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Nutrient intake, feeding patterns, and abnormal behavior of growing bulls fed different concentrate levels and a single fiber source (corn stover silage)

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ABSTRACT

Twenty-eight bulls weighing 227 ± 6.8 (SD) kg were randomly assigned to four concentrate levels (1-1.5 kg [low level of concentrate {LC}], 1.5-2 kg [medium level of concentrate], 2-2.5 kg [high level of concentrate {HC}], and 2.5-3 kg [highest level of concentrate {H^+C}]) and fed corn stover silage *ad libitum*. At the beginning of the experiment, the bulls in each treatment were fed 1, 1.5, 2, and 2.5 kg of concentrate, respectively, and these levels were increased by 0.25 kg at the end of each month to compensate for the growth requirements of the bulls. After three months, increases in the concentrate level from LC to HC resulted in increased ($P < 0.05$) trend of acid detergent fiber and neutral detergent fiber intake, whereas the decreasing ($P < 0.05$) trend of acid detergent fiber and neutral detergent fiber intake was observed when concentrate level was increased from HC to H^+C. The longest ($P < 0.05$) time required to consume the concentrate was observed in the H^+C treatment, whereas the lowest time ($P < 0.05$) required to consume the concentrate was observed in the LC treatment. The highest ($P < 0.05$) silage consumption was observed for the LC treatment at 16:00 (26 minutes). Chewing was highest ($P < 0.05$) at 04:00 and 18:00 for the H^+C treatment. The LC bulls showed longer ($P < 0.05$) lying behavior during 18:00 and 24:00 compared with other groups. Abnormal behavior was maximum ($P < 0.05$) in the H^+C bulls at 09:00 (17 minutes). Overall, increasing the concentrate in the diet altered specific behaviors and increased the abnormal behaviors, which could compromise the bulls' welfare.

Introduction

Ruminant animals intensively reared for meat production are fed a diet that includes concentrate and fiber from crop residues (Artioli et al., 2015; Devant et al., 2015; Muhammad et al., 2016). Concentrate supplies energy for growth of ruminants (Hill et al., 2008). Concentrate in combination with forage improve feed efficiency (Coverdale et al., 2004), ruminal environment (Khan et al., 2011), and reduce abnormal behaviors of the growing ruminants (Muhammad et al., 2016). To obtain a high growth rate and maximize production of ruminants, an *ad libitum* supply of concentrate is provided, although this is a costly practice. One of the strategies for reducing feed cost and increasing efficiency is to optimize the dry matter (DM) intake (Suarez-Mena et al., 2015), particularly the concentrate levels. High-concentrate diets are known to modify eating time, reduce rumination time, and lead to the development of abnormal oral behaviors of ruminants (DeVries et al., 2007; Devries and von Keyserlingk, 2009). During subacute ruminal acidosis, the rate of rumen short-chain fatty acid production exceeds rumen short-chain fatty acid absorption and results in an unhealthy depression of rumen pH. Consequences of subacute ruminal acid include fluctuations in feed intake, feed intake depression, reduced diet digestibility, gastrointestinal damage, liver abscesses, and lameness (Krause and Oetzel, 2006; Plaizier et al., 2008). Abnormal oral behaviors include excessive oral manipulation of troughs, buckets, and pen structures; tongue playing and rolling; sham chewing; and grazing other animals' coats (Miller-Cushon et al., 2013; Muhammad et al., 2016; Webb et al., 2012). In some cases, ruminants fed high concentrate diets to achieve a higher production rate and so-called behavioral (or ethological)

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needs may not be addressed (Aziz ur Rahman et al., 2017; Webb et al., 2014). Prolonged prevention of engaging in or having access to behavioral needs can also lead to the development of abnormal behaviors (Jensen and Toates, 1993), a warning sign for chronic stress and poor welfare. An important nutritional aspect in growing ruminants is the concept of precision feeding, which promotes greater efficiency of nutrient utilization and allows nutrient requirements to be met more precisely. Precision concentrate feeding programs provide the animals with the amount of nutrients required to reach the targeted average daily weight gain and maintain normal feeding behaviors.

