

HEAT TOLERANCE IDENTIFICATION ON ADULT MADURA BREEDS COW ACCORDING TO RHOAD AND BENEZRA COEFFICIENT

Fitra Yosi¹, Sri Bandiati Komar Prajoga², and Eten Marjuman Natawiria³

¹*Department of Animal Science, Faculty of Agriculture, Universitas Sriwijaya, Palembang, Indonesia.*

^{2,3}*Department of Animal Science, Faculty of Animal Husbandry, Universitas Padjadjaran, Bandung, Indonesia*
fitrayosi@unsri.ac.id

Abstract – Climate change causes the ambient temperature getting high. This condition will finally affect the physiology and performance of livestock. The aims of this study were to determine: 1) The average of respiratory rate and body temperature of adult male and female Madura breeds cow with fat and medium body condition between in the morning and at noon, and 2) The heat tolerance of male and female Madura breeds cow with fat and medium body condition based on Rhoad and Benezra coefficient that had been modified. This study used survey method, while the data were collected by using multi stage random sampling. There were 120 Madura breeds cow used in this study. Parameters observed were respiratory rate, body temperature, and heat tolerance. Results of this study showed that the average of respiratory rate of Madura breeds cow on fat and medium males was 31.07±3.17 and 30.27±2.87 breaths/minute, and on fat and medium females was 27.87±3.05 and 27.80±3.07 breaths/minute. The average of body temperature of Madura breeds cow on fat and medium males was 38.62±0.19°C and 38.58 ± 0.18°C, on fat and medium females was 38.57±0.23°C and 38.56±0.19°C. The average of heat tolerance of Madura breeds cow according to Rhoad and Benezra coefficient on fat males was 94.90±1.38 and 2.64±0.16, on medium males was 94.30±1.26 and 2.62±0.20, on fat females was 95.50±1.83 and 2.42±0.15, and on medium females was 96.22±1.28 and 2.38±0.20. It was concluded that the heat tolerance of adult Madura breeds cow was still high.

Keywords – *Body temperature, heat tolerance, Madura breeds cow, respiratory rate, Rhoad and Benezra coefficient.*

I. INTRODUCTION

Climate change is one main factor that causes the ambient temperature getting high. It was reported that the Earth's near-surface temperature rose by 0.6°C during the 20th century (Gregory 2010). Changes in extreme temperature will accompany continued global warming. Thus raising the question how livestock adapt to extreme temperature events. It was known that cattle are homeotherms which regulate their body temperature within a relatively narrow range to keep the optimal production and healthy. It was reported that the average thermal-comfort zone for optimum feed intake, physiological process, and performance of cow is expected to be 5–25°C (McDowell 1972). If the ambient temperature is above the thermoneutral zone range, it could creates stress conditions on cow. Heat stress on cow will be occurred when there is a change of weather patterns suddenly and an increases of the ambient temperature rapidly.

Many studies have been conducted to find out the effects of heat stress to livestock. It was reported that heat stress on livestock could decline feed intake (Mader and Davis 2004), performance (Klinedinst et al. 1993), health (Baylis and Githeko 2006), and reproduction (Amundson et al. 2005) and for some extreme cases, it could cause the death (Hahn and Mader 1997; Thornton et al. 2009), but little is still known about the interaction of climate change and livestock, especially how to measure the heat tolerance of cattle in facing climate change. Heat tolerance is expected to be one of important adaptability aspect. Adaptability aspect means that the ability of livestock to adapt environmental conditions, as well as climatic extremes (McManus et al. 2009).

Some physiological indicators that can be used to measure heat tolerance were respiratory frequency and body temperature. McManus et al. (2005) stated that there are several physiology measure of heat tolerance, some of them are

respiratory rate and rectal temperature. The aims of this study were to determine heat tolerance of cattle based on Rhoad and Benezra's formula that had been modified (Soeharsono 1978), with measuring the respiratory rate and body temperature of cattle between in the morning and at noon.

II. MATERIALS AND METHODS

Objects used in this study was adult Madura breeds cow aged 3 years and above, both males and females, in body conditions of fat and medium, exception for pregnant female cows was not observed. Adult cows chosen because the thermoregulation system in adult cows has been perfected so that its body temperature was relatively steady. Determination of adulthood on the cow was based on turnover of incisors (Murtidjo 1990) (Table 1), while the determination of the body condition of cows were based on observations of the ribs (Santosa 2003) (Table 2). The tools used, among others, counter, stopwatch, digital clinical thermometer, thermohygrometer, and vaseline.

