Impacts of shade on physiological and behavioural pattern of Dehong buffalo calves under high temperature

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Abstract

Shade shelter is widely used to reduce heat load for farm animals, but little research focus on the cooling effects for Dehong buffalo calves. The aim of this experiment was to evaluate the impacts of shade cooling on the physiological and behavioural parameters for Dehong buffalo calves. Shade with 99% blockage of solar radiation was covered on steel frame with a 2.5 m height above the loafing area floor (Shaded). The loafing area of the control group was the same as the shaded group,

apart from no shade shelter above the loafing area (non-shaded). Twenty-four Dehong buffalo calves were randomly and averagely allocated to the non-shaded and shaded groups. Six Dehong buffalo calves were loose housed in a barn, and they had access to loafing area. The results showed that the average daily air temperature of the loafing area under shade was lower 1.5°C than that of the non-shaded loafing area. No difference in rectal temperature was found between the non-shaded and shaded calves ($P > 0.05$), but respiration rate of the non-shaded group in noon (12:00h, 31.6 breaths) and evening (18:00h, 28.5 breaths) was greater than for calves in shaded group (26.1 and 25.3 breaths, respectively) ($P < 0.05$). When ambient temperature exceeded 30°C, shaded calves spent much of their time (21.7%) lying in the loafing area, and no calf in non-shaded group preferred to lie in the loafing area with strong solar radiation ($P < 0.05$). The use of shade for calves was affected by thermal environment, and the use of shade was greater (41.4%) in hot weather (above 30°C) than that of the warm weather (22-29°C) ($P < 0.05$). In conclusion, the provision of shade above the loafing area is conducive to improving thermal environment for Dehong buffalo calves in subtropical area characterized with high ambient temperature coupled with high humidity in summer.

Key words: Dehong buffalo calves; Behaviour; Cooling effects; Shade

1. Introduction

Dehong buffalo as swamp type is one of the most famous local breed for her gentle temperament, large body size and high fiber digestion ability in China (Mei et al., 2008). Dehong buffaloes are mainly used as draught power and meat production traditionally, but they are becoming an important source of milk and meat production due to the popularization of agricultural mechanization and high quality milk.

The main production area, Dehong State, belongs to subtropical climatic region, characterized with high temperature and high humidity in summer. The optimum temperatures and humidity for growth and reproduction are 13-18°C and 55-65%, respectively (Payne, 1990). Buffaloes are well adapted to high ambient temperature through immersing in water or wetland, but it may be sensitive to heat stress due to behavioural restriction in intensive production (without wallows available). The density of skin sweat glands for buffaloes is only one-sixth of cattle (Marai and Haebe, 2010), and a great deal of solar radiation absorption from their dark skin, so buffaloes are sensitive to heat stress when body heat load is great than heat dissipation. High ambient temperature coupled with high humidity may compromise cattle production and reproduction performance (De Rensis and Scaramuzzi, 2003), and even cause death in extreme cases (Armstrong, 1994). At high environmental temperature, buffalo calves show high rectal temperature (Nessim, 2004), so buffalo calves are also lack of the ability to regulate and maintain normal body temperature. Buffalo calves suffered from heat stress exhibit low growth gains and delayed puberty, resulting in economic losses and low level of animal welfare (Ganaie et al., 2013).

Decreasing heat load is beneficial to improve animal welfare and decrease economic loss by heat stress. Water spraying is a simple and effective strategy to increase heat dissipation with evaporation, but water spraying cooling increases air humidity and causes water wastage, even decrease evaporative cooling efficiency. Cows seek protection from solar radiation to alleviate heat stress, and the provision of shade shelter is an energy saving strategy. Schütz et al. (2009) demonstrated that dairy cows preferred to rest under shade, especially shade with high solar radiation blockage. Previous researches demonstrated that the provision of a well-designed shade shelter can decrease great heat load for cows (Muller et al., 1994). In fact, buffaloes also achieved daily weight gain (0.91 kg) on shaded pastures with high ambient temperature in Brazil (Castro et al., 2008). However, the information about the impacts of shade cooling on Dehong buffalo calves is scarce by far. Therefore, this study aims to investigate the impacts of shade on physiological and behavioural characteristics for Dehong buffalo calves.

2. Materials and methods

The study was conducted at Dehong State (24.43 ° north latitude, 98.57 ° east longitude and 870 m altitude) from July 20th to August 15th in 2014, and all animal handling procedures were approved by the Animal Ethics Committee under the Yunnan Province Animal Welfare Act 2007, China.

