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Short Communication

Effects of roof modifications on growth performance and physiological changes of crossbred beef heifers (*Bos indicus*)

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Abstract

The objective of the experiment was to examine and evaluate growth performance and physiological changes of cattle raised under normal roof versus a modified roof. Ten Hindu Brazil x Brahman heifers were used in the experiment. The animals were divided randomly into two groups. They were used to evaluate the effects of modified roofing on the subjects' physiological responses to heat stress and performance under hot humid conditions. It was found that the modified roof (MR) offered a more efficient way to lower heat stress in the cattle than the normal roof (NR). The difference was sufficient to enable the NR at 14:00 p.m. to have a THI higher ($P<0.001$) than that of the MR. Roof temperature of the MR (35.67±4.28°C) was found to be lower ($P<0.01$) than that of the NR (44.49±7.61°C). Rectal temperature (RT) and average rate of gain (ADG) of the cattle kept under MR (39.02°C; 0.632 kg/d) was lower ($P<0.01$) and higher ($P<0.01$), respectively than the NR (40.05 °C; 0.350 kg/d) cattle.

Keywords: roof modification, temperature humidity index, growth performance, physiology, beef heifer

1. Introduction

The effects of heat stress on animal production are well known and have been investigated and documented for a number of years. In pioneering research at the Climatology Laboratory in Missouri, the relationships between high ambient temperature and increased rectal temperature of dairy cows (Johnson, 1987) and the subsequent impact on milk yield, feed, and energy intakes (Tyrrell *et al.*, 1988; Kirchgessner *et al.*, 1991) were established. The impact of heat stress can be reduced by recognizing the adaptive ability of animals, and by proactive application of appropriate counter-measures such as sunshades and evaporative cooling in conjunction with mechanical ventilation (Hahn *et al.*, 1992).

Heat stress is caused by an inappropriate combination of environmental factors including air temperature, solar radiation, humidity, and wind velocity. There have been many attempts to develop an index that relates these specific environmental characteristics to the physiological variables of an animal such as heart rate, respiration rate and volume, sweating rate, and body temperature.

Thermal stress in cattle results in major decreases in production each summer (McDowell, 1958). These decreases have been documented in many studies and reviews (Collier *et al.*, 1982; Ray *et al.*, 1992; Armstrong, 1994; Ravagnolo and Miztal, 2000; Willmer *et al.*, 2000). Igono *et al.* (1992) proposed that the *temperature humidity index* (THI) could be used to evaluate the level of thermal stress imposed by the environment. This index combines relative humidity and temperature parameters into a single value that provides an estimate of the potential environmental heat load. An environment is generally considered stressful for cattle when the THI exceeds 72; when THI is at or above this level, adverse effects including rises in rectal temperature (Legates *et al.*,

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1991) are expected. Other researchers have also suggested (Hahn *et al.*, 1992; Khongdee *et al.*, 2006) that the feed intake of cattle will be reduced when ambient temperatures exceed 23.9°C.

Shades, including the addition of simple roofing, have been shown to reduce solar radiation (Blackshaw and Blackshaw, 1994). For example, polypropylene fabric sheet shade cloth with 70-80% shading has been placed above animals to reduce the solar radiation load on livestock (Bucklin *et al.*, 1993). Khongdee *et al.* (2005, 2008) placed a polypropylene fabric sheet (80%) 100 cm above the roof of a dairy cattle shed. The dairy cattle which were housed in such sheds have yielded more milk than those which lived under a bare roof shed.

Therefore, an experiment using a black woven polypropylene sheet (WPSC = shade cloth with 80% shade factor, Polysac Co., Bangkok, Thailand) was designed, to investigate some of the biological performances of beef (*B. indicus*) in Thailand.

2. Materials and Methods

A herd of Hindu Brazil–Brahman crosses (50% Hindu Brazil X 50% Brahman) was maintained at the Chainat College of Agriculture and Technology, Chainat Province (latitude 15° 162 N, longitude 100° 062 E and at 18 m above sea level). The study was carried out at the college for 157 days (27 December 2010 – 30 May 2011).

The animal housing was a free-stall type of open shed, orientated East–West in direction and with the front facing North. The animal house was fitted with a corrugated galvanized iron roof (CGIR), and had a highest height point of 4 m above the ground with a slope of 0.375 m/m.

