The Circadian Behavior of Crossbred Duhan Sheep

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Abstract: The first generation offspring of Dorper sheep crossed with small-tailed Han sheep was here named "Duhan sheep". The Duhan cross has high heterosis with a distinct mutton-type physique, enhanced production, disease resistance and strong reproductive performance. In order to determine the timing of animal behaviors such as feeding (eating, drinking and ruminating), moving and sleeping to have a basic understand of Duhan sheep behavior and to make raising and handling sheep less stressful for both the sheep and shepherd the experiment was conducted to observe the behavior of Duhan sheep in household. The results show that An ethogram of Duhan sheep was made up of feeding, sleeping, standing, moving, ruminating and others. There were behavioral differences among different time phage overall day and night under housing condition. The feeding time was 275.08 min, accounting for 19.44%; the resting time of it was 719.39 min, accounting for 50.85%; the movement time of it was 156.45, accounting for 11.06%; the standing time of it was 233.72, accounting for 16.52%; the other behaviors times was 30.26 min, accounting for 2.13% (including drinking water, defecation, grooming, sniffing and vocal, etc). Rumination includes standing rumination and lying rumination and the time of rumination was 275.08 min, accounting for 44.58%. The day movement occurred mostly between 8:00-12:00 and 16:00-21:00; the ingestion and the rumination behaviors both have two peaks, respectively 10:00-12:00, 16:00-19:00, 13:00-16:00 and 4:00-7:00. The resting behavior mostly occurred in the night, along with rumination. The other behaviors occurred at random but defecation occurred mostly in the feeding process. The occurrence of behaviors and rhythms of the Duhan sheep had closely relationship with both captive condition and feeding and manamement methods. The sheep houses could provide a good microclimate condition facility to management for keeper but some natural behavior of sheep could not be fulfilled due to the barren rearing environment and limited space the most important is to make raising and handling sheep less stressful with good project of management.

Key words: Dorper small tail han sheep, behavior, household, good project of managemen, captive condition and feeding

INTRODUCTION

Duhan sheep are the first generation offspring of Dorper sheep crossed with small-tailed Han sheep. The Dorper is a South African breed of mutton sheep that was originally created by crossing a Dorset Horn ram and a Blackhead Persian ewe. Dorper are heavily muscled with a compact body and high reproductive performance. This breed is in continuous estrus, mating all year and generally giving birth 3 times every 2 years with a reproduction rate of 150%. The carcasses of DorZper sheep are composed of approximately 65% muscle, 20% fat and 43-45.9% high-quality meat. Thus, this breed is especially suitable for production of lamb that is internationally known as diamond-grade for its tender and delicious meat (Youzhang, 2013).

The small-tailed Han sheep is a famous breed of sheep in China and has been called the "super sheep" and "the national treasure". This breed has a variety of superior agronomic traits. These include docile

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Fig. 1: Duhan sheep flock

Fig. 2: Duhan twins

temperament, resistance to crude feed, high adaptability and high dressing and meat percentages (52 and 40%, respectively). The Han sheep also matures early with young ewes starting to mate in 6 months has a fast growth rate with a monthly weight gain of 7.5-10 kg has a high lambing rate with two births per year and 3-5 lambs each pregnancy and has a large physique with adult rams weighing >100 kg each (up to a maximum of 180 kg).

The Duhan cross has high heterosis with a distinct mutton-type physique, enhanced production, disease resistance and strong reproductive performance. Compared with the small-tailed Han, the Duhan sheep shows great variations in the physical appearance and develops distinct black markings on the head and neck (Fig. 1 and 2). In Duhan lambs 33.5% have black heads and the remaining 66.5% have a mixture of black and white on the head and neck. There are no fine hairs on the head or legs, only white, distinctly coarse hairs (Wang *et al.*, 2010).

In recent years, China has experienced significantly improved living standards and changes in demand for meat. Owing to the increasing demand for lamb the sheep industry is regarded as a growth industry in China. Great efforts have been made to cross local mutton breeds with more exotic ones to produce better commercial mutton sheep and meet the market demand. Because of the benefits noted above the Duhan cross has become one of the most popular mutton breeds in China.

