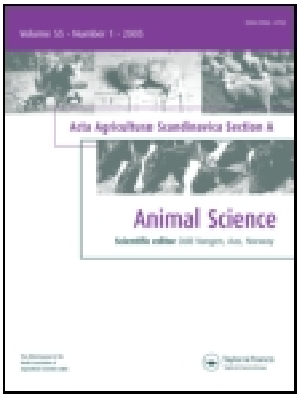
This article was downloaded by: [41.222.42.218]
On: 30 November 2012, At: 02:27
Publisher: Taylor & Francis
Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Acta Agriculturae Scandinavica, Section A - Animal Science
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/saga20

Physiological adaptation of local, exotic and crossbred turkeys to the hot and humid tropical environment of Nigeria

B. M. Ilori [a], S. O. Peters [a b], A. Yakubu [c], I. G. Imumorin [b], M. A. Adeleke [a], M. O. Ozoje [a], C. O. N. Ikeobi [a] & O. A. Adebambo [a]

[a] Department of Animal Breeding and Genetics, University of Agriculture, Abeokuta, Nigeria

[b] Department of Animal Science, Cornell University, Ithaca, NY, USA

[c] Department of Animal Science, Nasarawa State University, Lafia, Nigeria

Version of record first published: 09 Feb 2012.

To cite this article: B. M. Ilori, S. O. Peters, A. Yakubu, I. G. Imumorin, M. A. Adeleke, M. O. Ozoje, C. O. N. Ikeobi & O. A. Adebambo (2011): Physiological adaptation of local, exotic and crossbred turkeys to the hot and humid tropical environment of Nigeria, Acta Agriculturae Scandinavica, Section A - Animal Science, 61:4, 204-209

To link to this article: http://dx.doi.org/10.1080/09064702.2012.656141

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: http://www.tandfonline.com/page/terms-and-conditions

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae, and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand, or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

Acta Agriculturae Scand Section A, 2011; 61: 204–209

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

Physiological adaptation of local, exotic and crossbred turkeys to the hot and humid tropical environment of Nigeria

B. M. ILORI[1], S. O. PETERS[1,2], A. YAKUBU[3], I. G. IMUMORIN[2], M. A. ADELEKE[1], M. O. OZOJE[1], C. O. N. IKEOBI[1] & O. A. ADEBAMBO[1]

[1]*Department of Animal Breeding and Genetics, University of Agriculture, Abeokuta, Nigeria,* [2]*Department of Animal Science, Cornell University, Ithaca, NY, USA, and* [3]*Department of Animal Science, Nasarawa State University, Lafia, Nigeria*

Downloaded by [41.222.42.218] at 02:27 30 November 2012

Abstract

A total of 300 birds consisting of 120 local, 120 crossbred and 60 exotic turkeys were used to compare physiological adaptation of birds raised under the high-heat stress environment of Nigerian tropical humid climate. Genotype significantly ($P < 0.05$) affected heat tolerance traits with the highest mean values for rectal temperature, pulse-rate and heat stress index observed in exotic turkeys. Genotype also had significant ($P < 0.05$) effect on serum biochemical parameters such as glucose (GLU), potassium (K^+) and Chloride (Cl^-). The haematological indices of the birds such as haemoglobin, white blood cell count and heterophyl/lymphocyte ratio (H/L) were equally affected by the different genetic groups ($P < 0.05$). The significantly higher ($P < 0.05$) H/L ratio of the exotic turkeys was an indication of heat stress. The better performance exhibited by local and crossbred turkeys could be exploited in management, conservation and selection decisions of animal genetic resources under tropical conditions.

Keywords: *Adaptability, biochemical indices, haematological parameters, heat stress index turkeys.*

Introduction

The success of any living organism in the tropical environment has been due to various structural, physiological, morphological and behavioural specializations (Storey, 1990 cited in Hermes-Lima et al., 1998; Yakubu et al., 2009). Adaptability of an animal has been defined as the ability to survive and reproduce within a defined environment, or the degree to which an animal can remain/become adapted to a wide range of environments by physiological or genetic means (Barker, 2009). Adapted turkey line like many other poultry species development is a quick way to bridge the available protein gap in the developing countries (Mirkena et al., 2010). However, significant improvement in production traits without consideration for metabolic fitness and support systems can cause problems in overall fitness and survival.

