that may be associated with less frequent delivery of concentrate feed. However, increased cribbing frequency was noted in the ad libitum fed horses at feed delivery times (0:00, 07:00, 12:00 and 17:00 h; Figure 10, p. 24), but this was less so than was previously seen on the d 0 observation period when feed delivery occurred at 07:00 and 17:00h. Control horses maintained usual arousal levels associated with concentrate feed delivery at 07:00 and 17:00 h throughout the duration of the study. It is interesting to note however, that despite being in full view of ad libitum fed horses, cribbing frequency in the control horses did not seem to change in the hours before and after 0:00 and 12:00 h feed delivery to ad libitum horses (Figure 10, p. 24).

The ongoing stage of cribbing refers to long-term, established crib-biting behavior. Previous research implicates negative, stressful stimuli, e.g., prolonged confinement or decreased forage consumption, in the development of cribbing behavior. If this is accepted as true, an increase in cribbing frequency would be expected with pain, a negative, stressful stimulus, however anecdotal reports suggest a decreased cribbing frequency in injured or post-operative cribbing horses. In a follow-up study to the present one, decreased cribbing frequency was seen in one control horse used in the present study when it was placed in a smaller paddock while

maintaining free choice access to hay, grass, water and fence-line contact with two other horses. It could be that environmental familiarity and contentment, or lack of stress, allow for ongoing performance of cribbing while negative, stressful stimuli diminish cribbing behavior in established cribbing horses. If this is true, the negative impact of ad libitum concentrate feeding (obesity) may be responsible for the decreased frequency of crib-biting seen in this study. Further research should be conducted to determine changes in cribbing frequency associated with both psychological stress (environmental changes) and physiological stress (pain).

Because horses in this study were group fed, there is no way to quantify the actual amount of food each individual horse consumed. Satiation of treatment horses can be assumed, however, because of the considerable weight gain noted in treatment horses and the presence of concentrate from the previous feed delivery in feed buckets at the succeeding feed delivery time. Satiety is just one of many factors that could be responsible for the decrease in cribbing as a result of ad libitum concentrate feeding. Rumination is a stereotypic behavior that involves the effortless regurgitation of stomach contents following meal consumption, without nausea or retching, then realimentation of the food. The behavior has been documented in captive lowland gorillas (Lukas, 1999) as well as human babies and mentally retarded individuals (Johnston, 1993). Even though horses are not capable of regurgitating, it is interesting to note the similarities between dietary treatment of rumination in humans and the results of this study. Slight increases in amount of food given did not decrease frequency of rumination, and in some cases actually increased rumination frequency. Continued increases in amount of food resulted in decreased performance of rumination, and once satiation levels were reached, ruminating often stopped completely. These lower levels of rumination were maintained as long as the satiation diet was maintained and would return to normal levels once satiation was discontinued. It was determined that increased caloric density, increased stomach distension, and increased oropharyngeal and esophageal stimulation produced with satiation diets were responsible for decreasing frequency of rumination (Johnston, 1993). Oropharyngeal and esophageal stimulation, and increased stomach distension are not likely contributing factors to the present study as all horses were maintained on free choice hay and pasture.

Studies investigating increased amounts of individual dietary components may prove beneficial in altering cribbing frequency. For example, could increasing the fat content of the diet alone result in decreased frequency of crib-biting behavior? Yurtman et al. (2002) found

that confined lambs given a high protein diet were more likely to display oral stereotyped behaviors than those given a lower protein diet. Parsons et al. (2005) found no change in cribbing behavior when diets of cribbing horses were supplemented with fat. Another study has been conducted examining the effects of a starch and sugar dietary supplement and a fat and fiber dietary supplement on normal behavior, reactivity and stress responses in weanling-aged horses (Nicol et al., 2005). The study found that horses receiving a fat and fiber dietary supplement were less distressed when confronted with novel, stressful stimuli, than those receiving a starch and sugar supplement.

Studies have implicated concentrate diets in the development of cribbing and other stereotypic behaviors (Gillham et al., 1994; Waters et al., 2002). These studies often restrict access to hay and forage, whereas horses in this study were maintained on pasture with free choice access to hay. Willard et al. (1977) found that cecal acidity was increased in horses fed only concentrates compared to those fed hay alone. It is possible the presence of hay in the cecum negated the acidic environment caused by concentrates, but further research would be needed to determine how the cecal environment changes in the face of both hay and concentrate feeds. It has been suggested that cribbing may function to correct altered gastrointestinal physiology, such as decreased gastric pH during times of food deprivation (Murray and Eichorn, 1996). Additionally, restricted feeding patterns have been shown to increase performance of stereotypic behaviors in other animals (Yurtman et al., 2002). Most horses are subjected to once or twice daily feeding of concentrates due to time constraints of the owner. Chewing produced by once or twice daily delivery of concentrates may not result in sufficient levels of saliva to buffer stomach contents. Mastication could be presumed to increase in the face of ad libitum feeding. It is not clear why ad libitum hay might produce lower levels of mastication or saliva compared to concentrates.

