Rectal Temperature Changes in Broilers Kept Under Hot and Dry Conditions

H. J. Chepete

Botswana College of Agriculture, Private Bag 0027, Gaborone, Botswana.

hchepete@bca.bw

ABSTRACT

This study investigated the effects of environmental conditions on rectal temperature of broilers subjected to different heat loss- and heat gain-enhancing treatments. Twenty six-week old broilers with similar body weight were used in the study. The four treatments were allocated to the broilers in a Completely Randomized Design: (i) Beak and Wings Taped (BWT) where birds could not pant or droop wings; (ii) Beak Taped (BT) where birds could not pant; (iii) Wings Taped (WT) where birds could not droop wings and; (iv) the Control (C) where birds could pant and droop wings. The experiment was replicated five times (5 birds per treatment). The rectal temperature (RT) probes were used to measure RTs of the broilers every 20 seconds during each 8-hour experimental period. Environmental conditions, i.e., air temperature (T); relative humidity (RH); air velocity (V), and duration of heat exposure were measured and used as independent variables in linear regression models of rectal temperature. The resulting models were $RT_{BWT} = 0.640T + 0.225RH - 0.578V + 15.223$; $RT_{BT} = 0.811T + 0.353RH - 0.142V + 5.433$; $RT_{WT} = 0.257T - 1.288V + 35.602$ and $RT_C = 0.382T + 0.062RH - 1.179V + 29.339$. For the latter, the models developed were $RT_{BWT} = 0.681t + 41.013$; $RT_{BT} = 0.775t + 41.410$; $RT_{WT} = 0.391t + 41.014$ and $RT_C = 0.438t + 40.967$. Both panting and drooping of wings were effective in relieving the birds of heat stress. Panting was the dominant heat loss mechanism as air temperature approached or exceeded body temperature of the birds. The birds died at varying degrees of cumulative body heat loads which seemed to depend on the individual bird's ability to cope with heat stress. The average lethal cumulative heat loads were 7.1, 8.3, 9.0 and 11.0^oC-hr for the BWT, BT, WT and C treatments, respectively. For future similar experiments, improvement should be made on the tunnel to accommodate more than one bird per cage.

Keywords: Panting, drooping, heat stress, broiler chickens , rectal temperature, heat load, Botswana.

1. INTRODUCTION

Broilers subjected to high environmental temperatures exhibit many behavioral changes which allow them to re-establish heat balance within their surroundings. Broilers rest more or crouch near walls during periods of heat stress (Yanagi *et al.*, 2002). Heat stress depletes potassium and other minerals in the body which causes poor production performance (Tao and Xin, 2003). Panting and drooping of the wings are some of the thermoregulatory mechanisms used by broilers to relieve themselves of heat stress.

Panting is when the broilers rapidly pass air in and out of their open beak, to increase evaporative cooling. It is a physiological method of heat stress reduction. It requires increased muscle activity and this result in an increased energy requirement which is associated with heat stress (Tao and Xin, 2003). Panting would normally be expected to occur when the ambient temperature is near or above 30º C. The normal body temperature of the chicken is 41°C (Teeter *et al.*, 1992). Relative humidity (RH) influences evaporative heat loss through panting by decreasing the amount of moisture evaporated, hence decreasing the amount of heat lost, resulting in a rise in body temperature. Death due to heat exhaustion will occur very quickly, especially in heavier birds, if both temperature and humidity are high.

Drooping of wings is when the broilers spread their wings away from the body to expose the unfeathered parts of the body. It is a physical method of heat stress reduction that promotes convective heat loss by increasing the surface area of the body. The moisture from the exposed body parts escapes thereby promoting cooling and reducing heat stress. As the environmental temperature approaches the body temperature of the bird (41º C), the efficiency of drooping wings diminishes (Etches *et al.*, 1989). At this point the evaporation of water from the respiratory tract becomes the major heat loss mechanism of the bird.