Smallholder farmers prefer to feed animals using separate feeding systems instead of mixing the total rations because of the associated costs (Devant et al., 2015). However, separately feeding concentrate and forage enhances the intake of the concentrate component at the time of feeding before forage consumption in young ruminants (Devries and von Keyserlingk, 2009), which disturbs normal feeding patterns. These intake patterns may lead to improper nutrient intake (Devries and von Keyserlingk, 2009), affect ruminal health by decreasing rumen pH, increase the possibility of ruminal acidosis (Beauchemin et al., 2002), and prevent the normal display of natural behaviors such as eating and chewing, alter lying patterns, and stimulate the development of abnormal oral behaviors (Artioli et al., 2015; DeVries et al., 2007; Devries and von Keyserlingk, 2009; Selemani and Eik, 2016). Young ruminant studies have indicated that forage intake (Schulze et al., 2015), eating time, chewing time, lying time, and normal animal behavior (Rustas et al., 2010) are influenced by the amount of forage. A previous study by Webb et al., 2013 suggested that ruminants provided insufficient access to forage may develop abnormal oral behaviors, such as tongue playing and rolling, sham chewing, and grazing other animals' coats. Most studies to date have focused on forage supplementation, particle size, forage amounts, and forage type (Broom and Fraser, 2007; Castells et al., 2012; Redbo and Nordblad, 1997; Suarez-Mena et al., 2015); however, studies have not described how cattle behave when crop residues are the only source of fiber (Methu et al., 2001; Wang et al., 2014). Because of higher corn production in recent years, corn stover has become an abundant corn crop by-product that is expected to increase in quantity in the coming years (Menardo et al., 2015). Corn stover silage has the potential for use as a promising forage source for smallholder farmers because of its high production, ease of harvesting, low cost, and wide availability. To our knowledge, previous studies have not determined the effect of concentrate levels (restricted amount) on the daily feeding patterns and abnormal behaviors of young ruminants fed crop residues *ad libitum* as the sole source of fiber. Therefore, a study was planned to determine the effect of different levels of concentrate with corn stover silage on the nutrient intake, feeding patterns, chewing, and abnormal behaviors of growing Chinese Holstein bulls.

Materials and methods

The bulls were managed according to the principles and specific guidelines of the State Key Laboratory of Animal Nutrition, China Agricultural University in Beijing. All of the procedures were approved by the China Council on Animal Care and Protocols. The experiment was approved by the Institutional Animal Care and Use Committee of the China Agricultural University (Permit Number: SKLAB-2014–04–12). Experiment was carried out from January to march, 2015. Twenty-eight eight-month-old Holstein male bulls weighing 227 ± 6.8 (SD) kg were selected of experimental purpose. Data of twenty-eight animals were used for intake, whereas the data of only 16 bulls were used in our study for behavior parameters. The experimental bulls were fed diets that allowed them to choose between dietary concentrates or corn stover silage. The bulls were supplemented with corn stover silage *ad libitum* and randomly assigned to 1 of 4 treatments based on the concentrate level provided: 1-1.5 kg concentrate (low level of concentrate [LC]), 1.5-2 kg concentrate (medium level of concentrate [MC]), 2-2.5 kg concentrate (high level of concentrate [HC]), and 2.5-3 kg concentrate (highest level of concentrate). At the beginning of the experiment, the bulls in each treatment were fed 1, 1.5, 2, and 2.5 kg of concentrate, respectively, and these levels were increased by 0.25 kg at the end of each month. Corn stover were harvested in October 2014 and ensiled for three months. The chemical composition of the corn stover silage on a DM basis was 92.33% organic matter, 73.69% neutral detergent fiber (NDF), 43.19% acid detergent fiber (ADF), and 4.25% crude protein (CP). Corn stover silage was chopped using a STORTI HUSKY TMR mixer, model 9SJW-500, at 1900 rpm for 30 min before feeding to achieve short particle sizes. The corn stover silage particle size distribution was 25.08% >19 mm, 32.35% between 19 mm and 8 mm, 34.85% between 8 mm and 1.13 mm, and 7.72% <1.13 mm. The bulls were fed twice a day at 08:00 and 14:45. The concentrates were formulated to meet a growth level of 0.4 kg per day. The concentrate was formulated using corn grain (69.1%), soybean meal (5.88%), rapeseed meal (10.59%), wheat bran (10.93%), calcium carbonate (1%), dicalcium phosphate (0.5%), salt (1%), and mineral-vitamin premix (1%). The DM content, CP, NDF, and ADF of the concentrate were 86.28%, 15.92%, 20.7%, and 6.78%, respectively. Corn stover silage and concentrate were fed in separate troughs throughout the experiment. The bulls were individually raised in tie stalls and provided space to move (200 × 125 cm; length × width). Fresh normal temperature 30°C water was available throughout the experimental period.