Table 1. Determination of Adulthood on The Cow Based on Turnover of Incisors

Age (year)	Description
< 1.5	all milk teeth
2	a pair of permanent incisors
3	Two pairs of permanent incisors
3.5	Three pairs of permanent incisors
4	Four pairs of permanent incisors
6	Four pairs of permanent incisors and one pair of teeth wear out
7.5	Four pairs of permanent incisors and two pair of teeth wear out

Source : Murtidjo (1990)

Table 2. Determination of The Body Condition of Cows Based on Observations of The Ribs

Body condition	Description
Fat	The entire ribs does not appear behind the skin
Medium	Only partially ribs appear behind the skin (less than eight)
Thin	Most of the ribs appear behind the skin (more than eight)

Source : Santosa (2003)

The method used in this study was survey method, while the data collection was done by multistage random sampling. First of all, sampling procedure was done by grouping adult Madura breeds cow based on sex and body condition, so that it was obtained 4 groups of cows, namely; fat male cow, medium male cow, fat female cow, and medium female cow. After grouped, sampling was done randomly on each group of as many as 30 cows. Thus, the number of samples used in this study was 120. After that, the measurement of respiratory rate and body temperature was done on each cow. Measurement was conducted twice every day, namely morning and noon.

Variables observed were respiratory rate, body temperature, and heat tolerance. Respiratory rate was counted in the morning (05.00-06.00 a.m) and at noon (11.00 a.m-12.00 p.m) (Soeharsono 1978). The counting is repeated twice, by exposing backs of the hands in front of the cow's nostril. Respiratory rate was counted for 15 seconds then converted to 1-minute multiplied by 4. At the same time, it was also measured ambient temperatures and humidity. Cow's body temperature measured using digital clinical thermometer. The measurement of body temperature was done in the morning (05.00-06.00 a.m) and noon (11.00 a.m-12.00 p.m) (Soeharsono, 1978), after counting the respiratory rate and before the cow were fed. The measurement of body temperature was repeated twice, by inserting the thermometer into the rectum and silenced momentarily until the tool reads. Cow's body temperature could be directly known from the numbers that appeared on the tool. Heat tolerance was calculated by using the formula of Rhoad and Benezra that has been modified by Soeharsono (1978).

Rhoad's formula :

$$HTC = 100 - 10(Tf - Ti) \tag{1}$$

description :

- HTC : Heat Tolerance Coefficient (Rhoad Coefficient)
- Tf : Average of body temperature at noon (°F)
- Ti : Average of body temperature in the morning (°F)
- 100 : The number of perfect coefficient on Ti
- 10 : Constant

Benezra's formula :

$$BC = \frac{Tf}{Ti} + \frac{Rf}{Ri} \tag{2}$$

description :

- BC : Benezra coefficient
- Tf : Average of body temperature at noon (°C)
- Ti : Average of body temperature in the morning (°C)
- Rf : Average of respiratory rate at noon (breaths/minute)
- Ri : Average of respiratory rate in morning (breaths /minute)

Then, collected data were analyzed through centrally procedure statistical analysis by calculating averages, coefficients of variation, standard of deviation, maximum and minimum value.

III. RESULTS

A. Environmental Condition

Table 3 showed that the location of the research lies in a lowland area with a height of 15 m above sea level. The difference in air temperature between morning and afternoon was very great, where the air temperature in the morning around 23°C and daylight around 38°C. The air humidity at the location of the research was high enough, which was 83-92%.

Table 3. Physical State and Weather in The Research Locations

State	Value
Altitude	± 15 m
Ambient temperature	23 – 38 °C
Air pressure	1000.9-1011.3 mb/mounth
Relative humidity	83-92%
Wind speed	8-20 knot

B. Physiological Reaction

The result showed that respiratory rate and body temperature of adult male cow were higher than that of adult female cow, both in fat and medium of body condition (Table 4 and 5). The average of respiratory rate and body temperature of adult male Madura breeds cow were 30.67±3.01 breaths/minute and 38.60±0.19°C, while for adult female Madura breeds cow were 27.83±3.05 breaths/minute and 38.56±0.21°C. This showed that the respiratory rate of adult male cow was faster 2.84 breaths/minute and body temperature was higher 0.04°C than adult female cow. Meanwhile, the average of respiratory rate and body temperature of fat adult cow were 29,47±3.10 breaths/minute and 38,59±0,21°C, while those of medium adult cow were 29.03±2.96 breaths/minute and 38.57±0.19°C. Overall, the average of the respiratory rate and body temperature of adult Madura breeds cow were 29.25±3.02 breaths/minute and 38.58±0.20°C.