A hot environment is one of the important stressors of poultry production. The resultant heat stress comes from the interactions among air temperature, humidity, radiant heat and air speed, where the air temperature plays a major role (Lin et al., 2006; Ramnath et al., 2008). Mashaly et al. (2004) submitted that high environmental temperatures have deleterious effects on productive performance of different poultry species. A range of behavioural and physiological changes has been used to identify and quantify stress. These changes may differ qualitatively or quantitatively depending on the stressor so that a range of indices should be used in order to assess the extent of the stress or welfare. Measures of rectal temperature (RT), pulse-rate (PR) and respiratory rate (RR) are some of the most important determinants of the adaptation of poultry to the tropical environment. They also, to a large extent, determine the profitability of the

Correspondence: S. O. Peters, Department of Animal Science, Cornell University, Ithaca, NY 14853, USA. Tel: (607) 255 2850. Fax: (607) 255 9829 E-mail: sop6@cornell.edu

(Received 7 September 2011; revised 28 December 2011; accepted 6 January 2012)

ISSN 0906-4702 print/ISSN 1651-1972 online © 2011 Taylor & Francis
http://dx.doi.org/10.1080/09064702.2012.656141

Downloaded by [41.222.42.218] at 02:27 30 November 2012

poultry enterprise. The main haematological response is a change in the heterophyl/lymphocyte (H/L) ratio in leucocytes. The number of heterophyls per unit of blood increases and the number of lymphocytes decreases in birds under stress, but the ratio of these cell types is less variable and thus a better measure than individual cell numbers. Zulkifli et al. (2003) reported that the H/L ratio was a reliable indicator of avian stress. Another indicator of heat stress is prolonged panting (Justin & Stephen, 2004). Heat is produced by metabolism within the body, which includes maintenance, growth and egg production.

Locally developed species are seen as a pool of irreplaceable genetic material of unacknowledged merit and value that must not be lost but must be conserved for possible unknown and unseen future use (Wilson, 2009). A comparative assessment of heat tolerance traits in local, crossbred and exotic turkeys in a warm tropical environment such as Nigeria is lacking. Therefore, the purpose of this experiment was to study the effects of natural environmental heat stress on heat tolerance traits as well as blood haematological and biochemical parameters of local, crossbred and exotic turkeys in the tropical humid zone. This is to provide baseline information for the conservation and improvement of the indigenous turkey genetic resource.

Materials and methods

Study area

This research work was carried out at the Turkey Breeding Unit of the Teaching and Research Farm of the College of Animal Science and Livestock Production, University of Agriculture, Abeokuta, Ogun State, Nigeria. The study area has been previously described in Ilori et al. (2010) and Peters et al. (2011). Mean, minimum and maximum air temperatures, mean rainfall, relative humidity, sunshine and wind speed for the study period are shown in Table I.

Management of parent stock

The parent stocks for both local and exotic turkeys were subjected to standard methods of management at the breeder house. Multi-vitamin drugs were given to the birds on arrival on the farm to serve as an antistress and during the period of their acclimatization to stabilize their condition. They were fed *ad libitum* initially with grower mash while breeder mash was provided a month before laying. Clean water was also supplied *ad libitum*. Standard vaccination programme for turkey's parent stock was adhered to. Adequate sanitation was carried out to prevent occurrence of diseases. The two turkey populations were reared under the same management system as described by Oluyemi and Roberts (2000). The research was conducted in consonance with the guidelines of the Institutional Animal Care and Use Committee of the University of Agriculture, Abeokuta.

Mating scheme

Due to obvious differences in body size between the exotic and local parent stocks, artificial insemination technique as described by Lake (1962) was used. The exotic poults were generated by mating exotic male turkeys to exotic female turkeys while local poults were generated from the cross between local male and female turkeys. The crossbreds were generated by mating the exotic male to local females. Eggs from the three genetic groups were collected daily, identified appropriately with markers and set in the incubator on a weekly basis.

Management of poults

A total of 300 poults consisting of 120 local, 120 crossbred and 60 exotic poults were used for this study. The poults were brooded in deep litter pens according to their genetic groups. All poults were wing-tagged for proper identification and subjected to the same management practices throughout the experimental period. Commercial feeds were provided for the birds *ad libitum*. Starter mash containing 28% crude protein (CP), grower mash (24% CP) and finisher mash (20% CP) were fed to the birds from 0 to 6, 7 to 16 and 17 to 20 weeks, respectively. Clean and cold water were supplied *ad libitum*. Necessary vaccinations against Newcastle,

Table I. Meteorological data for the period of the study.