Ten beef heifers, approximately of 2 years of age (average weight 240 kg,) were randomly selected from the above herd of cattle and used in the present experiment. They were divided randomly into two groups of equal size and assigned to two treatments.

2.1 Treatment

Treatment 1 (normal roof, NR): Five crossbred beef heifers were maintained in the open shed (5×10 m) fitted with CGIR.

Treatment 2 (modified roof, MR): Five crossbred beef heifers were maintained in a similar open shed — adjacent to that of Treatment 1—except that at 80 cm above the CGIR, a WPSC (WPSC shade cloth with 80% shade factor, Polysac, Bangkok, Thailand) was stretched over the CGIR and the space between the shade cloth and the roof was freely ventilated.

A period of 14 days was allowed for adaptation, and all animals were injected with Ivermac® subcutaneously at 14 days prior to the commencement of the experiment. Roughages and concentrates (Table 1) were used in the present experiment. The animals were group fed twice daily. While the roughage was fed ad libitum, the amount of concentrate (commercially produced) offered to the animals was according to NRC (2001). Water was available to the animals at all times. The feed was analyzed (Van Soest *et al.*, 1991; AOAC, 2000) and shown in Table 1.

2.2 Temperature measurements

Thermometers (mercury in glass) comprising wet and dry bulb thermometer (Shanghai Yilian Control Temperature Apparatus Factory, Yangpu, Shanghai, PR China) and a Black Globe thermometer (BG, Somparn, 2004) were placed at each pen both inside (middle of the pen) and outside (2 m) away from the animal house at a height of 160 cm above floor i.e. beyond the reach of the animals. Temperature humidity index (THI) is determined by calculation using Armstrong's formula (Armstrong, 1994) as follows:-

$$THI = T_{db} + 0.36(T_{dp}) + 41.2 \qquad (1)$$

where T_{db} is the dry bulb temperature (°C) and T_{dp} is the dew point temperature (°C).

The values of the Black Globe, WB, DB, THI and roof temperatures from both the modified roof (MR) and normal roof (NR) were collected daily at 08:00, 14:00 and 17:00 h. The roof temperatures were collected from the underside of the roofs using an infrared thermometer (Infrared Thermometer Model ST-660, Sentry Optronics Corps., China).

2.3 Blood sampling

Blood samples were drawn from the coccygeal vein at weekly intervals. They were then transferred to a laboratory where they were spun with a centrifuge at 3,000 rev/min to separate the serum, which was then stored at -20°C for further analyses. The blood serum samples were analyzed for cortisol and free triiodotyronine (T_3) at the Hormones Laboratory, Faculty of Medicine, Chulalongkon University using Elecsys 2010/1010 (Roche, Mannheim, Germany) to detect T_3

Table 1. Feed compositions of rice straw, mixed grass and concentrates.

	Straw	Grass	Feed
Moisture (%)	7.04	7.8	7.63
Protein (%)	5.26	7.92	18.83
Lipid (%)	1.21	2.4	4.83
Ash (%)	13.72	9.73	11.74
Total fiber (%)	30.91	26.55	9.16
NDF (%)	69.08	61.97	31.31
ADF (%)	48.1	34.93	18.48
Ca (%)	0.22	0.4	1.38
P (%)	0.01	0.24	0.98
NaCl (%)	0.25	NA	0.45

and to measure cortisol (Siemens Medical Solutions Diagnostics, Erlangen, Germany).

2.4 Statistical analysis

The experiment was of completely randomized design (CRD) and used the statistical analysis used ANOVA to find the difference between NR and MR (Steel and Torrie, 1980). The model used was

$$Yij = \mu + Ai + \xi ij$$

where Yij = variable of animal No. j, in group ith ;
μ = population mean;
Ai = influence of animal No. i ($I = 1, 2$).
εIj = the experimental error from random;
$\varepsilon ij <$ NID ($0, \varepsilon e2$); and NID is normally independently distributed.

T-test was used PROC TTEST of SAS V. 9.0 (SAS Institute 1999) to find the difference between treatment and mean values. These are shown with ± SD (standard deviation).

3. Results and Discussion

Feed composition of rice straw, mixed grass and concentrates are shown in Table 1. The results of roof surface temperature, Black Globe temperature, ambient temperature (D.B.) and relative humidity (R.H.) measured at 8:00 am., 14:00 and 17:00 pm. under modified roof, normal roof, and outside the sheds are shown in Table 2.