The concentrate and corn stover silage consumption were recorded daily. Samples of the concentrate, fresh corn stover silage, and refusals were collected once a week to analyze the DM content and estimate the concentrate and corn stover silage intake. Video recordings were performed with an infrared anti-nozzle, four-color camera (DH-CA-FW48J; Zhejiang Dahua Technology, Zhejiang, Hangzhou, China) on day 90 of the experiment. Each camera was installed at a specific height to observe each group, and each group was monitored for five days. Video data recorded over 24 h were used to check the feeding patterns, chewing, and abnormal behaviors (Table). Video data were generated using the scan sampling method. Recent studies have used 10-min scan sampling to measure eating time, chewing time, lying time, self-grooming, and abnormal behaviors (Devant et al., 2015; Greter et al., 2013). To improve accuracy, researchers have also used 5-min scan sampling to measure eating time, chewing time, lying time, self-grooming, and abnormal

Table
Behavioral definitions

Concentrate eating time	Concentrate eating was defined as the animal having its head in the feeder and being engaged in chewing
Silage eating time	Silage eating was defined as the animal having its head in the feeder and being engaged in chewing
Chewing time	Chewing time was defined as mastication movements other than eating either animal is standing or lying
Lying	Lying time of bulls is the duration when no activity such as chewing, licking any surface, tongue rolling, consuming wood shavings, and rubbing any surface with head was performed by bulls
Tongue playing[a]	Tongue playing/rolling; repeatedly turning, rolling, or unrolling tongue extended outside or inside mouth
Oral manipulation of trough[b]	Licking, nibbling, or sucking trough
Oral manipulation of pen[c]	Licking, nibbling, or sucking portions of pen

a, b, and c are based on a previous study (de Wilt, 1985), where these behavior were collectively considered abnormal behavior.

behaviors (Faleiro et al., 2011; González et al., 2008; Mendes et al., 2015). Furthermore, Kitts et al., 2011 found that 10-min scans were sufficient (r = 0.95 in correlation to continuous recordings). To increase the accuracy of our measurements, the sample scanning frequency was increased to 3 min based on the methods described in a recent study (Muhammad et al., 2016). Scan sampling was used to measure the concentrate eating time, silage eating time, chewing time, lying time, and abnormal behaviors. Tongue playing, oral manipulation of the trough, and oral manipulation of the pen were collectively considered abnormal behaviors based on previous studies (Miller-Cushon et al., 2013; Muhammad et al., 2016; Webb et al., 2012). Abnormal behaviors were defined as the display of any of the abovementioned behavior during any specific scan. The total time for a given behavior was estimated by multiplying the scan time obtained for a given behavior by three. A BX-4 particle separator with three portable screens (19, 8, 1.3 mm in size) and a bottom that separates the particles into four particle size fractions was used to determine the particle size distribution of the fresh corn stover silage. Particle fractions that remained on top were considered long particles (>19 mm), whereas particle fractions on the second screen were considered medium particles (<19 mm, >8 mm); particle fractions on the third screen were considered short particles (<8 mm, >1.3 mm) and particle fractions that crossed all three screens were considered fine particles (<1.3 mm).

Samples were collected and maintained at −20°C until further analysis. Samples obtained for the DM and nutrient analyses were oven-dried at 55°C for 48 h. Samples were analyzed for DM (135°C; Association of Official Analytical Chemists (AOAC), 2000; method 930.15), ash (535°C; AOAC, 2000; method 942.05), NDF with α-amylase (heat stable) and sodium sulfite (Vansoest et al., 1991), ADF (AOAC, 2000; method 973.18), and CP (AOAC, 2000; method 990.03).

Data for the DM, CP, NDF, and ADF intake were summarized monthly for each bull in each concentrate treatment. Alterations in DM intake and nutrient intake between the concentrate levels over a three-month period were analyzed using the MIXED procedure in SAS with the month as a repeated measure. The model included the fixed effects of the month, concentrate level, and month by concentrate level interaction and the random effect of the replicate. The variance-covariance error structure was first-order autoregressive according to the best fit using Schwarz's Bayesian information criterion. Significance was set at a $P \leq 0.05$.

Data for the concentrate intake time, silage intake time, chewing time, lying time, and abnormal behaviors were summarized hourly for each animal in each concentrate treatment. Differences among the concentrate levels according to concentrate intake time, silage intake time, chewing time, lying time, and abnormal behavior over a 24-h period were analyzed using the MIXED procedure in SAS with the hour as a repeated measure. The model included the fixed effects of the hour, concentrate level, and the hour by concentrate level interaction and the random effect of the replicate. The variance-covariance error structure was first-order autoregressive, according to the best fit using Schwarz's Bayesian information criterion. All of the reported values are the least squares means. Significance was set at a $P \leq 0.05$.

