PJN
ISSN 1680-5194

PAKISTAN JOURNAL OF NUTRITION

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

OPEN ACCESS Pakistan Journal of Nutrition

ISSN 1680-5194
DOI: 10.3923/pjn.2018.190.198

Research Article
Transfer of Thai Native Cattle Feeding Technology to Cattle Farmers in Rural Communities in Sakon Nakhon Province, Thailand, in Response to Global Warming to Produce Cattle with the Characteristics of Physiological Adaptability, Heat Tolerance and Increased Production Performance

[1]Umpapol, H., [1]Songwicha, C., [1]Jitrajak, T., [1]Patkit, A. and [2]J. Sripandon

[1]Program in Animal Science, Faculty of Agriculture Technology, Sakon Nakhon Rajabhat University, 47000 Sakon Nakhon Province, Thailand
[2]Mukdahan Provincial Livestock Office, Department of Livestock Development, 4900 Mukdahan, Thailand

Abstract
Objective: The objective of this study was to investigate the integration of cattle feeding technology, which was appropriate to transfer to local farmers, to produce Thai native cattle with the characteristics of adaptable physiology and heat tolerance in response to global warming in the rural communities of Sakon Nakhon province, Thailand. **Methodology:** The experiment was conducted by raising 16 castrated male Thai native cattle; their body weights were commensurate with their body condition scores and genetic characteristics and they were allocated to a randomized complete block design. Blood samples were collected to analyze the hematocrit, hemoglobin, blood glucose and blood urea nitrogen. Four experimental concentrate formulas, each containing 12% protein and 72% total digestible nutrients (TDN), were used as follows: (1) Control feed concentrate, (2) 15% para rubber seed meal concentrate, (3) 15% palm kernel seed meal concentrate and (4) 15% cotton seed meal concentrate. Data analysis were conducted using an analysis of variance (ANOVA) to investigate the relation between the meteorological factors and the general physiological changes in Thai native cattle. **Results:** The values for the temperature humidity index (THI) showed that the ambient temperature was significantly related to each of the maximum, average and minimum temperatures and to the relative humidity, with a significant difference ($p<0.01$). The data analysis showed that although the THI values increased, they did not affect the general physiological changes of Thai native cattle ($p>0.05$). The general physiological parameters, welfare, behavior characteristics and hematological values of Thai native cattle were not significantly different ($p>0.05$). The production performance of experimental Thai native cattle as shown by the intake of concentrate and roughage feeds, initial body weight, final body weight and average daily growth rate or average daily gain (ADG), was significantly different ($p>0.05$). **Conclusion:** Thai native cattle that received 4 different concentrate formulas could tolerate high-ambient-temperature environments and the concentrate formulas had no effect on physiological changes and growth performance.

Key words: Physiological change, heat stress, animal welfare and behavior, appropriate technology transfer, Thai native cattle's production performance

Received: August 24, 2017 Accepted: February 08, 2018 Published: March 15, 2018

Citation: Umpapol, H., Songwicha, C., Jitrajak, T., Patkit, A. and J. Sripandon, 2018. Transfer of Thai native cattle feeding technology to cattle farmers in rural communities in Sakon Nakhon province, Thailand, in response to global warming to produce cattle with the characteristics of physiological adaptability, heat tolerance and increased production performance. Pak. J. Nutr., 17: 190-198.

Corresponding Author: Umpapol, H., Program in Animal Science, Faculty of Agriculture Technology, Sakon Nakhon Rajabhat University, 47000 Sakon Nakhon Province, Thailand