2.1 Animals, housing and management

Black shade shelter with 99% blockage of solar radiation was used, and the shade shelter was secured at steel structure with a 2.5 m height above the floor of

loafing area (8.0 m × 5.4 m) as shaded treatment. The orientation of the shade was east-west trend, and the shaded loafing area was shaded at all times of the day. The control group was the same as the shaded treatment, apart from no shade shelter above the loafing area (non-shaded). To prevent shadow of shade shelter from overlap the loafing area of the control barn, the non-shaded and shaded barns were separated with an empty barn (8.0 m in width). The shading area is 5.0 m² per calf (Fig.1).

Twenty-four health Dehong buffalo calves that ranged from 9 to 12 month were randomly assigned to the non-shaded and shaded treatment. There were two groups in per treatment, and 6 calves were group-housed in an open-sided barn (8.0 m × 2.4 m) with anti-slippery concrete floor, and they had access to loafing area with the concrete surface. The indoor area is used as the bedding (feeding) area, and the surface of the bedding floor is also concrete (Fig.1). Single layer colored sheet steel was used as roof material of the calf house. Water trough was unshaded and located in the corner of the loafing area, and buffalo calves can obtain fresh drinking water ad libitum. All kinds of indices were individually measured for each buffalo, so each buffalo was as an experimental replication. Corn silage and green forage was distributed twice at 08:00h and 18:00h. Clean of the barns and loafing area was conducted manually twice a day.

2.2 Environmental measurements

Thermometers (±0.2°C, Testo 175H1, Testo instruments international trading, Co., Ltd, Shanghai, China) were hung 2.0 m above the bedding and loafing area floor to record the ambient temperature and relative humidity at 15 min intervals. Temperature-humidity index (THI) was calculated from temperature and relative

humidity (Tucker et al., 2008):

$$THI = (1.8 \times T + 32) - [(0.55 - 0.0055 \times RH) \times (1.8 \times T - 26)]$$

where T is the air temperature (°C), RH the relative humidity (%)

2.3 Respiration rate and body temperature measurement

Respiration rate (RR) was measured with a stopwatch at 08:00, 13:00 and 18:00, when the buffalo calves were quiet. The chest movements in a continuous 3 min were converted to breaths min⁻¹, and each measurement was recorded three times to obtain average value. Keeping calves tethered makes it easy and safe to record their body rectal temperature. Rectal temperature was recorded using veterinary electronic thermometer after respiration rate measurement to avoid disturbing the calves.

2.4 Animal behavioural observation

After 1 week of acclimatization to the environment and the experimental personnel, buffalo calves were considered free of artificial disturbance. Six calves per treatment were observed from 08:00h to 18:00h on 6 d of testing, and a frame was extracted from per 10 frames to store the video data. If the maximum ambient temperature in a sunny weather day was above 30 °C at the next day according to the local weather forecast, behavioural observation was conducted to record the impacts of shade above the loafing area on the behavioural changes for buffalo calves. Calf behaviours observed included standing, lying, drinking and the use of shade in the loafing area (Table 1). We speculated that calves may take optimal lying postures to decrease adverse effects of high ambient temperature, so horizontal and vertical lying postures were used to describe their lying posture. Horizontal lying posture was defined as

lying paralleled to the long axis of the calf house, and vertical lying posture was defined as lying paralleled to the wide of the calf housing.

2.5 Statistical analysis

Analyses were performed using IBM SPSS 21.0 (IBM Corporation, New York, N.Y., USA). Physiological and behavioural parameters were obtained from individual buffalo calf, and then data was combined in group level. Physiological parameters including rectal temperature and respiration rate were analyzed using student t-test. Behavioural data were analyzed using Mann-Whitney's U-test because of their non-normal distribution.

3. Results

3.1. Environmental conditions

Weather variables including air temperature, humidity and calculated THI are summarized in Table 2 and Fig 2. Average daily air temperature and THI were lower in shaded loafing area than that of environmental parameters in non-shaded loafing area, and the same case for the behavioural observation day from 08:00h to 18:00h.

3.2 Respiration rate and body temperature

Table 3 summarizes the rectal temperature and respiration rate of buffalo calves during the current experiment. No significant difference in rectal temperature was found between the non-shaded and shaded Dehong buffalo calves ($P > 0.05$). Although no effects of shade on respiration rate in the morning tests (08:00h), calves respiration rate of the non-shaded calves was greater compared to the shaded calves at 13:00h and 18:00h tests ($P < 0.05$).

3.3 Calves behaviour

The Dehong buffalo calves behaviours are shown in Table 4. The time budget of standing (including walking) in barns for non-shaded calves was higher than for shaded calves in warm and hot weather condition ($P < 0.05$). The time allocation of indoor standing for calves in warm condition was greater than for calves in hot condition in both non-shaded and shaded groups ($P < 0.05$).