Table 4. The Respiratory Rate and Body Temperature of Adult Madura Breeds Cow with Fat Body Condition

Measurement	Time	Sex	
		Male	Female
Respiratory rate (breaths/minute)	Moring	23.73±2.96	23.20±2.86
	Noon	38.40±3.42	32.53±3.28
Body temperature (°C)	Morning	38.48±0.19	38.44±0.24
	Noon	38.76±0.21	38.69±0.22

Table 5. The Respiratory Rate and Body Temperature of Adult Madura Breeds Cow with Medium Body Condition

Measurement	Time	Sex	
		Male	Female
Respiratory rate (breaths/minute)	Moring	23.33±2.80	23.60±2.85
	Noon	37.20±3.00	32.00±3.32
Body temperature (°C)	Morning	38.42±0.17	38.44±0.24
	Noon	38.73±0.18	38.67±0.19

C. Heat Tolerance

According to the result of measurement by using Rhoad and Benzra formula showed that the average of the HTC of adult Madura breeds cow with fat body condition was higher 0.06 and the average of BC was lower 0.03 than adult Madura breeds cow with medium body condition. Based on sex, the average of the HTC of adult female cow was higher 1.26 than adult male cow, while the average of the BC of adult male cow was higher 0.23 than adult female cow. Overall, the average of HTC and BC of adult Madura breeds cow was 95.23 ± 1.44 and 2.51 ± 0.18 .

Table 6. Heat Tolerance of Adult Madura Breeds Cow with Fat and Medium Body Condition According to Rhoad and Benzra Coefficient

Heat Tolerance	Sex	Body Condition	
		Fat	Medium
Rhoad	Male	94.90±1.38	94.30±1.26
	Female	95.50±1.83	96.22±1.28
Benzra	Male	2.64±0.16	2.62±0.20
	Female	2.42±0.15	2.38±0.20

IV. DISCUSSION

Based on result of this study, it appears that an increase of respiratory frequency and body temperature during daylight was as much as 14.67 breaths/minute and 0.28°C on fat male cow, 13.87 breaths/minute and 0.31°C on medium male cow, 9.33 breaths/minute and 0.25°C on fat female cow, and 8.4 breaths/minute and 0.21°C on medium female cow. It showed that the change of respiratory rate and body temperature of male cow was higher than female cow, both in fat or medium of body condition. It indicates that the adult male cow has heat tolerance lower than adult female cow. According to body condition, it showed that the respiratory rate and body temperature of fat adult Madura breeds cow were higher, namely 29.47 ± 3.10 breaths/minute and 38.59 ± 0.21 °C, than medium adult Madura breeds cow, namely 29.03 ± 2.96 breaths/minute and 38.57 ± 0.19 °C. Compared to another cattle, the value of body temperature was not far different. McManus et al. (2009) reported that the rectal temperature in Holstein breed was 39.02 °C, while Nellore were 38.63 °C. Furthermore, it was reported that the difference of rectal temperature between the morning and afternoon was varied between 0.41 (the Crioulo Lageano breed) and 1.4°C (Holstein cattle). Those breed was developed in Brazil region with very high fluctuations in ambient temperature.

Overall, the average the respiratory rate of adult Madura breeds cow in the morning, both in fat and medium of body condition, was still in the range of normal, but in the day time the respiratory rate was higher than the normal range. Fradson (1992) stated that the normal range of respiratory rate on cattle was 20-27 breaths/minute. In line with this, Swenson and Reece (1996) stated that basal respiration frequency on cow is about 20 breaths per minute. This condition is not good for cattle because it causes disease. McManus et al. (2009) reported that it could be considered as a tachypnea if the respiration rate increase up to 40 breaths per minute. Unlike the case with body temperature, where the average of body temperature of adult Madura breeds cow, both in fat and medium of body condition, was still in the range of normal. Reksohadiprojo (1984) stated that the normal range of body temperature on cattle was 38.0-39.3°C, while Dirksen et al. (1993) stated that rectal temperature in adult cattle was generally 38.0-39.0°C. Increasing respiratory frequency in cattle reported by brown-brandl et al. (2005) that respiratory frequency and body temperature increased as rising ambient temperature. McManus et al. (2009) also reported that there was an increase of

respiratory rate on Holstein cattle between morning and afternoon.