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The production of Thai native (TN) cattle, particularly Zebu cattle (*Bos taurus indicus*), has been ongoing for many years in Thailand. When they are young, they are raised as draught animals for drawing a cart and plowing. When they become old, they are removed from the herd for slaughter. TN cattle propagation has increased widely and continuously. As shown in the 2014 statistical record, there were more than 2 million heads of TN cattle[1]. This type of cattle has a compact body and is adaptable to the local environment. They have a high tolerance for heat, high grazing ability, good reproductive system and regular annual calving ability. Given the aforementioned advantages, raising TN cattle is popular with Thai farmers. However, research data and knowledge about raising TN cattle efficiently and effectively are quite rare. Global warming has affected the products of animal origin, such as beef and meat. Even milk and dairy products have been greatly affected, the high ambient temperature causes heat stress in animals and interferes with the general physiological function, hematological system function, mechanisms of hormone production and secretion, animal behavior and welfare and animal production/performance[2]. Since the TN cattle that live in the tropical zone can adapt well to the environment by reducing their food intake for body thermoregulation, they can create a heat balance in their bodies. Because TN cattle evolved long ago, their bodies are so compact, jaunty and active that they can survive in Thailand's climate[3]. In addition to these strengths, if they have an opportunity to obtain some positive factors, such as sufficient nutritional food supplements to meet the body's needs, they will grow well and provide many benefits to the farmers who raise them. The results of this study can be used efficiently by farmers to earn their living, leading to an improvement of their cattle production practices. Thus, this study aimed to investigate a transfer of the appropriate integrated technology to TN cattle farming practices. The goal was to harmonize with TN cattle physiological adaptability and heat tolerance in response to global warming in the rural community conditions in Sakon Nakhon province by using local feedstuff, such as para rubber seed meal (PSM), palm kernel seed meal (PDSM) and cotton seed meal (CSM) at 15% of the feed formula with 12% protein and 72% total digestible nutrient (TDN).

MATERIALS AND METHODS

Sixteen castrated male TN cattle that had similar body weights, body condition scores and a similar genetic balance were evaluated in a preliminary experimental period of 2 weeks for their body adjustments and were then allocated in a randomized complete block design (RCBD). During this period, all cattle were arranged to obtain the factors of interest. Blood samples were collected to analyze the hematological values, namely, hematocrit (Hct), hemoglobin (Hb), blood glucose (BG) and blood urea nitrogen (BUN). Four experimental concentrate feed formulas with 12% protein and 72% total digestible nutrients (TDN) were used as follows: (1) Control concentrate feed with 3% minerals, (2) 15% PSM concentrate, (3) 15% PKSM meal concentrate and (4) 15% CSM concentrate. The experimental roughage used was rice straw and cattle mineral blocks from the Department of Livestock Development were used for free choice licking. The cattle houses in this study belonged to local farmers and were covered with a single-slope shed roof of zinc mixed-metal sheets with no ceiling. They were open houses under the normal climatic conditions and normal ventilation. Inside the houses, they were divided into individual lots with individual waterers and feeders.

Data were collected on the meteorological factors and general physiological changes, the respiration rate, rectal temperature and pulse rate[4], heat tolerance coefficient[5], sweating rate[6], hematological values were obtained by the micro-hematocrit method, the hemoglobin levels were obtained by the acid hematin method[7] and the cortisol levels were obtained by the RIA method using the Amerlex Cortisol RIA Kit Code IM. 2021 Kodak Clinical Diagnostics Ltd., Amersham UK[8]. Data on the production performance of experimental cattle were collected, such as the weights of concentrate and roughage intake and the body weights of the cattle. Analysis of concentrate and roughage quality, such as dry matter, crude protein, lipid, ash, calcium and phosphorous, was conducted[9]. Analysis of roughage for the percentage of acid detergent fiber (ADF) and neutral detergent fiber (NDF)[10] was also performed.

The data were analyzed for the relation between the meteorological factors and general physiological changes in the experimental cattle through polynomial regression analysis and an analysis of variance of general physiological changes and cattle production performance[11] was also performed. The differences between the means of studied factors were compared using least squares means. Analysis of animal welfare and behavior of TN cattle was performed using assessment tools that had been developed by the researchers in this study.

The locations, houses and TN cattle evaluated in this experiment belonged to the local farmers. Analyses of hematological values (hematocrit, hemoglobin, blood glucose, blood urea nitrogen and cortisol levels) were conducted at the Department of Animal Science, Faculty of Agricultural Technology, Sakon Nakhon Rajabhat University. Analysis of the composition of cattle feeds was done at the Department of Animal Husbandry, Faculty of Agriculture, Kasetsart University (Bangkhen campus, Bangkok) and at the Science Center of Sakon Nakhon Rajabhat University. This experiment started in October, 2008 and ended in September, 2009.

RESULTS

The result showed that the housing characteristics influenced the inside environment surrounding the cattle. The observed value for the temperature humidity index (THI) was 88.74±3.46 and it was affected by ambient temperature environments (Table 1). The analysis of the relation between THI and ambient temperature showed a significant difference ($p<0.01$) (Table 2), additionally, the influence of solar radiation on TN cattle housing affected the ambient temperature environments, which showed a THI of 80.03±2.48 (Table 3). From polynomial regression analysis, the relation between the ambient environmental values for THI and general physiological changes of experimental cattle was significantly different ($p>0.05$) (Table 4).