The results (Table 2) revealed that the WPSC effectively reduced ambient temperature, especially when there was strong sunlight (14:00 pm.). This was because part of the solar heat load was absorbed by the WPSC and therefore the solar energy was much reduced by the time it reached the roof underneath. Therefore, the roof surface temperature of the MR (35.67±4.28°C) was found to be significantly lower than that of the NR (44.49±7.61°C) (Table 2). Such reduction of roof surface temperature occurred throughout the experi-

Table 2. Mean±SD °C of roof surface temperature (°C); Black Globe, ambient temperatures, relative humidity (% R.H.) and temperature humidity index measured at 8:00 am, 14:00 and 17:00 pm under modified roof, normal roof and outside the sheds.

Time	MR±SD	NR±SD	OS±SD	P value
Roof Temp (°C)				
	35.67±4.28^{y}	44.49±7.61^{x}		0.005
Ambient Temperature (Black Globe; °C)				
8:00	23.37±2.24^{y}	22.85±1.89^{y}	24.75±2.39^{x}	<0.0001
14:00	33.02±2.77^{y}	33.14±2.82^{y}	43.10±3.10^{x}	<0.0001
17:00	30.53±2.12	30.05±1.76	30.53±1.99	NS
Ambient Temperature (Dry Bulb; °C)				
8:00	23.02±2.33	23.42±2.25	23.39±2.25	0.5853
14:00	31.68±2.21^{z}	32.73±2.34^{y}	36.15±2.65^{x}	<.0001
17:00	29.93±2.17	30.41±2.09	30.72±2.10	0.1307
Relative Humidity (%)				
8:00	84.75±8.44^{y}	84.00±8.97^{y}	88.77±6.00^{x}	0.0025
14:00	52.07±7.83^{b}	55.40±8.94^{a}	56.89±9.82^{a}	0.0128
17:00	60.54±9.15^{y}	63.31±8.42^{y}	69.59±9.48^{x}	<.0001
Temperature Humidity Index (THI)				
8:00	71.49±3.43	71.97±3.34	72.29±3.49	0.4421
14:00	80.26±3.02^{z}	82.00±3.09^{y}	86.73±3.39^{x}	<.0001
17:00	78.88±2.90^{y}	79.75±2.72^{y}	80.80±2.91^{x}	0.0015

a, b, c – Means within a row with different superscripts are significantly different (P<0.05). x, y, z – Means within a row with different superscripts are highly significantly different (P<0.01).

mental period (day time). Furthermore, the results from Table 2 indicated that ambient temperature under the modified roofs was lower ($P<0.05$) than in locations where there was a complete absence of roofing (i.e. open air outside the shed), especially in the afternoon.

It can be seen (Table 2) that there is no statistical difference ($P>0.05$) in the THI under MR, NR, and OS areas in the morning (71.49±3.43, 71.97±3.34 and 72.29±3.49, respectively). This may be attributed to the fact that solar radiation in the morning is less strong than during other parts of the day (Amakiri and Funsho, 1979; Bonan, 2008). However, there are high statistical differences ($P<0.001$) in the THI at 14:00 and 17:00 pm. of the MR, NR and OS areas. The values of the THI at 14:00 pm. of these areas were such that the THI of MR (80.26±3.02) was significantly ($P<0.001$) lower than that of NR (82.00±3.09), which in turn was significantly ($P<0.001$) lower than that of OS (86.73±3.39^{x}). Furthermore, the values of the THI at 17:00 pm. of the MR, NR and OS areas were such that the THI of MR (78.88±2.90) was significantly ($P<0.001$) lower than that of NR (79.75±2.72), which in turn was significantly ($P<0.001$) lower than that of OS (80.80±2.91). The threshold of THI for beef cattle (*B. taurus*) was found to be 72.9 (Amundson *et al*., 2006). Although the THI did not include direct solar heat load to the animal's body (Gaughan *et al*., 2008), in the present experiment the animals were kept under modified and normal roofs. Therefore cattle that were kept under MR were less stressed by heat than those that were kept under NR, particularly with respect to the later part of the day. This is due to the fact that part of the incoming solar energy was absorbed and dissipated by the shade cloth above the MR.

Table 3. Rectal temperature (°C) of the cattle kept under modified roof (MR±SD) and normal roof (NR±SD) over the experimental period.