The annual mean minimum and maximum temperatures in eastern Botswana (17 and 27°S latitude and 20 and 30° E longitude) range between 4 to 19° C and 22 to 33° C respectively, while RH range from 28 to 47%. Most broiler houses in Botswana are not insulated and lack cooling systems resulting in high heat loads in the houses which consequently cause heat stress to the birds (Chepete and Tsheko, 2006).The birds mainly rely on physical and physiological means to reduce heat stress. Thus, the objectives of this study were to (i) develop models that describe the relationship between air temperature, RH and air velocity on rectal temperature; (ii) develop models that describe the rate of rectal temperature rise over the duration of heat exposure and; (iii) determine the lethal heat load level of the birds due to heat exposure.

2. MATERIALS AND METHODS

The experiment was carried out using a horizontal wind tunnel (Figure 1) in the Environment Control Laboratory at the Botswana College of Agriculture. A similar tunnel design was used by Yanagi *et al.* (2002). The outside dimensions of the tunnel were 0.84m and 0.75m for the width and height, respectively.

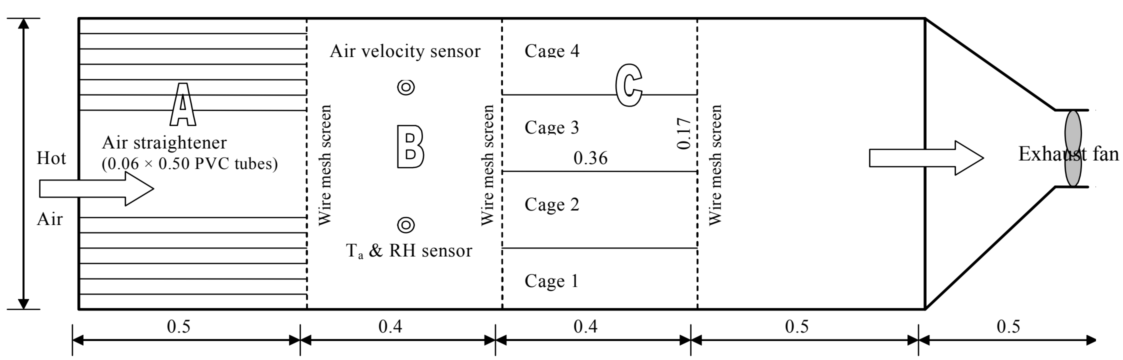

Figure 1. Schematic diagram of the wind tunnel used in the experiment. The dimensions are in meters.

The frame of the wind tunnel was made of 0.03 m square mild steel tubes. The frame was covered with 0.039 m thick perspex board. The wind tunnel comprised of the following compartments; A: air straightener made of 0.060 m diameter by 0.50 m long PVC tubes which were piled together to provide uniform air movement within the wind tunnel; B: the compartment where the air temperature (T), RH and air velocity (V) were measured; C: four cages (0.38m × L 0.23m ×W 0.68m H each) and each was able to hold a single broiler bird. The air flow was measured using air speed transmitter (model HD2903TC12H, Delta Ohm, Italy). The air temperature and RH were measured using temperature and humidity data logger (model AZ8835 IP65, AWR Smith Process Instrumentation, South Africa). Inlet air was heated using a 3 kW fan heater and drawn through the wind tunnel by an exhaust fan at the outlet.

2.1 Handling of the Experimental Broilers

Twenty six-week old female Ross broilers of similar body weight were procured from a local broiler farm to be used in the experiment. The weight of a single bird averaged 1.93±0.03 kg. Upon arrival at the experimental site, the broilers were put in a holding chamber and fed feed similar to what they had while at the farm. The treatments were randomly allocated to the four birds which were randomly picked from the holding chamber (Table 1) and allowed to acclimatize at thermo neutral temperature (24º C) from 1800 to 0700 h of the following day. Because of the cage size, only one bird could be accommodated at a time per cage. During this period water and feed were provided *ad libitum* and all birds were not taped with an insulation tape.