Results

The level of dietary concentrate, length (month) of administration, and their interaction had an effect on the DM, CP, ADF, and NDF

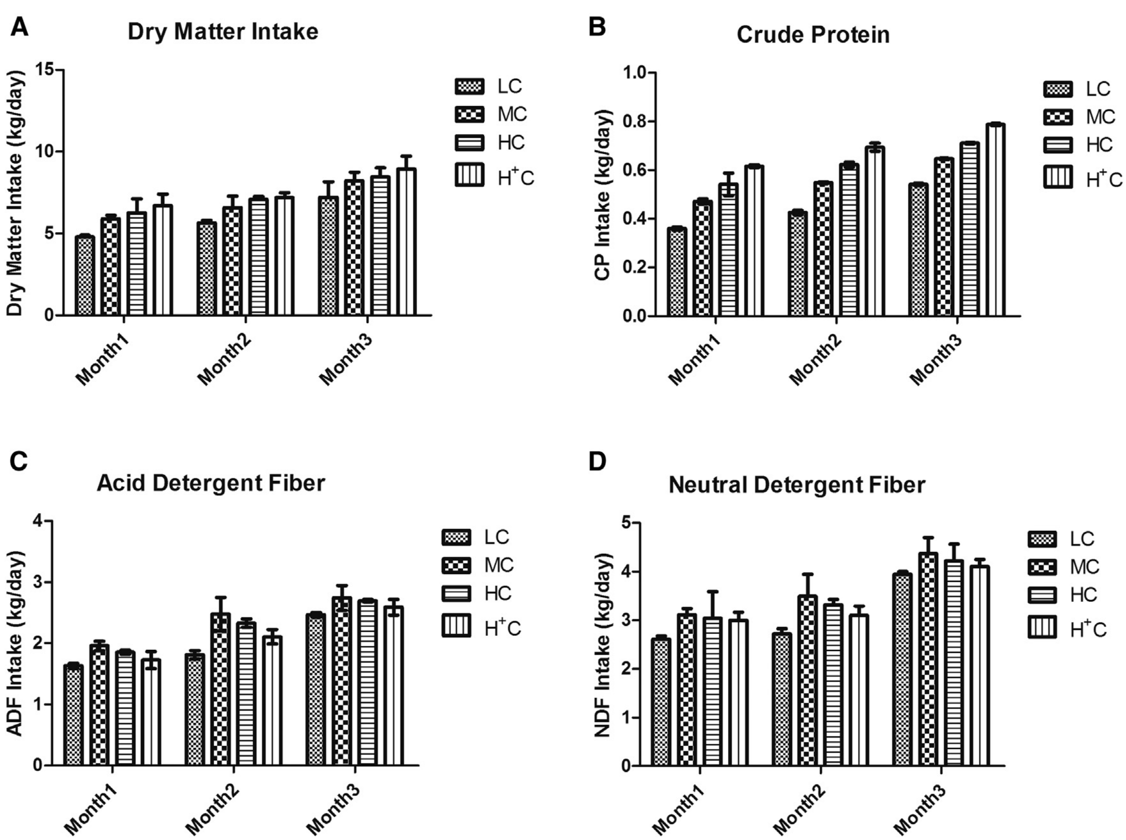

Figure 1. Monthly averages for the (A) dry matter intake time (kg/day), (B) crude protein intake (kg/day), (C) acid detergent fiber intake (kg/day), and (D) neutral detergent fiber (kg/day) in growing Chinese Holstein bulls fed LC (low level of concentrate 1-1.5 kg), MC (medium level of concentrate (1.5-2 kg), HC (high level of concentrate 2-2.5 kg), or $H^{+}C$ (highest level of concentrate 2.5-3 kg) and *ad libitum* corn stover silage. Data are averaged over 30 d for 4 bulls in each treatment group. $P < 0.05$ for the treatment × month interaction. Error bars indicate the standard error.

intake (Figure 1A-D). In the third month, the highest ($P < 0.05$) intake value of DM, CP, ADF, and NDF was found (Figure 1A-D). Increasing concentrate levels also increased ($P < 0.05$) the DM and CP intake (Figure 1A and B). In addition, increasing the concentrate level between treatments resulted in increased ($P < 0.05$) ADF and NDF intake in the LC and MC treatments and decreased ($P < 0.05$) ADF and NDF intake in the HC and H^+C treatments (Figure 1C and D).

An analysis of the diurnal pattern of concentrate intake time, silage intake time, chewing time, lying time, and abnormal behaviors showed a treatment by hour interaction ($P < 0.05$).

Regardless of the dietary treatment, the claves ate the concentrate in one meal, which showed that the bulls had a higher preference toward the concentrate; moreover, increasing the concentrate level increased the concentrate intake time at the time of feed delivery (Figure 2A). The increase in concentrate intake time with increasing concentrate levels was highest during the evening feed delivery (Figure 2A). The longest ($P < 0.05$) concentrate consumption time was observed in the H^+C bulls, whereas the lowest ($P < 0.05$) concentrate consumption time was observed in the LC.

The silage intake time increased after feed delivery. The longest ($P < 0.05$) silage intake consumption time was observed at 09:00 and 16:00 (Figure 2B). The MC calves had the longest ($P < 0.05$) silage consumption time at 09:00 (32 minutes). The longest ($P < 0.05$) silage consumption time was observed for the LC bulls at 16:00 (24 minutes), whereas the lowest ($P < 0.05$) silage consumption time at 16:00 (14 minutes) was observed for the H^+C bulls.