The amount of time that the buffaloes chose to lie inside was not affected by shade treatment under warm condition, but significant difference was found calves of non-shaded group spent more than half of their time (account on 56.7%) under hot weather condition (above 30°C) compared to calves of shaded group. Under hot weather condition, non-shaded calves spent only 10.0% of their time standing in the loafing area, but no calf of the six animals observed preferred to lie in the loafing area. However, shaded calves spent great time standing (19.8%) and lying (21.7%) in the loafing area. The ambient temperature and THI had great effects on the use of shade for calves. The use of shade for calves under hot weather condition was greater compared to warm weather. We found significant effects of the shade treatment and weather conditions on the time percentages (%) of drinking for calves (Table 4).

The two main lying postures were lying in a horizontal posture (paralleled to the long axis of the calf house) and vertical posture (paralleled to the wide of the calf housing). Due to the short length of the indoor bed (2.4 m), we presume buffalo calves of the non-shaded group would adopt a horizontal lying posture to reduce solar radiation in hot weather condition, but they spent great proportion of the time lying in

vertical posture. Inversely, buffalo calves adopted horizontal posture to lie inside in shaded group (Fig.3).

4. Discussion

The calf house temperature was greater than for the loafing area under shade, and one possible reason is the low eaves and ridge (2.7 m, 4.0 m, respectively) of the calf house. Low roof and eaves may reduce air velocity, and hence increase heat load for buffalo calves. Another reason is the colored sheet steel roof with poor heat insulation ability, so sheet steel roof with insulation layer may prevent the roof from absorbing great radiant heat to keep calves thermal comfort. In the current experiment, provision of shade above the loafing area decreased the air temperature 1.5°C compared to outdoor air temperature.

Though high ambient temperature and THI in the loafing area without covering shade shelter were higher than that of the loafing area, no significant difference in rectal temperature was found between non-shaded and shaded groups for Dehong buffalo calves ($P>0.05$). One of the main reasons is calves spent most of their time on lying or standing inside to decrease solar radiation for thermal comfort, which agrees with the previous research that cow stay inside to obtain shelter to decrease heat load (Arave and Albright, 1981).

Normal respiration rate for Brahman cattle with high thermal tolerance capacity is about 20 breaths per min (Thomas and Pearson. 1986). The respiration rate for Dehong buffalo calves is similar to that of Brahman cattle, which means the Dehong buffalo calves may be certain thermal tolerance capacity. Though the age of calves

(from 9 to 12 month) may impact the respiratory rate, the respiration rate of Dehong buffalo calves in the shaded group during noon and evening was lower compared to calves of the non-shaded group. The provision of the shade shelter in the loafing area is beneficial to alleviate heat stress. Increase of the respiration rate is an effective way to increase heat dissipation (Richards, 1985). At temperature exceeded 30.0 °C, no calf of non-shaded group preferred to lie in the loafing area, but shaded calves spent 21.7% of their time lying in the loafing area, due to relative comfortable environment under shade.

Cows with water cooling spent less time near the water trough as compared to cows with no cooling treatment, when the THI increased (Legrand et al., 2011). Other researchers also reported that cows with shade cooling spent less time near the water trough (Schütz et al., 2010). However, our experiments found the time near the water trough for non-shaded calves is lower than that of shaded calves under hot weather condition (above 30.0 °C), which might be the drinking trough was located in the loafing area, and calves might be hesitate to drink in the loafing area with strong solar radiation.

In short length of inside bed (2.4 m), we presumed that adopting a horizontal lying posture for buffalo calves in the non-shaded group may reduce solar radiation. Inversely, shaded calves took great time percentage of their time lying inside in a horizontal lying posture (Fig.3). Here, we can't explain the phenomenon accurately. The shade use by farm animal is affected by the solar blockage of shade (Schütz et al., 2009; Rovira, 2014). The shade use is also affected by the solar radiation (Schütz et

al., 2009), and we found the shade use was greater in hot weather than that of warm. When temperature exceeded 25.0 °C, Fisher et al. (2008) demonstrated cow increase the use of shade, and the provision of shade can improve buffaloes' production performance in warm climates (Ablas et al., 2007). In the area with water shortage, the provision of shade above the loafing area is a water-saving cooling strategy for cows in hot weather climates. Due to the outdoor temperature exceeded 25.0 °C from 09:40h to 22:30h in most cases during the experiment, the provision of shade is beneficial to improve the thermal comfort for Dehong buffalo calves in the main production area in summer (Dehong State, subtropical climate area with high temperature and humidity).