Table 1. The treatments used in the experiment

Treatment	**Description**
Beak & Wings Taped (BWT)	Both the wings and the beak were taped with an insulation tape so that the birds could not pant or droop its wings
Beak Taped (BT)	The beak was taped with an insulation tape so that the bird could not pant but could droop its wings
Wings Taped (WT)	The wings were taped to the body with an insulation tape so that the bird could not droop its wings but could pant
Control (C)	Both the wings and the beak were not taped so that the bird could pant and droop its wings

At about 0630 h, the birds were taped as per their treatment allocations. At 0700 h, the experiment was started by exposing the birds to hot air (36 – 38^{o}C) until 1500 h. The heat was provided by a 3kW heater fan placed at one end of the tunnel. An air conditioning unit (Model LG, LG Electronics, Inc.) in the laboratory was used to keep the RH low. During the experimental period, water was provided while feed was not.

The rectal temperature (RT) of the broilers were measured using temperature probes (model

PT907, Pace Scientific, Inc., Charlotte, North Carolina) connected to the data logger (model XR5, Pace Scientific, Inc., Charlotte, North Carolina). Measurements were recorded every 20 seconds during the 13 hour acclimatization period and the 8 hour experimental period. Visual observations were continuously made on bird behavior throughout the experiment. Dead birds at the end of the experiment were incinerated and those which survived were euthanized and incinerated. This procedure was repeated over a 5-day period with new set of birds used each day.

2.2 Data Handling and Analysis

For each treatment, the mean RT were plotted against time and linear regression models fitted in order to determine the rate of RT rise. To achieve this, the data from the onset of heat exposure to point of death or end of experiment for those birds that survived were used. Since the birds were subjected to similar conditions, the mean RT was obtained by averaging RT of all the five birds until the first bird in the treatment died, then averaging four birds until the second bird died, and so on until the point where the fourth bird died. Microsoft Excel (2003) Spreadsheet was used to perform the calculations of the means while SigmaPlot (2001, SPSS, Inc.) was used to fit linear regression models and calculate the standard errors of the means. The mean for each environmental conditions corresponding to the mean RTs were used to determine their impact on RTs. This was achieved with a variable selection method (stepwise multiple linear regression procedure) using the Statistical Analysis Software (SAS, 2002-2003, SAS Institute, Inc. Cary, North Carolina, USA). Further, the General Linear Model (GLM) procedure of SAS was used to determine if there were any differences in the rate of RT rise between the treatments by contrasts.

The concept of body heat load (β_{body}) developed by Chepete and Xin (2000) was used to measure the treatment effects on heat tolerance of the birds and has the form

$$\beta_{body} = \sum_{i=1}^{N} [T_{b(i)} - T_{b(TN)}] \cdot \frac{\theta}{3600} \qquad \text{(Chepete \& Xin, 2000)} \qquad [1]$$

where β= heat load (° C·hr), $T_{b(i)}$= body temperature at sampling time i (° C), $T_{b(TN)}$= mean body temperature under thermoneutrality (° C) and θ = sampling time interval, s.
In each treatment, birds could die at different times. Thus, a weighted average was calculated to determine the average β for the treatment.

3. RESULTS AND DISCUSSION

3.1 Effects of Environmental Conditions on Rectal Temperature

Table 2 shows the mean body mass of the birds and the environmental conditions experienced in each treatment. The conditions covered are those from the onset of heat exposure until death or end of experiment for those birds that survived.

Table 2. Mean body mass and environmental conditions experienced by the birds during the experiment (N=5 per treatment)

Treatment	Body mass (kg)	Air temperature (^{o}C)	Relative humidity (%)	Air velocity (m/s)
BWT	1.94 ± 0.06	36.6 ± 0.1	24.8 ± 0.2	2.119 ± 0.007
BT	1.92 ± 0.06	36.2 ± 0.1	25.4 ± 0.2	2.105 ± 0.008
WT	1.94 ± 0.08	37.9 ± 0.1	23.0 ± 0.1	2.153 ± 0.006
C	1.93 ± 0.07	37.9 ± 0.1	23.0 ± 0.1	2.153 ± 0.006

Table 3a shows the results of a stepwise multiple linear regression models developed using the forward-selection technique where the mean rectal temperatures and environmental conditions were fitted.