An increase of respiratory rate was an effort to retain body temperature to keep stable, especially to overcome an increase in ambient temperature by day reaching 38°C. It is as stated by Amakiri and Heath (1995) that one way cattle to retain body temperature in the range of normal was by increasing respiratory frequency. In line with this, Atmadilaga (1991) also stated that the increase of respiratory activity as a result of rising the ambient temperature was one way to maintain body temperature in normal range. The body temperature must be kept in normal range because the cattle was the homeoterm (Sirohi and Michaelowa 2007). It means that they have to regulate their body temperature in normal range. It is important so that the optimum productivity could be reached. In this study, the ambient temperature and relative humidity could reach 38°C and 92% at noon. McDowell (1972) stated that the normal range of ambient temperature for cattle was 5–25°C, while Kurihara and Shioya (2003) stated that the respiratory frequency in cow was still normal at ambient relative humidity 80%. It means that the ambient temperature was higher than normal range for cattle. That is the reason why the respiratory rate of the cattle was higher than normal.

The rapidly increase of respiratory rate and body temperature on cattle due to changes in ambient temperature can be used as indicators to determine heat stress. This is as stated by Brown-Brandl (2003) that some indicators that can be used to measure heat stress were respiration rate and rectal temperature. Wise et al. (1988) and Ominski et al. (2002) also reported that while faced with heat stress, respiratory frequency and temperature on cattles was rising. The high of ambient temperature was suggested to be a main factor that cause heat stress on cattle. Besides that, high relative humidity condition was expected to be another factor that also make the cattle heat stress. This is as stated by Sirohi and Michaelowa (2007) that factors caused heat stress on cow were hot and humid environmental condition. Furthermore, if the relative humidity was high, the cows could not eliminate their body heat well. Johnson (2005) also stated that the high relative humidity could affected the mechanism of body heat dissipation on cattle through respiration. This situation was not good because it can make the cow more suffer. Eventually, the performance of livestock will decline.

One thing to be remembered that the important factor which causes the increase of ambient temperature was climate change. IPCC (2007) stated that according to Fourth Assessment Report (AR4), ambient temperature is estimated increasing in the range 1.8–4 °C in 2090–2099 relative to 1980–1999. For livestock, the impacts of climate change on livestock are well known. Many research showed that the effect of climate change on livestock. Firstly, climate change causes heat stress and then it could decrease feed intake (Mader and Davis 2004), performance (Klinedinst et al. 1993), health (Baylis and Githeko 2006), and reproduction (Amundson et al. 2005) on livestock. Finally, it will cause financial impacts on farmers or livestock producer.

According to the result of this study, it was known that the average of HTC of adult Madura breeds cow with fat body condition was higher and the average of BC was lower than the average of HTC and BC of adult Madura breeds cow with medium body condition. This showed that Madura breeds cow with medium body condition has the ability of issuing body heat higher than Madura breeds cow with fat body condition. Adriani (1990) reported that the process of dissipation of body heat affected by the surface area of the body, where the skinny body of livestock, the more surface area the body of livestock.

These conditions create heat releasing process getting bigger. Based on sex, the average of HTC of adult female cow was higher 1.26 and the average of BC was lower 0.23 than adult male cow. Overall, the heat tolerance of adult Madura breeds cow based on HTC and BC was still high. The high heat tolerance in adult Madura breeds cow in this study is assumed that this cattles are derived from Zebu breeds that have high adaptation to environmental change. Hansen (2004) stated that cattles from zebu breeds have a better ability to regulate their body temperature than cattles from *B. taurus* breeds. It was also stated by Seif et al. (1979) and Rocha et al. (1998) that cattles from zebu breeds have a higher adaptation to warm climate than *Bos taurus* breeds.

V. CONCLUSION

According to the value of HTC and BC, it was concluded that the heat tolerance of adult Madura breeds cow was still high. However, with the increase of ambient temperature cauced by climate change, it affected the physiology function of adult Madura breeds cow, eventually potentially lowering productivity of the cow.

ACKNOWLEDGEMENT

The authors greatly acknowledge everyone that helped this research and Rector of Universitas Sriwijaya for financial support to attend The Sustainability Science Symposium 2014 in Bandung.