The experimental cattle fed different concentrates for treatments 1, 2, 3 and 4 showed general physiological changes, heat tolerance coefficients, sweating rates and drinking water volumes that were not significantly different ($p>0.05$) (Table 4). The animal welfare and behavior of the experimental cattle was not significantly different ($p>0.05$) (Table 5) and there was no effect on the hematological values (Hct, HG), cortisol concentrations and blood urea nitrogen (BUN) levels, which were not significantly different ($p>0.05$) (Table 6-10).

Comparison of nutrient compositions among experimental feeds of treatments 1, 2, 3 and 4 including nutrient composition in roughage was found that they were not significantly different ($p>0.05$) (Table 11 and 12). Analysis of effect of experimental feed (concentrate and roughage) on production performance (final body weight, gain in weight and ADG) of TN cattle was not significantly different ($p>0.05$) (Table 13).

Table 1: Factors of ambient temperature environments affecting environmental conditions during the experimental session

Ambient environments	Mean±S.E.
Maximum temperature (°C)	35.02±0.41
Average temperature (°C)	29.68±0.28
Minimum temperature (°C)	24.34±0.16
Different temperature (°C)	10.68±0.26
Relative humidity (%)	80.78±1.20
Black globe temperature (°C)*	48.78±0.94
Temperature of dry bulb thermometer (°C)	37.26±0.49
Solar radiation (°C)	11.52±0.62
Temperature-humidity index (THI)	88.74±3.46

*Temperature which was measured from the middle of brass bulb of thermometer that sprayed with black color, this figure was temperature and added with heat from solar radiation

Table 2: Analysis of relation between temperature humidity index (THI) and ambient environment (maximum, average, minimum and different temperatures)

	Ambient temperature				
Ambient environments	THI	Maximum	Average	Minimum	Different
THI	1.00**	0.72**	0.54**	0.72**	0.62**
Maximum temperature	0.74**	1.00**	0.62**	0.96**	0.90**
Average temperature	0.51**	0.64**	1.00**	0.78**	0.30**
Minimum temperature	0.72**	0.92**	0.78**	1.00**	0.80**
Different temperature	0.58**	0.90**	0.30**	0.76**	1.00**

**Means a highly significant difference ($p<0.01$)

Table 3: Effects of influence of solar radiation on ambient environments

Environment factors	Average parameters
Black globe temperature (°C)	37.42±0.62
Temperature of dry bulb thermometer (°C)	34.63±0.58
Solar radiation (°C)	2.79±0.34
Normal temp. in the house (mercury bulb) (°C)	32.86±0.24
Temperature in cattle house	
Maximum temperature (°C)	33.28±0.41
Average temperature (°C)	28.31± 0.19
Minimum temperature (°C)	23.34±0.16
Different temperature (°C)	9.94±0.24
THI	80.03±2.48

Table 4: Means of general physiological items of TNC in each feed formula

	Feed formula			
General physiological	1	2	3	4
Rectal temperature (°C)	39.34±0.03	39.30±0.03	39.32±0.03	39.24±0.03
Pulse rate (BPM)	70.24±4.76	68.86±3.62	68.20±3.89	67.98±3.84
Respiration rate (times sec^{-1})	70.34±5.68	72.00±6.73	72.00±6.73	70.34±3.51
Heat tolerant co-efficient (%)	80.95±4.60	82.65±5.14	82.74±4.20	83.96±2.47
Sweating rate(mL m^{-2} h^{-1})	924.12±26.83	938.42±20.48	942.86±21.74	940.49±18.68
Water consumption (L/day)	22.23±2.54	21.74±2.38	23.48±2.62	24.30±2.71

Means within the same row did not differ significantly (p>0.05)

Table 5: Means of animal welfares and behaviors of Thai native cattle in this experiment

	Feed formula							
	1		2		3		4	
Behaviors	Mean±S.D.	INTPN*	Mean±S.D.	INTPN	Mean±S.D.	INTPN	Mean±S.D.	INTPN
Rumination	4.16±0.12	High	4.20±0.16	High	4.24±0.14	High	4.16±0.15	High
Gasping								
Respiration	2.46±0.20	MOD.	2.36±0.24	MOD.	2.42±0.28	MOD.	2.34±0.26	MOD.
Standing and walking for drinking	2.36±0.32	MOD.	2.38±0.28	MOD.	2.38±0.26	MOD.	2.30±0.24	MOD.
Rest and lying	2.42±0.20	MOD	2.38±0.24	MOD.	2.32±0.25	MOD.	2.48±0.24	MOD.