Table 3a. Stepwise multiple linear regression models showing the relationship between the mean environmental conditions and mean rectal temperatures

Treatment	Variable	Parameter Estimate	Pr > F	R^2
BWT	Temperature	0.640 ± 0.023	>0.0001	0.86
	Relative Humidity	0.225 ± 0.018	>0.0001	
	Air velocity	-0.578 ± 0.113	>0.0001	
	Intercept	15.223 ± 1.410		
BT	Temperature	0.811 ± 0.019	>0.0001	0.91
	Relative Humidity	0.353 ± 0.015	>0.0001	
	Air velocity	-0.142 ± 0.098	0.1475*	
	Intercept	5.433 ± 1.189		
WT	Temperature	0.257 ± 0.005	>0.0001	0.76
	Relative Humidity	**	**	
	Air velocity	-1.288 ± 0.083	>0.0001	
	Intercept	35.602 ± 0.130		
C	Temperature	0.382 ± 0.018	>0.0001	0.88
	Relative Humidity	0.062 ± 0.013	>0.0001	
	Air velocity	-1.179 ± 0.073	>0.0001	
	Intercept	29.339 ± 1.037		

*Although the probability shows that air velocity was not significant, its partial correlation was greater than 50% and was retained in the model. ** Relative humidity had a partial correlation of less than 50% and did not qualify for entry into the model.

The models are of the form RT = aT + bRH + cV + I where a, b, and c are regression coefficients and I is the y-intercept. Other terms are as defined earlier. Table 3b shows the range of conditions over which these models are valid. They are conditions experienced by the birds up to the point of death or end of experiment if the bird survived.

Table 3b. The range of environmental conditions over which the models in Table 3a are valid.

Environmental parameter	BWT	BT	WT	C
Temperature (°C)	25.0 – 40.9	25.0– 40.4	25.0- 42.2	25.0 – 42.2
Relative Humidity (%)	18.9 – 43.9	20.0– 43.9	16.8 – 43.9	16.8 – 43.9
Air velocity (m/s)	0.5 – 2.6	0.5 – 2.6	0.5 – 2.6	0.5 – 2.6

The T had the largest partial correlation with RT in all the treatments. An increase in T resulted in a corresponding increase in RT and the partial R^2 among the treatments were 0.81, 0.83, 0.71 and 0.84 for the BWT, BT, WT and C. RH contributed to the rise in RT of the birds by 4 to 8% in the BWT, BT, and C treatments, respectively. These magnitudes are low probably because the RH was low (16.8 - 43.9%, Table 2) during the experiment. Increasing T limits the birds' ability to transfer heat from their bodies by sensible mechanisms (conduction, convection and radiation). However, lower ambient RH allow for improved heat transfer by evaporation from the birds' respiratory system and cutaneous moisture loss (Lacey *et al*., 2000). On the other hand, V decreased the RT as evidenced by negative slopes in the models. The highest decrease among treatments was 4% in the WT treatment. Burmeister *et al*. (1989) reported an increase in sensible heat loss with increased air speed at low temperatures, but with increasing temperature, the rate of sensible heat loss decreased.

As the T approaches the body temperature of the bird (41º C), the efficiency of drooping wings diminishes. Thus, as T approaches and/or exceeds the body temperature of the bird, BT approaches BWT and C approaches WT (Table 3a). This trend is evidenced by the magnitudes of the parameter estimates and further explains why the parameter estimates for these groups of treatments are comparable.