However, in sheep farming, excessive animal densities and inadequate environmental control technology can easily cause a buildup of moisture and harmful gases in barns. The constrained space and limited mobility of sheep in high stocking densities can lead to significant increases in the incidence of disease (Demiroren *et al.*, 1995). Additionally, the use of tethers fences and slatted floors forms a relatively monotonous and boring environment. In such an environment, the grazing behavior of sheep is largely inhibited (Sibbald *et al.*, 2000) and specific abnormal behaviors emerge such as grazing foreign matter and biting (Ouy *et al.*, 2003) significantly decreasing animal health and productivity.

With increasing public concern about animal welfare issues, the question of how to provide a comfortable yet productive environment that meets the behavioral and biological needs of the animals (Das *et al.*, 1999; Casamassima *et al.*, 2001) has become an important question. To better determine the needs of Duhan sheep we examined the behavioral adaptation of these sheep to barn living. Behavioral adaption research focuses on observation of individual animal behaviors in the context of group behavior observation, either continuously or intermittently at specific time intervals. Specifically, the present study was carried out to systematically observe circadian behavior under barn conditions. These results reveals a basic understanding of Duhan sheep behavior and will help farmers and veterinarians meet the breed's behavioral needs, improve animal welfare, modify feeding and management procedures, adjust breeding programs, improve the rearing environment and ultimately improve the meat quality of Duhan sheep.

MATERIALS AND METHODS

Animals: Duhan sheep were selected from the Qunyuan Farming Specialized Cooperative in Xinan County, Luoyang, Henan Province, China.

Study objective: The objective of this study was to determine the timing of animal behaviors, such as feeding (eating, drinking and ruminating) moving and sleeping.

Research methods

Study site: Qunyuan farming specialized cooperative is located in Xin'an County, lying in the western part of Luoyang in Henan Province. This county covers a hilly area with an average elevation of 1,384.7 m above sea level. It has a Northern temperate climate and an annual average temperature of 14.2°C. Monthly average temperatures are -0.2°C in January and 27.1°C in July. The annual average precipitation is 642.4 mm. The sheep farm covers a total area of 10,666.67 m² with a 2000 m² barn, a 500 m² office and auxiliary building area, a 200 m² dry-feed storehouse and a 500 m² ensilage pool with a sterilization room and infirmary. There are eight employees in the cooperative with a total of 1,500 Duhan and small-tailed Han sheep in stock. A total of 15 Duhan sheep and 15 Small-tail Han sheep were followed in this study.

Behavioral observation and recording: Sheep behavior was observed using all-occurrence sampling, focal animal sampling and instantaneous scan sampling. A 3 days pre-observation was conducted to construct an ethogram of sheep and allow observers to become acclimated to the sheep. Two groups of sheep were simultaneously observed and the timing of behaviors (start, duration and end) was recorded using a stopwatch. Behavioral frequency and number of behavioral cycles were also recorded to the nearest second. During night time, an observer in the corner of the barn monitored the sheep with faint light from the outside for illumination.

Feeding management: All animals observed were fed in the barn. Manual feeding was performed twice daily, i.e., 9:30-12:30 and 16:00-19:30. For each feeding, animals were first given concentrated fodder followed by coarse fodder including hay with a certain amount of concentrated fodder. This was followed by silage, mainly corn stalks and finally dry tree leaves. Drinking was allowed after eating by offering a small-millet gruel made in boiled water.

Data processing: Animal behaviors were examined and recorded day and night (day, 8:00-20:00; night, 20:00-8:00). Results are represented as the arithmetic mean±standard deviation of the mean.

RESULTS

Ethogram of Duhan sheep: An ethogram of Duhan sheep was constructed according to our observations in combination with previous research (Yuqin *et al.*, 2004; Wang *et al.*, 2010). The behaviors of Duhan sheep were divided into six types using the actual observations

including: feeding-sheep fed on fodder and silage or licked nutrition blocks and the newborns pushed-up and sucked milk during lactation; sleep-sheep lay on the ground, mostly on the side or on the stomach; standing-sheep stood on the ground with upright limbs supporting the body and maintained a stationary state; moving-sheep obviously changed the position of the body including walking and running; ruminating-sheep (lying or standing) regurgitated, re-masticated and re-swallowed food bolus, accompanied by collaborative movement of the upper and lower lips and others-drinking, mounting, defecating, environment exploring, grooming and vocalization occurred at low frequencies with short durations.