Increased chewing activity was observed after feed delivery, and the highest chewing time was observed at 04:00, 12:00, and 18:00 (Figure 3A). Chewing times tended to be higher after evening feeding compared with after the morning feeding. After the morning feed delivery, the H^+C bulls showed the highest ($P < 0.05$) chewing activity at 04:00, 12:00, 18:00.

Lying time was decreased between 07:00 and 17:00 (Figure 3B). The highest lying activity was observed between 18:00 and 06:00 (Figure 3B). The bulls in the LC and HC treatment showed higher ($P < 0.05$) lying behavior compared with the MC and H^+C treatments between 18:00 and 24:00 (Figure 3B). Between 01:00 and 06:00, the highest ($P < 0.05$) lying behavior was noted in the LC followed by the MC, HC, and H^+C treatments (Figure 3B).

Abnormal behaviors were highest ($P < 0.05$) at 09:00 and 16:00 (Figure 4). At 09:00 (17 minutes), the highest ($P < 0.05$) amount of

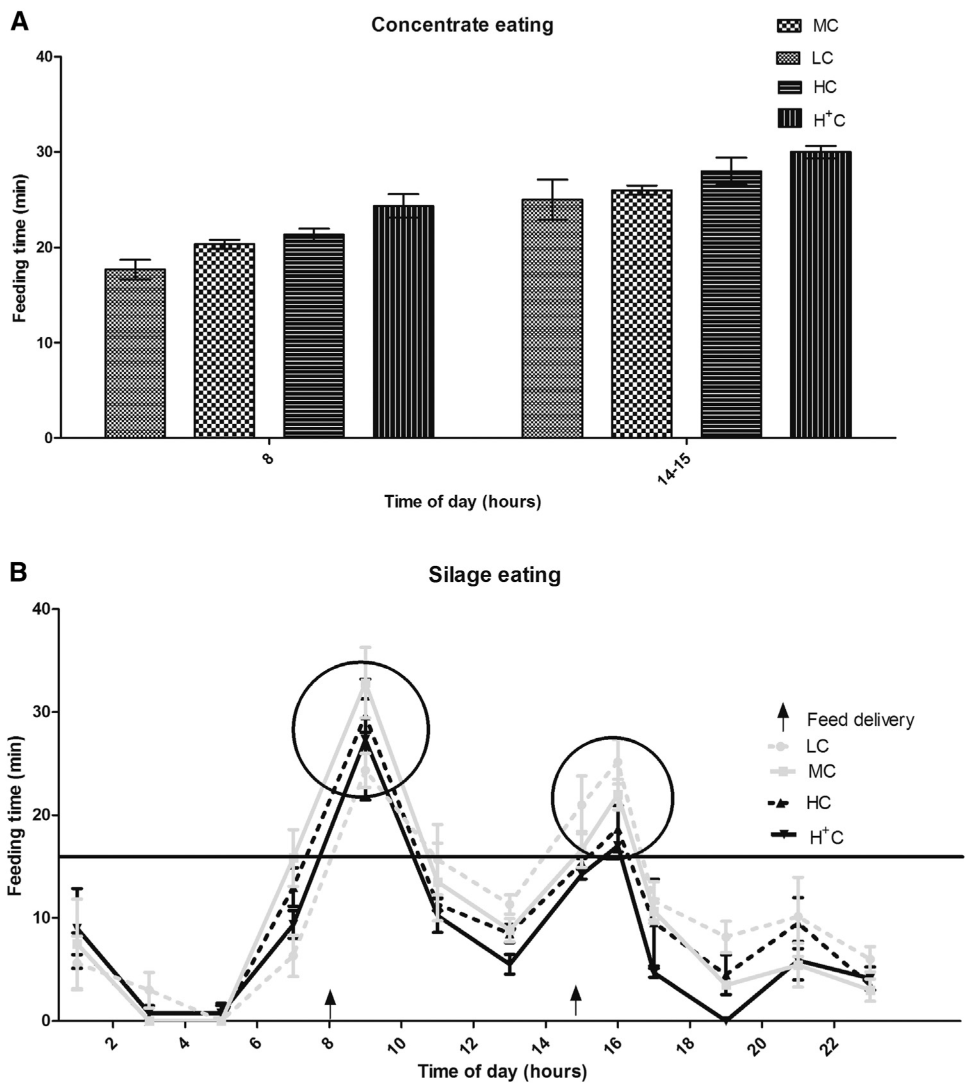

Figure 2. Hourly averages for the (A) concentrate eating time (min) and (B) silage eating time (min) in the growing Chinese Holstein bulls fed either LC (low level of concentrate 1-1.5 kg), MC (medium level of concentrate (1.5-2 kg), HC (high level of concentrate 2-2.5 kg), or H^+C (highest level of concentrate 2.5-3) and *ad libitum* corn stover silage. Data are averaged over 5 d for 4 bulls in each treatment group. $P < 0.05$ for the treatment × time interaction. Error bars indicate the standard error. Arrows indicate the feeding time.