Ad libitum feeding of concentrate rations would be improbable for most horse owners due to time and cost constraints, and also due to the possible adverse effects associated with overfeeding. It was noted that ad libitum horses began this study with body condition scores of approximately 4 to 5 and ended the ad libitum feeding period with body condition scores of approximately 6 to 8 on the Henneke scale (Henneke et al., 1983). Obesity in horses can lead to serious health concerns such as equine metabolic syndrome, laminitis, joint stress, and exercise intolerance. Returning ad libitum horses to baseline rations delivered four times daily resulted in

increasing levels of cribbing activity. However, it is unclear if dividing the baseline ration into more feedings would affect cribbing behavior. Some research has been conducted investigating the effects of prolonged concentrate delivery by utilizing foraging devices (Winskill et al., 1995), but this study did not look at these effects on stereotypic behaviors.

Some interesting qualitative observations were made over the course of the study. For example, several horses would alternate between cribbing and eating. An ad libitum fed horse that displayed this tendency before ad libitum feeding was started continued to do so even at ad libitum feeding levels. All horses displayed a preference for cribbing substrate and cribbing stance. One horse preferred to crib-bite on the posts of the cribbing stations. He would approach the post and assume his cribbing stance, which involved placement of his right foreleg more forward than his left and his left hind leg more forward than his right. He would then lick the post twice and begin cribbing. These observations show the variation among individual animals, but further demonstrate the repetition present in all aspects of performance of the behavior for each animal. While cribbing may serve some as yet unknown function for some horses, it is also possible that more established crib-biting horses perform the behavior simply out of habit or even contentment, as mentioned previously.

Access to pasture, hay, water and mineral can be ruled out as factors responsible for fluctuations in cribbing behavior noted in control horses as they were kept constant for all horses for the duration of the study. Because the study took place between June and December, seasonal changes including temperature, daylight hours and forage changes, could be accountable, as could increases in activity level on the farm as students returned from summer break. The loss of a control horse after d 75 due to lameness should also be mentioned, as his absence may have caused changes in the social structure of the control group. However, there do not appear to be any changes in cribbing frequency in the remaining control horses that could be attributed to the loss. No studies have been performed to evaluate the effects of season, surrounding activity level or changes in social structure on cribbing behavior.

V. IMPLICATIONS

Ad libitum feeding of concentrates to crib-biting horses significantly decreases the amount of time spent cribbing. The exact mechanism with which ad libitum feeding causes a decrease in cribbing remains unclear at this time, and this study suggests that further research is warranted.

A definitive cause for crib-biting behavior remains unclear. However, the results of this study seem to contradict the claims that concentrate feeds are somehow responsible for performance of the behavior.

Ad libitum concentrate feeding is not feasible for most horse owners due to time and cost constraints as well as obesity associated with ad libitum feeding. It is possible that increasing one component of the concentrate diet would yield similar results to those obtained in this study. Further research into feeding strategies such as feeding a baseline ration over 24 h may prove beneficial in producing a way to humanely decrease performance of cribbing behavior.

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Appendices

Appendix 1 Analysis of variance for number of bites taken in 24 h

Source of variation	**Df**	**F value**	**Pr>F**
Treatment	7.0	10.4	0.02
Period	264	1.1	0.4
Treatment X Period	264	7.0	0.001
Covariate	7.12	0.4	0.5

Appendix 2 Analysis of variance for total crib bout duration in 24 h

Source of variation	**Df**	**F value**	**Pr>F**
Treatment	1,7.0	14.1	0.01
Period	4,27.8	1.8	0.2
Treatment X Period	4,27.8	4.0	0.01
Covariate	1,7.58	9.6	0.02

Appendix 3 Analysis of variance for total number of crib bouts

Source of variation	**Df**	**F value**	**Pr>F**
Treatment	1,7.2	4.6	0.07
Period	4,23.4	2.1	0.1
Treatment X Period	4,23.4	8.4	0.0002
Covariate	1,7.0	2.04	0.2

Appendix 4 Mean bout duration (s) for ad libitum fed horses at each observation day

	d 0	d 28	d 66	d 102	d 136	d 170
Dapper	4874	3607	1077	1347	2830	2770
Dutch	7855	3453	0	55	5108	8192
Flashy	8136	116	0	180	4315	6626
Nilla	26319	1245	2978	1456	8997	18201
Sunkist	12162	8716	8730	3700	8810	14381

Appendix 5 Number of crib bites for ad libitum fed horses at each observation day

	d 0	d 28	d 66	d 102	d 136	d 170
Dapper	678	602	160	203	422	463
Dutch	750	470	0	5	816	874
Flashy	1027	13	0	28	473	911
Nilla	2098	176	124	102	521	1641
Sunkist	1522	1121	1231	431	1238	1723

Appendix 6 Number of crib bouts for ad libitum fed horses at each observation day

	d 0	d 28	d 66	d 102	d 136	d 170
Dapper	57	26	10	9	26	23
Dutch	30	13	0	1	24	16
Flashy	25	2	0	1	15	20
Nilla	65	6	8	6	24	41
Sunkist	61	105	75	40	68	62