Means within the same row with different superscript differed significantly (p<0.05), INTPN: Interpretation, MOD.: Moderate

Table 6: Means of hematocrit of experimental cattle in preliminary-experiment, during experiment, post-experiment and whole period of this experiment

	Hematocrit (%)			
Feed formulas	Pre-experiment	During experiment	Post-experiment	Whole period of experiment
1	29.34±0.32	32.46±0.41	34.26±0.39	32.02±0.37
2	29.72±0.30	34.04±0.34	36.86±0.42	33.54±0.35
3	29.38±0.34	35.72±0.46	37.02±0.37	34.04±0.39
4	30.40±0.43	33.24±0.32	36.14±0.40	33.26±0.38

Means within the same column did not differ significantly (p>0.05)

Table 7: Means of hemoglobin of experimental cattle in preliminary-experiment, during experiment, post-experiment and whole period of this experiment

	Hemoglobin (%)			
Feed formulas	Pre-experiment	During experiment	Post-experiment	Whole period of experiment
1	30.14±0.42	34.64±0.44	36.00±0.60	33.59±0.49
2	32.50±0.39	34.18±0.48	38.48±0.72	35.05±0.53
3	31.25±0.36	34.78±0.64	36.25±0.60	34.09±0.53
4	32.34±0.32	35.86±0.53	38.30±0.64	35.50±0.50

Means within the same column did not differ significantly (p>0.05)

Table 8: Means of cortisol hormone concentration in preliminary-experiment, during experiment, post-experiment and whole period of this experiment

	Cortisol hormone (ηg mL^{-1})			
Feed formulas	Pre-experiment	During experiment	Post-experiment	Whole period of experiment
1	13.02±0.04	12.62±0.04	10.24±0.04	11.96±0.03
2	14.72±0.03	13.48±0.02	10.76±0.04	12.99±0.03
3	13.28±0.04	12.14±0.04	9.82±0.03	11.75±0.04
4	12.54±0.05	12.02±0.04	10.04±0.02	11.53±0.05

Means within the same column did not differ significantly (p>0.05)

Table 9: Means of blood glucose concentration in preliminary-experiment, during experiment, post-experiment and whole period of this experiment

	Blood Glucose (mg/100 mL)			
Feed formulas	Pre-experiment	During experiment	Post-experiment	Whole period of experiment
1	42.20±0.48	42.40±0.68	44.36±0.70	42.99±0.62
2	42.14±0.74	42.65±0.69	42.45±0.64	42.41±0.69
3	44.50±0.64	45.29±0.72	45.47±0.62	45.09±0.66
4	43.26±0.68	43.40±0.48	44.36±0.72	43.67±0.63

Means within the same column did not differ significantly (p>0.05)

Table 10: Means of blood urea nitrogen concentration in preliminary-experiment, during experiment, post-experiment and whole period of this experiment

	Blood urea nitrogen (mg/100 mL)			
Feed formulas	Pre-experiment	During experiment	Post-experiment	Whole period of experiment
1	14.04±0.25	15.17±0.41	15.66±0.32	15.66±0.32
2	14.06±0.27	15.09±0.51	16.12±0.14	16.12±0.14
3	14.06±0.09	14.97±0.36	16.11±0.37	16.11±0.37
4	14.10±0.06	15.24±0.20	16.08±0.24	16.14±0.20

Means within the same column did not differ significantly (p>0.05)

Table 11: Composition of experimental feed (concentrate) in each treatment

	Feed formula			
Feed composition	1	2	3	4
Moisture (%)	8.36±0.20	8.84±0.32	8.68±0.34	8.74±0.36
Dry matter (%)	91.48±2.76	90.96±3.04	91.36±3.10	91.08±3.24
Crude protein (%)	12.32±0.18	12.48±0.14	12.24±0.16	12.34±0.12
Lipid (%)	5.72±0.04	6.20±0.04	6.28±0.03	6.34±0.04
NDF (%)	26.48±0.84	27.64±0.74	29.76±0.76	28.04±0.58
Lignocellulose (%)	22.68±0.64	24.84±0.72	24.06±0.64	24.72±0.70
Ash (%)	9.14±0.14	9.38±0.16	9.76±0.12	9.94±0.16
Calcium (%)	1.48±0.02	1.64±0.03	1.62±0.02	1.76±0.03
Phosphorous (%)	0.58±0.04	0.62±0.02	0.70±0.02	0.74±0.03
Energy (Kcal kg^{-1})	4.28±0.03	4.38±0.06	4.40±0.04	4.69±0.02