Location	Season	Month	Rainfall (mm)	Max. temp. (°C)	Min. temp. (°C)	Mean temp. (°C)	Relative humidity (%)	Sunshine	Wind speed (m/s)
UNAAB	Late wet	July–September	125.53	30.08	13.00	21.54	84.97	4.50	0.57
UNAAB	Early dry	October–December	54.37	38.83	12.57	23.20	73.60	3.80	0.57
UNAAB	Late dry	January–March	36.97	35.40	14.53	24.97	67.93	4.80	0.50

Source: UNAAB – University of Agriculture, Abeokuta, Nigeria fowl pox and Gumboro diseases as well prophylactic antibiotics and anticoccidial drugs were also administered to the birds.

Data collection

Data were collected on a weekly basis for 20 weeks from late wet (July–October), early dry (November–December) and late dry seasons (January–March). Parameters measured included RT, PR and RR. RT was measured by inserting a digital rectal thermometer into the rectum of the birds for 1 min after which the readings were taken. PR was measured by placing the finger tips under the wing vein and counting the number of beats per minute using the stopwatch while RR was determined for each bird by counting the movement of the abdominal region or the vent using stopwatch. RT, PR and RR of all the birds were measured early in the morning before sun rise between the hours of 7:00 am and 9:00 am and 1:00 pm and 3:00 pm, respectively, twice a week as described by Oladimeji et al. (1993). The RT was measured by inserting the thermometer about 3 cm, into the rectum via the cloaca until an alarm sound was produced, indicating the end of the reading (Adenkola and Ayo, 2009).

The relationship between PR and RR together with their normal average values were used to derive heat stress index (HSI) according to Oladimeji et al. (1993).

Blood samples were also collected from the three genotypes two times per season during the late wet season (July–October) when they were 6 and 8 weeks old, early dry (November–December) at 11 and 13 weeks of age and during late dry season (January–March) at 18 and 20 weeks of age. About 5 ml of blood was collected through the wing vein from each bird, 2 ml of which was dispensed into clean Bijou bottle containing ethylene diamine tetraacetic acid as an anticoagulant and labelled accordingly. The rest was allowed to clot and also labelled accordingly. The uncoagulated blood was used to determine the packed cell volume (PCV), red blood cell (RBC), white blood cell (WBC) count, H/L ratio, glucose (GLU) and haemoglobin (Hb). The clotted blood was spinned using a bucket centrifuge to separate the serum used for the analysis of sodium (Na^+), potassium (K^+) and chloride (Cl^-). All the parameters were determined according to the methods described by Edingston and Gilles (1981).

Statistical analysis

All data collected were subjected to analysis of variance using the PROC GLM procedure of SAS (2007) to determine the fixed effects of genotype on RT, PR, RR, HSI, PCV, RBC, WBC, H/L ratio, GLU, Hb, Na^+, K^+ and Cl^- of the turkeys. Means were separated using Duncan's Multiple Range test. Sex effect was not significant for all the parameters measured, hence sex was excluded as a factor.

The final model employed was:

$$Y_{ijk} = \mu + G_i + e_{ijk}$$

where Y_{ijk}, the parameter of interest; μ, overall mean for the parameter of interest; G_i, fixed effect of ith genotype (i – local, exotic and crossbred); e_{ijk}, errors are independent and identically distributed as normal with mean 0 and constant variance.

Results

Effect of genotype on heat tolerance traits

The least squares means of the effects of genetic group on heat tolerance traits revealed significant ($P < 0.05$) differences for all the parameters measured (Figures 1–4). The exotic turkeys had the highest mean value of RT (40.62 ± 0.01) at 20 weeks of age followed by the crossbred (40.52 ± 0.02) and the local genotype (40.36 ± 0.01). RR value was also higher in exotic birds. For PR, the exotic turkeys had the highest mean value followed by the crossbred and local turkeys. Genotype also had significant ($P < 0.05$) effects on HSI. The highest mean value ($P < 0.05$) of HSI was observed in exotic turkeys chronologically followed by the local and crossbred turkeys.