REFERENCE

- Amakiri S, Heath E (1995) Anatomy and physiology of tropical livestock. Edited by E. Heath and S. Olusanya. Logman, Singapore publisher, Singapore.
- Amundson JL, Mader TL, Rasby RJ, Hu QS (2005) Temperature and humidity index effects on pregnancy rate in beef cattle. In: Proceedings of 17th International Congress on Biometeorology. Deutscher Wetterdienst, Offenbach, Germany.
- Andriani L (1990) Effect of climate on livestock and vegetation. Faculty of Animal Husbandy, Universitas Padjadjaran, Bandung, Indonesia.
- Atmadilaga D (1979) Effect of climate to livestock. Faculty of Animal Husbandy, Universitas Padjadjaran, Bandung, Indonesia
- Baylis M, Githeko A (2006) The effects of climate change on infectious diseases of animals. Report T7.3, Foresight Project on Infectious Diseases: Preparing for the Future, UK Government Foresight Office, London.
- Brown-Brandl TM, Nienaber JA, Eigenberg RA, Hahn GL, Freetly H (2003) Thermoregulatory responses of feeder cattle. Journal of Thermal Biology 28:149-157
- Brown-Brandl TM, Eigenberg RA, Nienaber JA, Hahn GL (2005) Dynamic response indicators of heat stress in shaded and non-shaded feedlot cattle. Part 1: analyses of indicators. Biosyst. Eng. 90: 451-462.
- Fradson RD (1992) Anatomy and physiology of livestock. Gadjah Mada University Press, Yogyakarta, Indonesia.
- Gregory NG (2010) How climatic changes could affect meat quality. Food Research International 43: 1866-1873
- Hahn GL, Mader TL (1997) Heat waves in relation to thermoregulation, feeding behavior, and mortality of feedlot cattle. In: Proceedings 5th International Livestock Environment Symposium, Minneapolis, MN, pp 563-571
- Hansen PJ (2004) Physiological and cellular adaptations of zebu cattle to thermal stress. Anim. Prod. 82-83: 349-360
- Johnson HD (2005) The lactating cow in the various ecosystems: environmental effects on its productivity. Australian Journal of Agricultural Research 24(5): 775-782
- Klinedinst PL, Wilhite DA, Hahn GL, Hubbard KG (1993) The potential effects of climate change on summer season dairy cattle milk production and reproduction. Climatic Change 23: 21-36.
- Kurihara M, Shioya S (2003) Dairy cattle management in hot environment (http://cn.fftc.org.tw/htmlarea_file/library/20110801153254/eb529.pdf)
- Mader TL, Davis MS (2004) Effect of management strategies on reducing heat stress of feedlot cattle: feed and water intake. Journal of Animal Science 82: 3077-3087.
- McDowell RE (1972) Improvement of livestock production in warm climates. Freeman, San Francisco, California. pp. 711.
- McManus C, Paulo GR, Louvandini H, Garcia JAS, Egito AA, Mariante AS (2005) Heat tolerance in naturalised cattle in Brazil: physical factors. Arch. Zootec. 54: 453-458.
- McManus C, Prescott E, Paludo GR, Bianchini E, Louvandini H, Mariante AS (2009) Heat tolerance in naturalized Brazilian cattle breeds. Livest. Sci. 120: 256-264
- Murtidjo BA (1990) Raising beef cattle. Kanisius, Yogyakarta, Indonesia
- Ominski KH, Kennedy AD, Wittenberg KM, Moshtaghi-Nia SA (2002) Physiological and production responses to feeding schedule in lactating dairy cows exposed to short-term, moderate heat stress. J. Dairy Sci. 85: 730-737.
- Reksohadiprojo S (1984) Introduction to the science of tropical farm. BPFE, Yogyakarta, Indonesia.
- Rocha A, Randel RD, Broussard JR, Lim JM, Blair RM, Roussel JD, Godke RA, Hansel W (1998) High environmental temperature and humidity decrease oocyte quality in *Bos taurus* but not in *Bos indicus* cows. Theriogenology 49: 657-665.
- Santosa U (2003) Maintenance procedure of cattle. Penebar Swadaya, Jakarta, Indonesia
- Seif SM, Johnson HD, Lippincott AC (1979) The effects of heat exposure (31°C) on Zebu and Scottish Highland cattle. Int. J. Biometeorol 23: 9-14.
- Sirohi S, Michaelowa A (2007) Sufferer and cause: Indian livestock and climate change. Climatic Change 85: 285-298.
- Soeharsono (1978) Heat tolerance of Priangan sheep during drying out and effect of shearing. Faculty of Animal Husbandy, Universitas Padjadjaran, Bandung, Indonesia
- Thornton PK, Van de Steeg J, Notenbaert A, Herrero M (2009) The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. Agricultural Systems 101: 113-127
- Wise ME, Rodriguez RE, Armstrong DV, Huber JT, Wiersma F, Hunter R (1988) Fertility and hormone response to temporary relief of heat stress in lactating dairy cows. Theriogenology 29:1027-1036.