Means within the same row did not differ significantly (p>0.05)

Table 12: Composition of experimental feed (roughage)

Items	Means±S.E.
Moisture (%)	74.86±1.48
Dry matter (%)	25.14±0.32
Crude protein (%)	7.24±0.26
Lipid (%)	2.24±0.02
NDF (%)	70.96±2.86
Lignocellulose (%)	40.84±1.86
Ash (%)	7.84±0.30
Calcium (%)	0.48±0.04
Phosphorous (%)	0.26±0.02
Energy (kcal kg^{-1})	3.42±0.03

Table13: Production performance of TNC

	Treatment (feed formulas)			
Items	1	2	3	4
Feed intake				
Concentrate (kg)	4.80	4.80	4.80	4.80
Roughage (kg)	4.64±0.28	4.48±0.34	4.72±0.38	4.48±0.32
Production performance				
Initial body weight (kg)	220.64±3.86	218.36±3.28	226.40±3.82	220.62±3.24
Final body weight (kg)	270.20±3.62	268.40±3.44	277.80±3.56	271.60±3.42
ADG (kg)	0.42±0.01	0.42±0.02	0.43±0.01	0.43±0.02

Means within the same row did not differ significantly (p>0.05)

DISCUSSION

TN cattle have developed and adapted through evolution in the tropical zone. Therefore, they have become wrinkled and have evolved big ears, such as Zebu cattle (*Bos taurus indicus*). Their wrinkly skin, which increases the skin surface area can dissipate body heat to maintain a normal body temperature and can alleviate heat stress better than tight skin. According to the theory of heat transfer, a wide surface area can ventilate heat more effectively than can a narrow surface area in the same period of time, regardless of whether the heat is convention.

Stefan's law of radiation states that the rate of heat transfer by radiation from the body to the surroundings is related to the energy density of the radiation in a volume of space. Additionally, the increase in body temperature will depend on the temperature of the surroundings. The body both emits and absorbs radiation from its surroundings. Newton's law of cooling states that the rate of heat loss of a body is proportional to the difference in temperatures between the body and surroundings. One interesting fact about algebra claims that the change in surface area is equivalent to the power square of 2/3 of the body weight for a similar body shape and the same gravity[12]. However, animals of the same bred might have different body shapes and different gravities[13]. Under high ambient temperature, TN cattle reduced feed intake, but the quantity and weight of feed intake were still higher than those of European cattle (*Bos taurus*). Zebu cattle had higher critical temperatures, whereas, European cattle had lower ones. The upper critical temperature in Zebu cattle then had a greater influence on the body's thermoregulation and low temperature than did the lower critical temperature in European cattle[14,15]. The efficiency of growth was determined as the ratio of tissue production to metabolism and was expressed as energy. The difference between the two values of energy appeared to become heat energy[16]. The heat energy balance was an effective factor that caused the close relation between thermoregulation and the growth rate. Thus, TN cattle under heat stress would be affected by general physiological changes, hematological value changes and the function of endocrine glands that reduce roughage intake[17]. Animal bodies require energy for transferring body heat to the surroundings, which can lead to general physiological changes, hematological mechanisms and endocrine gland functions in response to normal body temperature regulation. That is why heat affects animal lipid metabolism.

The study found that TN cattle under local normal housing conditions showed changes in their general physiology, such as a higher rectal temperature, higher pulse rate, higher respiration rate and higher sweating rate, which is their mechanism for maintaining a higher balance of normal body temperature by transferring heat to cooling evaporation[18]. More energy is usually needed to make this process work. The study also revealed that TN cattle faced heat stress, which impacted the energy available for maintaining life[12], thereby reducing the hematocrit and hemoglobin levels[19]. Due to the animal thermoregulatory processes of sweat expulsion and evaporation, TN cattle unavoidably needed more water consumption[20]. The plasma level was thus increased, which increased the number of broken red blood cells and thereby reduced the hematocrit and hemoglobin levels[21]. This finding was congruent with the study of Umpapol *et al.*[18], who revealed that beef cattle raised in single-roof houses had lower hematocrit and hemoglobin levels than did those raised in double-roof houses.