Time budget of Duhan sheep for various behaviors: Under barn feeding conditions, individual Duhan sheep showed differences in time spent moving, ruminating and other behaviors between day and night. Significantly more time was spent moving during the day than the night whereas more time was spent ruminating in the night vs the day. Additionally, significantly more time was spent urinating, defecating, mounting and bleating during the day than the night. Duhan sheep spent most of their time resting (approximately 50.85%), followed by feeding (19.44%), standing (16.52%), moving (11.06%) and other behavior (2.13%). Overall, more time was spent moving and feeding during the day and ruminating and resting during the night. Despite being the least frequent behavior in both the day and the night, time spent performing other behaviors was distributed evenly throughout the day.

Statistical analysis of the duration of sheep behaviors at various time intervals (0:00-24:00, Table 1) showed that feeding behavior experienced two distinct peaks at 10:00-12:00 and 16:00-19:00 and a nadir in the early morning at 4:00-6:00. The peak rumination period in Duhan sheep was during the night. These results indicate that when fed under barn conditions, Duhan sheep need to spend substantial time digesting the feed ingested. In addition, under barn conditions, Duhan sheep movements tended to be of short duration. At 2 h time intervals, the maximal duration of movement only approached 25 min. Grooming and other behaviors were of even shorter duration. These observations indicate that to some extent, barn feeding is unfavorable for Duhan sheep, preventing them from fully expressing normal behaviors which may negatively affect animal welfare.

Ruminating behavior can be divided into standing and prone rumination. Rumination accounted for 44.58% of the total daily activity, making this the most time-consuming daily behavior. This is divided into two daily peaks, one in the afternoon and one at night. Duhan

Table 1: The duration of sheep behaviors at various time intervals (0:00-24:00) unit:min

Time	Ingestion	Rumination	Lying	Movement	Standing	Others
0:00~2:00	0.43±0.23	68.67±3.32	98.47±5.20	6.98±1.12	6.98±1.12	0.42±0.10
2:00~4:00	1.23±0.76	72.38±4.38	99.56±4.72	7.28±1.22	7.28±1.22	0.28±0.13
4:00~6:00	0.66±0.16	75.28±4.56	98.35±5.03	8.18±2.78	8.18±2.78	0.32±0.10
6:00~8:00	0.86±0.28	66.16±3.76	86.76±3.55	20.62±4.28	20.62±4.28	1.35±0.26
8:00~10:00	28.36±1.26	52.32±3.65	15.23±3.25	25.78±4.20	25.78±4.20	3.45±0.44
10:00~12:00	78.25±1.22	16.62±2.25	3.10±0.35	25.06±1.26	25.06±1.26	5.23±1.30
12:00~14:00	23.72±1.12	52.32±3.64	63.25±4.26	8.52±1.22	21.22±2.34	4.22±1.24
14:00~16:00	8.73±1.24	72.48±2.36	83.25±4.76	6.25±0.88	16.76±1.72	3.12±0.76
16:00~18:00	62.96±4.27	14.78±2.44	6.76±1.52	13.45±2.86	27.28±2.68	3.56±1.06
18:00~20:00	51.38±4.12	28.56±2.58	38.46±3.28	10.36±2.76	21.22±2.86	2.76±1.08
20:00~22:00	15.28±2.76	57.36±4.66	50.27±3.47	17.45±1.87	28.76±2.28	3.22±0.98
22:00~0:00	3.22±0.63	53.73±4.44	75.93±5.22	6.52±0.86	24.58±2.10	2.13±1.02