3.2 Relationships Between Rectal Temperature and Duration of Heat Exposure

Table 4 shows the linear regression models relating the mean RT with duration of heat exposure. The models are of the form RT = at + I where t is the duration of heat exposure (hr) and other terms are as described earlier.

Table 4. The linear regression models relating mean rectal temperature with time

Treatment	Slope	Intercept	P > F
BWT	0.681 ± 0.005	41.013 ± 0.018	<0.0001
BT	0.775 ± 0.008	41.410 ± 0.026	<0.0001
WT	0.391 ± 0.002	41.014 ± 0.011	<0.0001
C	0.438 ± 0.002	40.967 ± 0.009	<0.0001

Note: The times which are valid for the above models are: 0 - 5.9, 0 - 5.3, 0 - 8, and 0 - 8 hrs for BWT, BT, WT and CT, respectively

The rate of RT rise or slope for the BWT treatment was 0.68^o C/hr while that of the BT treatment was 0.78^o C/hr. These were significantly different ($P < 0.0001$). As the T approached and exceeded body temperature of the birds, the contribution of drooping the wings to heat loss diminished. This resulted in the slope of BT approaching that of BWT. On the other hand, the slope of WT treatment was significantly different ($P = 0.0003$) from that of the C treatment (0.39 vs 0.44^o C/hr, respectively). Similarly, as T increased, the slope of C treatment approached that of WT treatment due to reduced effectiveness of the sensible heat loss through the underside of the wings and other non-feathered body parts. In this situation, panting became the predominant heat loss mechanism especially that RH became low as T increased. This is consistent with findings by Lacey *et al*., (2000).

The treatments which had the opportunity to utilize the wings to lose heat (BT and C) tended to have higher rates of RT rise when compared to those that had the wings taped (BWT and WT). This may be caused by increased activity of the wings as the birds became restless due to heat discomfort especially during the first two hours of heat exposure. By the time the birds became calm and panted, they had already gained a substantial amount of heat load. The lower rates of RT rise in the WT and C versus that of BWT and BT clearly suggest that panting (evaporative or latent heat loss) is indeed much more effective as a heat loss mechanism when compared to sensible heat loss as T increased. This is consistent with findings by Simmons *et al*. (1998) who reported a general decrease in sensible heat loss accompanied by a general increase in latent heat loss as T was increased. The intercepts in the models represent the thermoneutral body temperature of the birds which is about 41^o C (Teeter *et al.*, 1992).

3.3 Bird Tolerance to Heat Stress Exposure

There was 100% mortality in the BWT treatment and the lethal cumulative β_{body} among the birds ranged from 3.0 to 12.1^o C-hr with a *weighted* average of 7.1^o C-hr. The length of time the birds took before succumbing to heat stress (survival time) ranged from 123 to 357 min averaging 240 ± 48 min. There was no apparent association between β_{body} and survival time as these varied depending on the individual bird's ability to cope with heat stress. At the time of death, the birds had reached RTs ranging from 45.1 to 46.7^o C with a *weighted* average of 46.4^o C. This represented RT rises of 3.2 to 5.6^o C with a *weighted* average of 5.3^o C. In the BT treatment, mortality was also 100% with the lethal cumulative β_{body} among the birds ranging from 3.5 to 10.1^o C-hr with a *weighted* average of 8.3^o C-hr. The survival times ranged from 194 to 417 min averaging 309 ± 40 min. At the time of death, the birds had reached RTs ranging from 46.0 to 46.8^o C with a *weighted* average of 46.6^o C. This represented RT rises of 3.8 to 5.1^o C with a *weighted* average of 4.5^o C. Chepete and Xin (2000) reported lethal RT rise of 4.7 to 8.2^o C in *Control* laying hens. Comparing the BWT and BT treatments, it seems the critical parameter which determines death of the bird is RT which is about 46^o C, and not so much about how long or how much the bird absorbed the heat. Further, the BT treatment had a higher average β_{body} accumulation than the BWT treatment (8.3 vs 7.1^o C-hr). The cause of the elevated average β_{body} accumulation in the BT treatment could be movement of the wings during period when the birds were restless before calming down. The muscular movement of the wings generates some internal body heat.