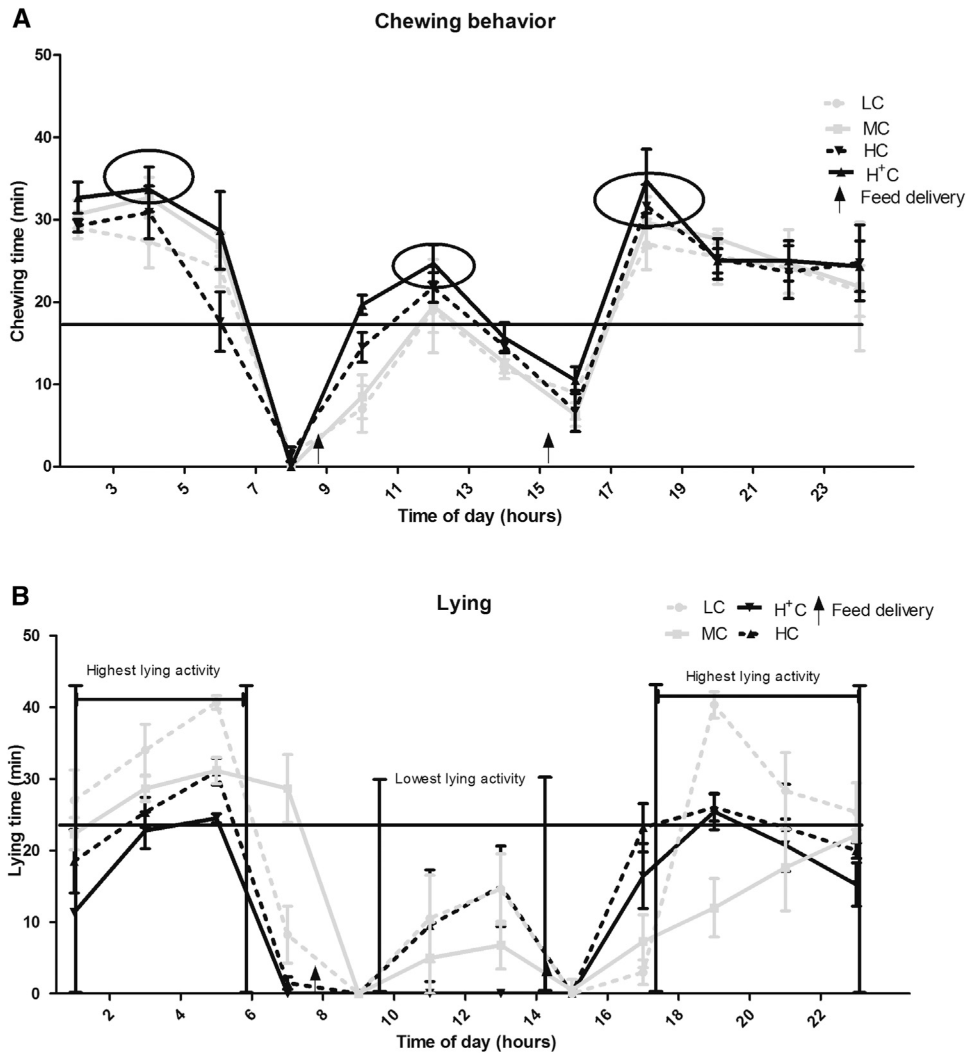

Figure 3. Hourly averages for the (A) chewing time (min) and (B) lying time (min) in growing Chinese Holstein bulls fed either LC (low level of concentrate 1-1.5 kg), MC (medium level of concentrate (1.5-2 kg), HC (high level of concentrate 2-2.5 kg), or $H^{+}C$ (highest level of concentrate 2.5-3 kg) and *ad libitum* corn stover silage. Data are averaged over 5 d for 4 bulls in each treatment group. $P < 0.05$ for the treatment × time interaction. Error bars indicate the standard error. Arrows indicate the feeding time.

abnormal behaviors were observed in the $H^{+}C$ treatment followed by the LC, MC, and HC treatments. However, at 16:00, this pattern was reversed for the $H^{+}C$ and LC treatments, with the LC showing higher ($P < 0.05$) abnormal behaviors (14 minutes) compared with the $H^{+}C$ (13 minutes).