Time	MR±SD (°C)	NR±SD (°C)	P value
T1(Dec wk4)	39.28±0.19	39.14±0.39	0.4931
T2(Jan wk1)	38.98±0.48	39.44±0.44	0.1511
T3(Jan wk 2)	39.02±0.36^{b}	39.62±0.41^{a}	0.0397
T4(Jan wk3)	38.88±0.63	39.52±0.36	0.0834
T5(Jan wk4)	38.98±0.29	39.28±0.53	0.2954
T6(Feb wk 1)	38.82±0.29^{y}	39.54±0.36^{x}	0.0089
T7(Feb wk 2)	38.94±0.26^{y}	39.58±0.38^{x}	0.0142
T8(Feb wk 3)	38.66±0.50^{y}	39.78±0.23^{x}	0.0019
T9(Feb wk 4)	38.70±0.27^{y}	39.64±0.09^{x}	<.0001
T10(Mar wk1)	38.72±0.30^{y}	40.46±0.59^{x}	0.0004
T11(Mar wk2)	38.90±0.42^{y}	40.36±0.59^{x}	0.0020
T12(Mar wk3)	38.80±0.27^{y}	40.20±0.45^{x}	0.0003
T13(Mar wk4)	38.50±0.00^{y}	40.38±1.08^{x}	0.0048
T14(Apr wk1)	39.30±0.27^{y}	40.42±0.68^{x}	0.0093
T15(Apr wk2)	39.54±0.29^{y}	40.68±0.49^{x}	0.0020
T16(Apr wk3)	39.46±0.35^{y}	40.38±0.15^{x}	0.0006
T17(Apr wk4)	39.22±0.26^{y}	40.68±0.49^{x}	0.0004
T18(May wk1)	39.42±0.40^{y}	40.42±0.35^{x}	0.0029
T19(May wk2)	39.16±0.21^{y}	40.64±0.35^{x}	<.0001
T20(May wk3)	39.30±0.27^{y}	40.66±0.33^{x}	0.0001
T21(May wk4)	38.92±0.24^{y}	40.16±0.54^{x}	0.0016
All	39.02±0.41^{y}	40.05±0.67^{x}	<.0001

a, b – Means within a row with different superscripts are statistically different ($P<0.05$). x, y – Means within a row with different superscripts are highly statistically different ($P<0.01$).

The results of rectal temperature (RT; Table 3) revealed that the rectal temperature (RT) of the cattle kept under MR (39.02±0.41°C) were significantly lower ($P<0.01$) than that of their counterpart animals which were kept under the NR (40.05±0.67°C). This is due to the difference in the ambient heat load applying, respectively to the two groups of animals ($P<0.01$; Table 3). Khongdee *et al.* (2005) found that the RT of dairy cattle (Holstein Friesian crossbred) kept under similar MR were also significantly ($P<0.01$) lower than those of the Holstein crossbreds that were kept under NR. When the RT value of B. taurus reaches 41.7°C as a result of heat stress, this could be fatal (Vajrabukka, 1978).

Plasma hormones are important as potential indicators of the physiological status of cattle and reflect the physiological compensations undergone by the cattle at various stages of exposure to heat stress (Aggarwal and Upadhyay, 2013). The results over the experimental period (Table 4) demonstrate that the cortisol of the animals housed under

Table 4. Cortisol (µg%) values of cattle kept under modified roof (MR) and normal roof (NR) over the experimental period.

Cortisol (µg%) and			
Month	MR±SD	NR±SD	P value
Dec	0.93±0.67	0.70±0.26	0.6028
Jan	0.77±0.21	1.40±0.89	0.2958
Feb	1.60±0.87	2.23±1.07	0.4711
Mar	2.03±1.00	2.07±1.11	0.9711
Apr	1.70±0.66	2.77±1.33	0.2812
May	2.03±1.01	2.83±0.06	0.2433
All	1.51±0.83	2.00±1.09	0.1402
Free triiodotyronine (pg/ml)			
Month	MR±SD (pg/ml)	NR±SD (pg/ml)	P value
Dec	4.69±0.33^{x}	3.41±0.271^{y}	0.0066
Jan	4.23±0.39	4.83±0.93	0.358
Feb	4.04±0.51^{a}	3.15±0.27^{b}	0.0546
Mar	4.55±0.92	4.58±0.89	0.9729
Apr	3.40±0.56	2.78±0.42	0.204
May	3.59±0.62	3.74±0.53	0.7611
All	4.08±0.69	3.75±0.92	0.2254

a, b – Means within a row with different superscripts are statistically different ($P<0.05$). x, y - Means within a row with different superscripts are highly statistically different ($P<0.01$).