Table 2: Ruminations behavior of Duhan sheep

Iterms	Total rumination cycles per day (time)	Times of each food bolus remasticated (time)	Seconds of each food bolus remasticated (sec)	Interval time (sec)	Minutes of rumination present after feeding (min)	The number of ruminations at the peak	Second of each food bolus rumination at peak (sec)
Duhan sheep	47.76±10.4	21.35±1.2	72.38±11.7	43.28±11.4	6.76±1.23	25.2±4.26	75.3±12.1
Small-tail Han sheep	45.28±11.2	17.38±1.4	65.24±9.70	42.36±12.2	5.36±1.62	33.2±3.68	68.4±10.8

Table 3: Feeding behavior of Duhan sheep and Smal-tailed Han sheep

Iterms	Feeding frequency (bites per minute)	Feeding rate (%)	Feeding time (min)
Duhan sheep			
Concentrated fodder	32.26±2.36	100	12.86±0.64
Coarse fodder (hay)	20.28±2.78	99	38.56±2.69
Silage	18.36±1.92	95	55.42±4.03
Dry tree leaves	14.46±1.96	98	38.42±2.33
Small-tailed Han sheepcon			
Centrated fodder	26.54±1.84	100	15.86±1.12
Coarse fodder (hay)	16.84±2.06	96	46.35±2.98
Silage	16.44±1.62	92	59.78±4.64
Dry tree leaves	12.26±2.68	95	46.24±3.02

sheep spent more time ruminating at the night (62.41% of rumination time) than during the day (37.59%). All rumination activities occurred 25 min after feeding and peaked at approximately 1 h after the start of rumination. Between the supplies of different feeds, Duhan sheep ruminated once for 15-20 min. There were approximately 21 total rumination cycles per day with more cycles at night (15-16 cycles) than during the day (5-6 cycles). Each rumination lasted approximately 40 min and each food bolus was remasticated 42-113 times (most commonly 60-90 times) with an interval time (gap between the complete swallow of the last food bolus and regurgitation of the next food bolus) of 4-10 sec. At the peak, the number of ruminations increased (70-100 times) with shorter time intervals between ruminations, increased re-mastication of food boluses and increased re-masticating time per food bolus (Table 2).

Duhan sheep had a higher feeding frequency with more bites per minute than small-tailed Han sheep. Comparing with the behaviors of Small-tail Han sheep which was researched in other report showed that the Duhan had a higher feeding rate and shorter feeding time, with a slightly higher total feed intake than the small-tailed Han sheep (Table 3).

DISCUSSION

Ruminating characteristics of Duhan sheep: Through rumination, sheep further grind the ingested feed and adjust the rumen environment to be conducive to rumen microbial growth and digestion. In Duhan sheep, behavioral characteristics, such as the total number, frequency and duration of rumination were related to the type, quality, processing method of forage ingested as well as to the different physiological stages and the physical situations of the sheep. The higher the crude fiber content of coarse feed, the longer the ruminating time. Fatigue or strong external stimuli might cause altered rumination or cessation of rumination altogether, yielding an adverse effect on sheep health (Shi *et al.*, 2003).

Our observations and statistical data indicated that Duhan sheep gradually increased the number of ruminations for each food bolus after feeding; this breed had more and longer rumination cycles for each food bolus than small-tailed Han sheep. Duhan sheep also had faster and more frequent feedings than small-tailed Han sheep. This is likely a factor in the former's faster growth rate, greater mass and higher dressing percentage than those of the latter. In terms of production, Duhan sheep are of greater feeding value than small-tailed Han sheep.

Time budget of Duhan sheep: The time budget of animal behavior reflects food availability, environmental conditions and behavioral characteristics (Lian *et al.*, 2007; March, 1981). In this study, Duhan sheep demonstrated obvious crepuscular activity patterns, consistent with the common ruminant activity pattern of feeding-break-feeding (Shi *et al.*, 2003).

Different animal populations often evolve unique feeding modes to adapt to specific habitat conditions as well as to ensure survival and reproductive success. To

further those goals, feeding behavior is one of the most important activities in the life of animals. In this study, feeding times of Duhan sheep were mainly concentrated at 9:30-12:00 and 16:00-19:00 which is radically different from wild ungulates. This is a result of barn feeding conditions where abundant forage is provided that generally meets the energy needs of the sheep whereas wild animals have to spend substantial time foraging and guarding against the attack by predators (Villalba *et al.*, 2011).