Discussion

The dietary treatments increased the DM, CP, NDF, and ADF intake because of the increased concentrate supply each month at the rate of 0.25 kg per month. In the third month, increasing the concentrate level increased the DM and CP intake because the DM contents in the concentrate were controlled under the restricted concentrate supplementation. The lowest concentrate level was confirmed to maintain the daily nutrient requirements of the bulls. Therefore, the higher concentrate levels caused an increase in the DM and CP intake because of a lower gut fill effect of the concentrate caused by the lower NDF and higher starch content. Our results are consistent with recent studies that assessed increasing levels of concentrate increase the DM and CP intake in cattle (Quang do et al., 2015). Furthermore, a higher level of concentrate causes ruminal acidosis (Beauchemin et al., 2002; Devries and von Keyserlingk, 2009). The decrease in NDF and ADF intake in the $H^{+}C$ bulls may have been caused by a decrease in ruminal pH after consuming a higher level of concentrate. This decrease in ruminal pH might suppress corn stover silage intake because corn stover silage is the sole source of NDF and ADF, although the decreased ruminal pH did not affect the concentrate intake.

The trend toward a treatment by hour interaction reflects the higher concentrate intake time after feed delivery in the $H^{+}C$ treatment bulls compared with those in the other dietary treatments. Stimuli from the location, such as the sight of neighboring bulls, might have maintained a motivation to consume the concentrate quickly in one meal. Devries and von Keyserlingk (2009) found that feeding forage and concentrate separately resulted in the consumption of a higher proportion of concentrate than intended. Therefore, under certain conditions, bulls may consume more concentrate than intended, even in situations where a restricted amount of concentrate is provided to each bull. Our results are also consistent with reports that component-fed lactating cows consumed the concentrate portion faster than the forage portion of their ration (Beauchemin et al., 2002, 2008). The high rate of concentrate consumption may affect ruminal fermentation patterns and reduce the ruminal pH (Beauchemin et al., 2008; Maekawa et al., 2002). Moreover, component-fed cows rapidly consume their concentrate in a smaller number of large

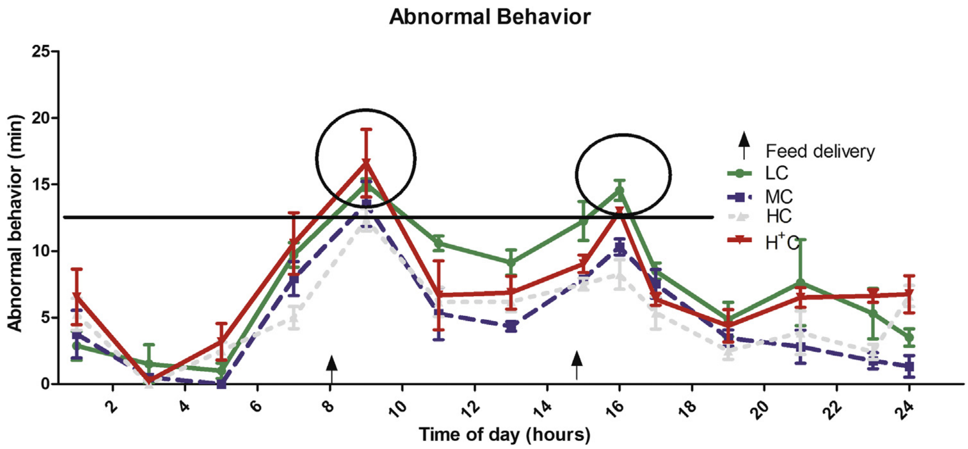

Figure 4. Hourly averages for the abnormal behaviors (min) in the growing Chinese Holstein bulls fed either LC (low level of concentrate 1-1.5 kg), MC (medium level of concentrate (1.5-2 kg), HC (high level of concentrate 2-2.5 kg), or H^+C (highest level of concentrate 2.5-3 kg) and *ad libitum* corn stover silage. Data are averaged over 5 d for 4 bulls in each treatment group. $P < 0.05$ for the treatment × time interaction. Error bars indicate the standard error. Arrows indicate the feeding time.

meals; therefore, they experience higher levels of subacute ruminal acidosis (Beauchemin et al., 2002; Devries and von Keyserlingk, 2009). Although the concentrate intake time was higher in the H^+C treatment after feed delivery both in the morning and evening, the concentrate intake time was highest in the evening. This result indicates that the morning concentrate feeding pattern reduces ruminal acidosis, although the bulls still showed interest in the concentrate at the evening feed delivery, which further decreased the ruminal pH. Furthermore, the silage intake time for the H^+C bulls was lower compared with the bulls in the other treatments at 16:00 because these bulls ate the maximum level of concentrate. Based on these findings, we can hypothesize that bulls may experience postprandial drops in ruminal pH when fed concentrate and forage components separately, even when the concentrate is fed in limited quantities. Our hypothesis is supported by a previous study (Gonzalez et al., 2008) that reported that more than 50% of feedlot heifers experience moderate acidosis (pH<5.6) when fed concentrate and straw *ad libitum*. Similar to our study, the bulls were fed concentrate in restricted amounts and ruminal fermentation was not measured; therefore, further research is required to validate these hypotheses.