The body heat production of TN cattle under a high ambient temperature for a long time decreased due to their low food intake and low net energy, which was caused by high ambient temperature environment, which directly impacted the function of the hypothalamus and the anterior pituitary gland[22] and increased the secretion of cortisol from the adrenal cortex. However as the cattle were under continuous heat stress for a long time, the cortisol concentration declined[23]. The mechanism of body adjustment might decrease the body heat production from food metabolism due to excess cortisol, to an adjustment of cortisol metabolism that suppresses the function of 17-Hydroxylase in the adrenal cortex or to a threshold sensitivity evaluation or set point sensitivity evaluation of the adrenal cortex[24].

At this point, it was revealed that TN cattle had faced heat stress throughout the experimental period with high THI, which caused the decline of the heat tolerance coefficient[25] and affected the functions of the endocrine glands, especially the increase in cortisol levels, which decreased the body heat production due to a food intake reduction[26]. Later, the cattle's bodies could decrease their cortisol levels to the body heat balance level. The TN cattle could finally self-adjust well to the normal body temperature level because they had a positive characteristic of high heat tolerance[27].

The influence of high air temperature and high relative humidity could cause heat stress in TN cattle but their bodies had general physiological changes for reducing such stress by ventilating heat out of their bodies. This ventilation was accomplished through respiratory regulation centered in the hypothalamus, which was sensitive to blood temperature changes. When the blood temperature increased, this respiratory regulation center would increase the rate of cattle respiration for heat evaporation[28] and body thermoregulation[24]. The TN cattle under a high ambient temperature that faced heat stress could increase their body heat via the fermentation of fiber in the rumen[3].

An increasing body heat can exhaust the cattle with normal body temperature regulation and these cattle reduce their rumination activities to keep their body heat balanced[29]. TN cattle under high ambient temperature drink much more water for body heat regulation and water which has a high specific heat value can accommodate more temperature changes by not allowing a rapid body temperature alteration[30]. Usually, the volume of water used in sweat expulsion is an efficient mechanism of cattle body heat transfer. At the same time, the cattle tried to perform gasping respiration to regulate their body heat, although it was not an efficient way for them to adjust their normal body temperature balance without any water consumption. Therefore, they required a large amount of water for normal body temperature regulation[31], which was normally accompanied by frequent standing up and walking to drink water in high-ambient-temperature environments.

TN cattle housed in high-ambient-temperature environments had general physiological changes that caused gasping respiration as well as muscle and diaphragm function that required more metabolizable energy from lipid metabolism of ingested food[32]. If the cattle bodies had less metabolizable energy, this could affect production performance, such as growth and carcass quality[3]. TN cattle must adapt themselves to high ambient temperatures by reducing body movements, keeping still for rest and lying[31] to reduce the utilization of energy for body maintenance[33].

The situation of heat stress was related to a low heat tolerance co-efficient that was derived from the impact of endocrine gland functions, in particular, the cortisol hormone level was increased[34] to maintain a normal body heat balance by reducing the food intake to regulate the body to such an extent that the cortisol hormone level declined and the animal body heat became normal. This adjustment function of TN cattle required energy to maintain life by reducing both the average daily gain[25] and the feed digestibility of the cattle. Therefore, the high-ambient-temperature environment was one factor that stimulated the cattle bodies to regulate a normal body temperature by reducing their feed intake, which is useful for animals under heat stress. Although they relied on energy for thermoregulation, the hormone level changes among the TN cattle could also affect their growth performance. The results of using PSM, PKSM and CSM supplements in feed formulas as good sources of energy that caused changes in the general physiology, hematological values, hormone levels and animal welfare behavior, were not significantly different from the results obtained by using control feed. In addition, all feed formulas were composed of essential nutrients for body growth, namely, protein, vitamins and minerals, which were sufficient for the growth requirements of TN cattle[35].

Therefore, the TN cattle that received PSM, PKSM and CSM supplements in feed formulas could improve their efficiency of heat transfer to the extent that they were able to maintain a normal body heat balance efficiently, further, all of the feed formulas could increase energy for TN cattle growth[36]. The mechanism of body heat balance of the experimental cattle caused them to consume more roughage and obtain enough high energy from the concentrate to provide relief from heat stress. Although the animals obtained more body maintenance energy, especially for the heat transfer process[34], they still retained normal body temperatures and increased their net energy for high yield production[24]. For PSM, PKSM and CSM supplementation in feed formulas, the study revealed that the supplements were sources of high-quality nutrients such as energy, good protein and useful fiber for TN cattle[3]. The supplementation of PSM, PKSM and CSM at 5, 10 and 15%, respectively, would be beneficial in feed formulas for body thermoregulation, thus increasing the levels of utilizable nutrients for body maintenance the yield production of cattle[23] and leading directly to the improved growth performance and carcass quality of TN cattle[23].