One out of five birds in both WT and C treatments died. In the former treatment, the dead bird had a lethal cumulative β_{body} of 9.0^o C-hr in the 362nd min with RT of 45.9^o C, while that in the latter had cumulative β_{body} of 11.0^o C-hr in the 411th min with RT of 46.9^o C. The rest of the birds in these treatments that survived the heat stress exposure had accumulated β_{body} ranging from 6.7 to 12.2^o C-hr averaging 8.7±1.3^o C-hr and 6.4 to 19.5^o C-hr averaging 12.7±3.5^o C-hr for the WT and C treatments, respectively on the 480th minute. The birds experienced rises in RTs during heat stress exposure which reached peaks and later subsided as birds coped. The peak RTs during this period had reached ranges of 43.1 to 45.1^o C averaging 44.5±0.5^o C and 43.7 to 45.4^o C averaging 44.7±0.4^o C for the WT and C treatments, respectively. At these peaks, the RT rises ranged from 1.7 to 3.7^o C averaging 3.0^o C and 2.6 to 4.3^o C averaging 3.7^o C for the WT and C treatments, respectively. Chepete and Xin (2000) reported a lethal average maximum RT rise of 5.4 to 5.8^o C averaging 5.7^o C for *Control* laying hens exposed to 40^o C and 45% RH with average body weight of 1.3 to 1.5 kg, respectively.

It was observed that the birds in the BWT and BT treatments accumulated heat in their bodies at a faster rate than the WT and C counterparts. This may be attributed to the fact that birds in the former treatments were not allowed to pant while those in the latter did. As T increased, panting was much more effective in relieving the birds of heat stress than other sensible heat loss mechanisms (Etches *et al.*, 1989).

Figure 2 shows an illustration of the cumulative β_{body} of two selected birds – one from the BWT treatment which died and the other from the C treatment which survived.

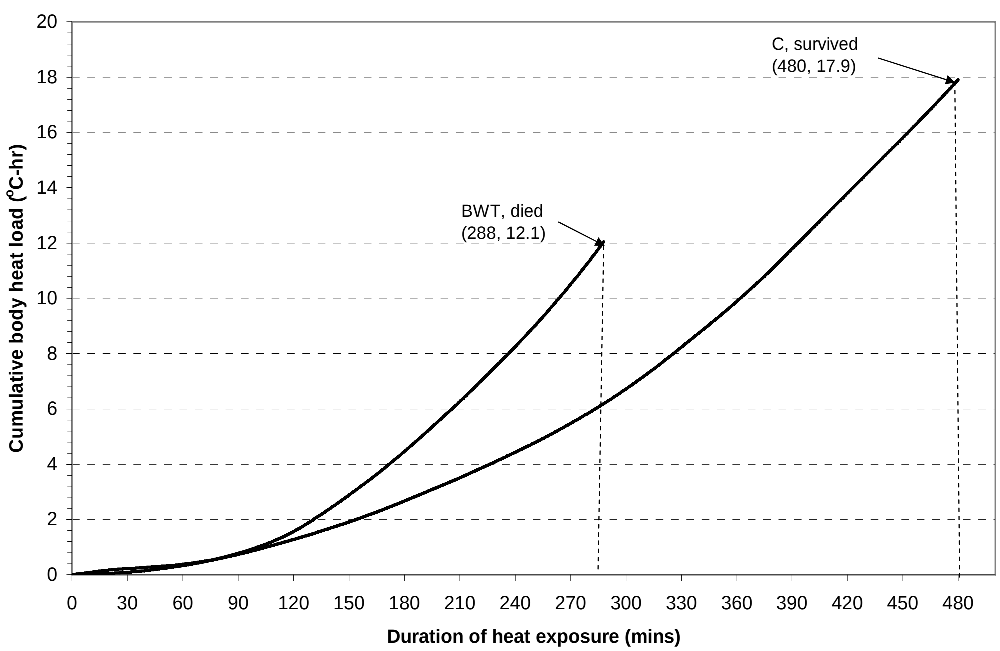

Figure 2. Typical cumulative body heat load (β_{body}) profiles of two selected birds