Compared with our expectations based on previous research, the present study did not show that decreased NDF and ADF intake reduced chewing activity (Muhammad et al., 2016; Rustas et al., 2010; Selemani and Eik, 2016). The ability of the H^+C diet to increase chewing time is counterintuitive; however, similar results have been previously reported (Krause et al., 2002; Maulfair and Heinrichs, 2013). Krause et al. (2002) determined that increasing rumen fermentable carbohydrates tended to increase chewing time and increase chewing minutes per kilogram of NDF intake. In this study, because corn stover silage was the only dietary component that could stimulate chewing, the increased chewing activity was likely caused by an adaptive response to the higher concentrate levels that attenuates the low ruminal pH via increased saliva secretion.

The highest lying behavior was observed in the night and morning hours, which corresponds to the periods with the highest chewing activity because bulls generally like to chew while lying (Albright, 1993). Our results showing that animals prefer to chew while lying are consistent with the results of recent studies (Greter et al., 2012; Muhammad et al., 2016).

Regardless of the dietary treatment, the bulls displayed abnormal behaviors, particularly one hour after the morning and evening feeding. Abnormal behaviors were highest in the H^+C animals, which were likely undergoing ruminal acidosis. The higher abnormal behaviors in the H^+C treatment was most likely because of the decreased NDF and ADF intake, which increase the development of abnormal behaviors (Redbo and Nordblad, 1997). Conversely, the decreased NDF and ADF intake of the H^+C bulls resulted in higher abnormal behaviors after the morning feeding but not after the evening feeding, which was characterized by higher chewing activity and, presumably, lower ruminal pH. This finding may indicate that chewing behavior after the morning feeding is essential for the H^+C animals to overcome the abnormal behavior. The chewing activity observations after the morning feeding could show that the H^+C bulls devoted additional time to chewing to overcome the abnormal behaviors associated with the morning feeding time because the H^+C bulls spent the highest amount of time chewing from the morning feeding until after the evening feeding. These results confirm that the development and performance of abnormal behaviors in growing bulls fed higher concentrate levels are strongly related to chewing activity. Interestingly, decreased amounts of concentrate in the LC bulls led to lower chewing activity after the morning feeding and were associated with enhanced abnormal behaviors after the evening feeding, which may have been related to the decreased NDF and ADF intake in the LC bulls (Faleiro et al., 2011; Redbo and Nordblad, 1997; Schulze et al., 2014). Furthermore, Schulze et al. (2014), Faleiro et al. (2011), and Redbo and Nordblad (1997) reported that low forage intake induce abnormal behaviors; therefore, high levels of abnormal behaviors, which are related to low fiber intake, might indicate issues related to the ruminants' welfare (Broom and Fraser, 2007). If this were the case, *ad libitum* amounts of corn stover silage should be associated with higher NDF and ADF intake and chewing in the LC fed bulls, which would lead to less abnormal behaviors. However, in the present study, the opposite results were observed. The decreased NDF and ADF intake and decreased chewing activity in the LC bulls were related to corn stover silage as the sole source of fiber, which might cause abomasal damage. In addition, the bulls likely did not prefer eating corn stover silage as the sole source of fiber, although it was also the only source of fiber for the LC bulls in this study. Previous studies have reported that maize silage pellets, straw, and grains are associated with abomasal damage (Brscic et al., 2011; Mattiello et al., 2002; Webb et al., 2013). Abomasal damage in beef and veal bulls is believed to be caused by factors that include the abrasive action of coarse feedstuff (Katchuik, 1992; Mattiello et al., 2002). Therefore, the abnormal behaviors observed after the evening feeding in the LC bulls might have been caused by abomasal damage (Katchuik, 1992; Mattiello et al., 2002).

Overall, providing concentrate and corn stover silage separately encouraged the young growing bulls to consume the concentrate portion rapidly in one meal before consuming the corn stover silage portion of their ration. This pattern of intake enhances DM and CP intake, although it reduces NDF and ADF intake at higher concentrate levels. Moreover, increasing the level of concentrate in the diet alters the animal behavior and silage intake time, enhances rumination activity, and increase abnormal behaviors, which could compromise the bulls' welfare. Therefore, further research is required to determine whether corn stover silage with other fiber sources can be used as alternative forage for growing bulls to reduce abnormal behavior associated with corn stover silage.

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Authors' contribution: M.A.R. conducted the experiments, finished the data analysis, and drafted the article. X.C.Q. and J.L.M. participated in the experiments and helped with the data collection and analysis. C.B. and S.H. conceived the experiment and finished the article.

Conflict of interest

There are no conflicts of interest in the submission of this article, and the article was approved for publication by all the authors.

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