In the day, the resting time of Duhan sheep was concentrated at noon and in the afternoon. Compared with the small-tailed Han, Duhan had relatively short resting periods. Resting periods of Duhan sheep at other time intervals were even shorter. At night, feeding lasted for a very short period without peaks whereas ruminating behavior clearly experienced two peak periods, 12:00-16:00 and 2:00-6:00. At 2 h time intervals, the longest continuous ruminating time was 82 min. These observations indicate that during barn feeding, Duhan sheep have to spend substantial time digesting feed. In comparison, small-tailed Han sheep have relatively long ruminating times but a low ruminating rate. Thus, Duhan sheep can achieve more complete digestion of feed and higher feed utilization efficiency than small-tailed Han sheep.

Diurnal activity rhythm of Duhan sheep: Diurnal activity rhythms of Duhan sheep involved two activity peaks of feeding in the morning and afternoon. Night time feeding behavior was brief. Resting was mainly in the night and afternoon while moving behavior was most frequent before feeding. Standing was typically limited to 20-30 min during most time intervals except for at night when it could last up to several hours. These observations indicate that similar to other ruminants Duhan sheep maintain a feeding-break-feeding activity pattern despite an uneven distribution.

Comparison of behavioral characteristics between Duhan and small-tailed Han sheep: Duhan sheep had slightly longer periods of movement than small-tailed Han sheep which helps improve meat quality. The former also had faster feeding rates with relatively high feed intake. In contrast, small-tailed Han fed for a longer time; this was related to feeding frequency but not directly linked to feed intake. Our observations indicate that Duhan sheep have slightly higher feed intake than small-tailed Han sheep. The former breed has greater body weight and higher meat quality than the latter. Additionally, the former has a larger number of ruminating cycles with faster ruminating rate and greater number of food bolus ruminating times than the latter.

Duhan sheep spent less time resting per day than small-tailed Han sheep while still displaying fewer behaviors indicating irritability. Both breeds spent similar amounts of time on other behaviors (drinking, defecating, grooming, sniffing, standing and bleating). However, the cold winter season and low temperatures during our observations may have influenced the proportion of time resting for the Duhan sheep. Previous studies have found that cold weather decreases moving time and increases standing time (Zang *et al.*, 2005).

Influence of environmental conditions on Duhan sheep: During barn feeding there was little space for activity for Duhan sheep. In addition, there was no need to forage as the feed was supplied at fixed time intervals that met the energy requirements of the sheep. Consequently, time spent feeding was significantly reduced while time for resting was substantially increased under barn feeding conditions compared with grazing conditions (Animut *et al.*, 2005; Osoro *et al.*, 2013). Despite being related, ruminating time had no significant relationship with feeding time. Nevertheless, the sheep required rumination time corresponding to the feeding time to further digest the food bolus through chemical and mechanical mechanisms. Therefore, feed management needs to ensure that there is adequate ruminating time for feed digestion and absorption.

Environmental factors have great influences on sheep behaviors. A quiet habitat and minimal interaction can aid normal feeding, ruminating and resting of Duhan sheep. Feed management should avoid adverse stimuli to create favorable conditions to maximize production efficiency.

CONCLUSION

The behavioral characteristics and activity rhythm of Duhan sheep are closely related to management conditions, especially barn feeding. Through observation and study of Duhan sheep behavior we have learned the behavioral characteristics and rhythmic activity of this breed under specific feed management and ecological conditions. This information will allow adjustments to feeding programs which will lead to an improved feeding environment and further improve the meat quality of Duhan sheep.

We have also further clarified the biological rhythm of Duhan sheep, providing a reference point to allow veterinarians and farmers to meet the sheep's behavioral needs, improve animal welfare and develop improved feeding management programs for this breed, ultimately aiding the breeding of new mutton sheep cultivars suitable for fat lamb production in China.

ACKNOWLEDGEMENTS

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