Generally, the rate of increase of the cumulative β_{body} began to increase faster between the 30 and 40th minute in the BWT and BT treatments while it did so between the 120 and 140th minute in the WT and C treatments. This further shows that panting was more effective in relieving the birds of heat stress.

3.4 Visual Observations of Bird Behaviour

Before the onset of heat exposure, the birds were observed to be calm. After about 30 min after onset of heat, the birds showed signs of discomfort as they moved about the cage seeking a way out. By the first hour, they became more restless and those with untapped wings tried to fly out of the cage. Those with untapped beaks began to pant. After ninety min, the birds had drastically reduced activity and calmed down. Some birds drooped their wings and panted rigorously. None of the birds drank water or fed during the experimental period.

4. CONCLUSIONS

The models that describe the relationship between air temperature, relative humidity and air velocity with rectal temperature of the birds have been developed as well as those that describe the rate of rectal temperature rise with the duration of heat exposure. The average lethal cumulative heat loads were 7.1, 8.3, 9.0 and 11.0^{o}C-hr for the Beak and Wings Taped, Beak Taped, Wings Taped and Control treatments, respectively. For future similar experiments, improvement should be made on the tunnel to accommodate more than one bird per cage.

5. ACKNOWLEDGEMENTS

The author wishes to thank Mr K. Kebabonye and Dr. B. Sebolai for assistance with the conduct of the experiment and statistical analysis, respectively.

6. REFERENCES

Burmeister, A., M. Jurkschat, M. Nichelmann and T. Postel. 1989. The influence of age, wind speed, and ambient temperature on nonevaporative heat loss in turkeys *(Meleagris gallopavo). J. Therm. Biol.* 14(3): 139-145.

Chepete, H. J. and H. Xin. 2000. Alleviating heat stress of laying hens by intermittent partial surface cooling. *Transactions of the ASAE* 43 (4): 965-971.

Chepete, H. J. and R. Tsheko. 2006. Hot and cold weather heat load dynamics of uninsulated broiler house in Botswana. Agricultural Engineering International. The CIGR Ejournal, Manuscript BC 06 001. Volume 8, May, 2006.

Etches, R. J. 1989. Poultry production in hot climates. CAB International, Wallingford, UK.

Lacey, B., T. K. Hamrita, M. P. Lacy and G. L. Van Wicklen. 2000. Assessment of poultry deep body temperature responses to ambient temperature and relative humidity using an on-line telemetry system. *Transactions of the ASAE* 43(3): 717-721.

SAS. 2002-2003. SAS User's Guide: Statistics. SAS Institute, Inc. Cary, North Carolina.

SigmaPlot v7. 2001. SPSS Science, Inc. USA.

Simmons, J. D., B. D. Lott and J. D. May. 1998. Heat loss from broiler chicken subjected to various air speeds and ambient temperatures. *Applied Engineering in Agriculture* 13 (5): 665-669.

Tao, X. and H. Xin. 2003. Acute synergistic effects of air temperature, humidity and velocity on homeostasis of market size broilers. *Transactions of the ASAE* 46 (2): 491-497.

Teeter, R. G, M.O. Smith, and C. J, Wiernusz. 1992. Broiler acclamation to heat distress and feed intake effects on body temperature in birds exposed to thermo neutral and high ambient temperatures. *Poultry Science* 71: 1101-1104.

Yanagi, J. R., H. Xin and R. S. Gates. 2002. A research facility for studying poultry responses to heat stress and its relief. *Applied Engineering in Agriculture* 18(2): 255-260.