CONCLUSION AND FUTURE RECOMMENDATION

The THI values showed that the ambient temperature was highly related to maximum, average, minimum temperatures and high relative humidity. The data analysis found that THI was high but did not affect general physiological changes in TN cattle.

TN cattle that received 4 different concentrate formulas could tolerate high-ambient-temperature environments and the concentrate formulas had no effect on physiological changes, such as rectal temperature, pulse rate, respiration rate, heat tolerance coefficient, sweating rate and drinking water volumes and the hematological values, namely, hematocrit, hemoglobin, blood glucose, blood urea nitrogen and cortisol levels, including animal welfare behaviors such as rumination, gasping respiration, standing up, walking to drink water, rest and lying down.

TN cattle under high-ambient-temperature environments could be fed well with local feedstuffs such as PSM, PKSM and CSM at 15% in feed formulas and there was no effect on growth performance compared to control concentrate in this experiment.

REFERENCES

1. Department of Livestock Development, 2014. Information and communication technology center. Ministry of Agriculture and Cooperatives. Bangkok.
2. Vajrabukka, C., 1996. Physiology of environment for animal in tropical zone. Department of Animal Husbandry, Faculty of Agriculture, Kasetsart University, Bangkok, pp: 347.
3. Wanapat, M., 1996. Research priorities for improving animal agriculture by agro-ecological zone in Thailand. Khon Kaen Publishing Company Ltd., Khon Kaen, Thailand.
4. Rosenberger, G., 1979. Circulation, Respiratory System. In: Clinic Examination in Cattle, Rosenberger, G. (Ed.)., Verlag Paul Parey, Berlin, pp: 101-182.
5. Sirvastana, S.M. and N.S. Sidhu, 1977. Heat tolerance studies on various crossbred genetic groups of cattle in U.P. (Izatnagar). Indian J. Here., 2: 77-83.
6. Turner, H.G., 1972. Selection of beef cattle for tropical Australia. Aust. Vet. J., 48: 162-166.
7. Benjamin, M.M., 1978. Outline of Veterinary Clinical Pathology. 3rd Edn., Iowa State University Press, Iowa, pp: 255.
8. Bangprathaiya, P., 1987. Selection and application of constant reagent Kit for radioimmunoassay technique and cautions for technical practices. Proceedings of the Manual of Workshop Principles and Application of Techniques for RIA and ELISA., (PAT'87), Department of Microbiology and Radiation, Faculty of Medicine, Khon Kaen University, Khon Kaen, pp: 125.
9. AOAC., 1990. Official Methods Of Analysis. 14th Edn., Association of Official Analytical Chemists, Washington, DC, USA., pp: 1141.
10. Goering, H.K. and P.J. van Soest, 1970. Forage Fiber Analysis (Apparatus Reagents, Procedures and Some Applications). Agriculture Handbook No. 379. United States Department of Agriculture, Washington DC., pp: 188.
11. Steel, R.G.D. and J.H. Torrie, 1980. Principles and Procedures of Statistics: A Biometrical Approach. 2nd Edn., McGraw Hill Book Co., New York, USA., ISBN-13: 9780070609266, Pages: 633.
12. Johnson, H.D., 1985. Physiological Responses and Productivity of Cattle. In: Stress Physiology in Livestock, Yousef, M.K. (Ed.). CRC Press, Boca Raton, Florida, ISBN: 0849356679, pp: 3-24.
13. Esmay, M.L., 1978. Principles of Animal Environment. AVI Publishing Co. Inc., Westport, Connecticut, pp: 358.
14. Seif, S.M., H.D. Johnson and A.C. Lippincott, 1979. The effects of heat exposure (31°C) on zebu and Scottish highland cattles. Int. J. Biometeor., 23: 9-14.
15. Hansen, P.J., 2004. Physiological and cellular adaptations of Zebu cattle to thermal stress. Anim. Rep. Sci., 82-83: 349-360.
16. Robertshaw, D. and V. Finch, 1976. The Effects of Climate on the Productivity of Beef Cattle. In: Beef Cattle Production in Developing Countries, Smith, A.J. (Ed.)., Centre for Tropical Veterinary Medicine, Univ. Edinburge, Lewis Reprints, Ltd., Tunbridge Wells.
17. Hillman, P.E., N.R. Scott and A. van Tienhoven, 1985. Physiological Responses and Adaptations to Hot and Cold Environments. In: Stress Physiology in Livestock, Volume 3, Yousef, M.K. (Ed.)., CRE Press Inc., Florida, pp: 1-58.
18. Umpapol, H., T. Jitrajak, C. Songvicha, P. Tantisirin, R. Hanmontree, J. Sripandon and S. Umpapol, 2014. Effect of raising beef cattle in the double shaded house on their fattening performance in Thailand. Pak. J. Nutr., 13: 657-660.
19. Singh, A.S., D.T. Pal, B.C. Mandal, P. Singh and N.N. Pathak, 2002. Studies on changes in some of blood constituents of adult cross-bred cattle fed different levels of extracted rice bran. Pak. J. Nutr., 1: 95-98.
20. Sjaastad, O.V., K. Hove and O. Sand, 2003. Physiology of Domestic Animals. Scandinavian Veterinary Press, Oslo, pp: 735.
21. Knowles, T.G., J.E. Edwards, K.J. Bazeley, S.N. Brown, A. Butterworth and P.D. Warriss, 2000. Changes in the blood biochemical and haematological profile of neonatal calves with age. Vet. Rec., 147: 593-598.
22. Willmer, P., G. Stone and I. Johnston, 2005. Environmental Physiology of Animals. 2nd Edn., Blackwell Science, London, pp: 768.
23. Ecdert, R., D. Randall and G. Augustine, 1988. Animal Physiology: Mechanisms and Adaptations. 3rd Edn., W.H. Freeman and Company, USA., pp: 683.
24. Umpapol, H., T. Jitrajak, C. Songvicha, P. Tantisirin, R. Hanmontree, J. Sripandon and S. Umpapol, 2011. The utilization of whole cotton seed as a substitute in diets on general physiological changes, animal welfare behavior and productivity of fattening beef cattle in Thailand. Pak. J. Nutr., 10: 229-232.
25. Boonprong, S., 2010. Heat tolerance indicators for beef cattle in the tropics with special reference to blood biochemical properties. Ph.D. Thesis, Graduate School, Kasetsart University, Bangkok.
26. NRC., 2002. Nutrient Requirements of Beef Cattle. 7th Edn., National Academy of Sciences, Washington, DC.
27. Bergman, R.K. and H.D. Johnson, 1963. Temperature effects on plasma cortisol of cattle. J. Anim. Sci., 22: 854-854.
28. Houpt, K.A., 2011. Domestic Animal Behaviour for Veterinarians and Animal Scientists. 5th Edn. Wiley-Backwell, Singapore.
29. Umpapol, H., T. Jitrajak, C. Songvicha, P. Tantisirin, R. Hanmontree, J. Sripandon and S. Umpapol, 2014. Response on general physiology, animal welfare behavior and productivity of the different lineage level of charolais crossbred cattle for fattening beef cattle production performance in Thailand. Pak. J. Nutr., 13: 648-652.
30. Boonsiri, P., P. Areejitranoosorn, U. Cha-On and P. Thuwajit, 2008. Text of Biochemistry. 5th Edn., Department of Biochemistry, Faculty of Medicine, Khon Kaen University, Khon Kaen.