5. Conclusions

In hot weather condition, Dehong buffalo calves change behavioural (increase the use of shade or staying indoor) and physiological responses to avoid absorb high solar radiation. Therefore, the provision of shade shelter above the loafing area is beneficial to decrease heat stress for Dehong buffalo calves in subtropical climate area with high temperature and humidity in summer.

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Table 1. Description of the Dehong buffalo calves behaviors

Behaviour	Definition or description
Lying	Body flank is in contact with the ground
Standing	Body weight is supported with four legs
Drinking	Muzzle is in contact with water
Feeding	Feed is visible in the mouth at the feed trough
Shade use	Main body is within the shadow from the shade

The location of the animals observed including the inside of the barn and loafing area.

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Table 2. Daily environmental conditions from July to August 2014

	Daily (24 h)			Observation period (8:00a.m-18:00p.m)		
	Indoor	Outdoor	Shaded	Indoor	Outdoor	Shaded
Temperature (°C)	25.3(20.9-34.6)	25.2(20.5-35.9)	23.7(20.8-30.4)	28.8(22.9-33.6)	29.8(22.5-35.0)	28.1(22.6-32.3)
Relative humidity (%)	82.9(41.9-95.3)	85.6(40.8-96.8)	87.5(42.0-97.3)	66.0(46.1-89.2)	62.5(41.8-92.3)	72.7(55.3-94.9)
THI ^a	75.7(65.9-93.3)	75.8(65.4-95.9)	73.5(65.8-86.3)	79.0(68.7-90.4)	79.9(67.9-93.4)	78.9(69.1-89.2)

Mean values and ranges (minimum to maximum) are presented.

^a Temperature–humidity index.

Table 3. Rectal temperature (°C) and respiration rate (breaths/min) for Dehong buffalo calves (mean±S.E).

	Rectal temperature		Respiration rate	
	Non-shaded	Shaded	Non-shaded	Shaded
08:00h	38.6 ± 0.3	38.6±0.2	24.7±5.0 ^a	23.1±4.6 ^a
13:00h	38.9 ± 0.2	38.7±0.3	31.6±7.3 ^a	26.1±6.6 ^b
18:00h	38.9 ± 0.2	38.9±0.1	28.5±4.5 ^a	25.3±3.8 ^b

Superscripts of different letters in the same row indicate a significant difference ($P < 0.05$).

Table 4. Time percentages (%) of observed behaviours between the non-shaded and shaded groups for Dehong buffalo calves at different periods (mean±S.E).

		Standing-in	Standing-out	Lying-in	Lying-out	Drinking	Shade use
Warm	Non-shaded	42.4 ± 4.7 ^a	13.0 ± 2.1 ^a	15.1 ± 6.4 ^a	29.5 ± 8.2 ^a	0.8 ± 0.3 ^a	-
	Shaded	55.7 ± 10.7 ^b	8.6 ± 3.9 ^b	20.3 ± 3.5 ^a	15.3 ± 4.1 ^b	0.2 ± 0.1 ^b	23.9 ± 2.6 ^a
Hot	Non-shaded	33.2 ± 3.3 ^c	10.0 ± 1.9 ^a	56.7 ± 2.7 ^b	0.0 ± 0.0 ^c	1.6 ± 0.3 ^c	-
	Shaded	20.7 ± 4.4 ^d	19.8 ± 3.0 ^c	37.8 ± 10.4 ^c	21.7 ± 5.2 ^d	2.6 ± 0.5 ^d	41.4 ± 6.2 ^b

The study was conducted from July 20th to August 15th in 2014. Dehong buffalo calves behaviours were observed from 08:00 to 18:00 h, and a frame was extracted from per 10 frames to store the video data. Warm: the outdoor air temperature ranges from 25.0 to 30 °C, and the observation time began from 08:00 to 12:41; Hot: the outdoor air temperature is greater than 30 °C, the observation time began from 12:41 to 18:00; Standing-in: indoor standing; Standing-out: standing in the loafing area; Lying-in: indoor lying; Lying-out: lying in the loafing area; Superscripts of different letters in the same column indicate a significant difference ($P < 0.05$).

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Fig. 1. Plan and cross-section of the buffalo calves house

Fig. 2. The profile of the temperature, relative humidity and THI for the outdoor ambient environment.

Fig. 3. The time percentage of the two lying postures for Dehong buffalo calves

Horizontal lying: calf body length paralleled to the long axis of the calf house; Vertical lying: calf body length paralleled to the span of the calf house.