MR (1.51±0.83 µg%) was lower ($P>0.05$) than that of the animals housed under NR (2.00±1.09 µg%). Elevated plasma cortisol and lowered plasma triiodotyronine (T_3) concentration in an animal may reflect stress due to high temperature (Chaiyabutr *et al.*, 2008). Furthermore, it can be seen that the T_3 of the animals under MR (4.08±0.69 pg/ml) was higher ($P>0.05$) than that of the animals under NR (3.75±0.92 pg/ml). In response to heat stress, the level of cortisol in dairy cattle has been shown to increase (Wise *et al.*, 1988) while the level of T_3 decreased due to heat stress (West, 2003).

Heat stress reduces dry matter intake (DMI) (Fuquay, 1981; Beede and Collier, 1986; McGuire *et al.*, 1991; Bova *et al.*, 2014). However, the DMI of the MR heifers (7.61 kg/d) was slightly higher than that of the NR heifers (7.39 kg/d). Furthermore, the water intake (WI) of the MR animals (28.97 l/d) was also slightly higher than that of the NR animals (27.19 l/d). Ambient temperature may influence both DMI and WI of cattle, such that increasing ambient temperature will decrease DMI but increase WI (NRC, 1981; Arias and Mader, 2011).

The results of the present experiment (Table 5; Figure 1) indicate that the cattle housed under the MR (Average Daily Gain, ADG = 0.632 kg/d) grew significantly ($P<0.01$) better than the NR (ADG = 0.350 kg/d) cattle. This could be due to the MR animals being less stressed by heat than the NR animals as reflected by a significantly higher RT of the NR heifers, and thus maintenance requirements increase as the cattle attempt to dissipate excess heat load (West, 1999). The more thermally stressed an animal is, the more energy it will spend to get rid of the excessive heat, as indicated by the NR animals having higher FCR than the MR animals.

The results of the present experiment have shown that the installation of a WPSC above the roof effectively ameliorates heat stress of animals living under it, thereby resulting in improved growth performance of beef heifers.

Table 5. Live weight (kg/hd{head}), ADG (kg/d/hd), DMI (dry matter intake; kg/d/hd), WI water intake; litre/d/hd) and FCR of the cattle kept under modified roof (MR±SD) and normal roof (NR±SD) over the experimental period.

Day	MR±SD	NR±SD	P value
1	245.60±6.07	224.40±19.87	0.0519
20	248.80±8.20	236.80±12.36	0.108
34	262.40±11.51^{a}	241.20±12.30^{b}	0.0227
64	271.80±14.57^{a}	246.00±10.77^{b}	0.0129
78	281.40±14.31^{x}	249.40±9.15^{y}	0.0029
99	310.60±12.44^{x}	267.20±7.08^{y}	0.0002
157	344.80±9.39^{x}	279.40±3.71^{y}	<0.0001
ADG (kg/d/hd)	0.632±0.009^{x}	0.350±0.046^{y}	<0.0001
DMI (kg/d/hd)	7.61	7.39	group fed
WI (liter/d/hd)	28.97	27.19	group fed
FCR	12.05	21.12	

a, b – Means within a rows with different superscripts are statistically different ($P<0.05$). x, y - Means within a rows with different superscripts are highly statistically different ($P<0.01$).

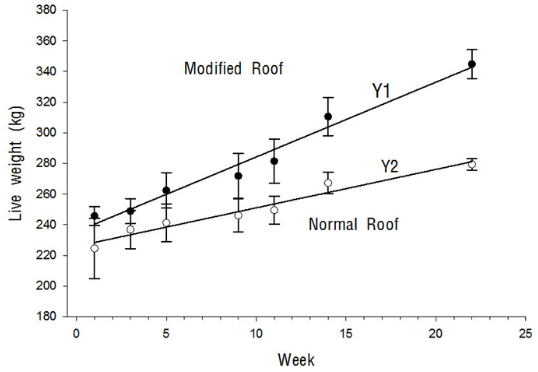

Figure 1. Live weight (kg) of the cattle kept under modified roof (MR±SD) and normal roof (NR±SD) over the experimental period $Y2=225.8+2.51X$, $R^2=0.95$; $Y1=235.4+4.87X$, $R^2=0.97$.

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