31. Yousef, M.K., 1976. Thermoregulation in Wild Ungulates. In: Progress in Animal Biometeorology: The Effect of Weather and Climate on Animals, Volume 1, Johnson, H.D. (Ed.)., Swets and Zeitlinger, Amsterdam, Netherlands, pp: 108-122.
32. Berg, G.M., J.L. Tymoczko and L. Stryer, 2007. Biochemistry. 6th Edn., WH. Freeman and Company, New York.
33. Church, D.C., 1979. Digestive Physiology and Nutrition of Ruminants. 2nd Edn., O and Books, Inc., Oxford Press, Oregon, ISBN: 9780960158652, Pages: 452.
34. Umpapol, H., T. Jitrajak, C. Songvicha, P. Tantisirin, R. Hanmontree, J. Sripandon and S. Umpapol, 2016. Effect of potassium chloride supplement in salt blocks on the fattening performance of charolais crossbred beef cattle under heat stress. Pak. J. Nutr., 15: 176-179.
35. Aggarwal, A. and R. Upadhyay, 2013. Heat Stress and Animal Productivity. Springer, New York, USA., ISBN: 9788132208792, Pages: 188.
36. Hafez, E.S.E., 1968. Adaptation of Domestic Animals. Lea and Febiger, Philadelphia, pp: 430.