Effect of genotype on blood parameters

The least squares means and standard errors of blood parameters as influenced by genotype are shown in Table II. The local turkeys had the highest ($P < 0.05$) blood glucose level while the K^+

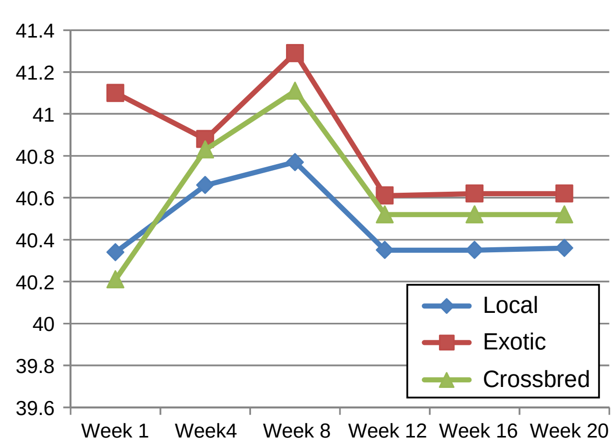


Figure 1. Mean RT (°C) of turkeys as affected by genotype and age (weeks).

Downloaded by [41.222.42.218] at 02:27 30 November 2012

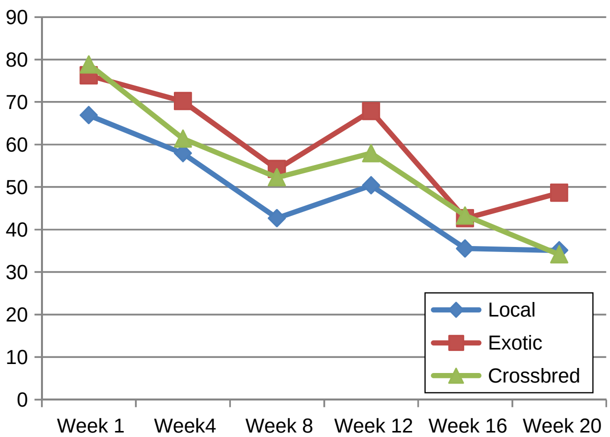


Figure 2. Mean RR (breaths/min) of turkeys as affected by genotype and age (weeks).

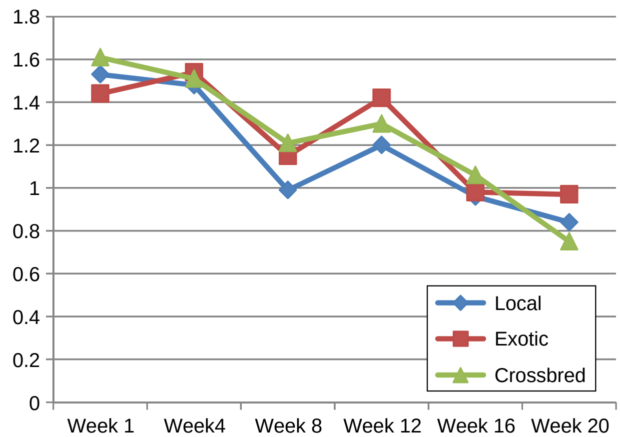


Figure 4. Mean HSI of turkeys as affected by genotype and age (weeks).

concentration was more in their crossbred counterparts. Cl^- and WBC concentrations were higher in both local and exotic turkeys, although the latter was not significantly different in WBC from the crossbreds. Hb value was higher ($P < 0.05$) in exotic turkeys, which equally had the highest ($P < 0.05$) H/L ratio. However, Na^+ and RBC values were not affected ($P > 0.05$) by genotype.

Discussion

The animal and its environment make up an integrated system, where each acts on the other. Tropical regions are characterized by high levels of solar radiation and environmental temperature which may adversely affect animal production (Castanheira et al., 2010). Stress response is mainly associated with the activation of hypothalamo–pituitary–adrenal gland and orthosympathic nervous system, which aggravates the detrimental effect of high body temperature (Lin et al., 2006), and may compromise animal welfare (Blokhuis et al., 2010). The result of the study revealed that the genotypes differ in terms of RT with the exotic turkeys having the highest value. Their higher RR is consistent with the report of Robert (1994) that the size of the animal also affects the RR. As ambient temperature increases, birds start to pant to lose heat which is accompanied by increase in RRs. This is in agreement with the findings of Brown-Brandl et al. (1997). Lin et al. (2005) also reported that high temperature in addition to changes in RT could lead to the disturbance of thermal balance of birds. The result of the PR could be attributed to the fact that the local turkeys were well adapted to the prevailing harsh production environmental conditions. This could be due to natural selection which might have aided them in the accumulation of genes for adaptability. HSI indicated that crossbreds and the local turkeys adapted better than their exotic counterparts. This is not surprising considering the inherent higher heat load of the latter.

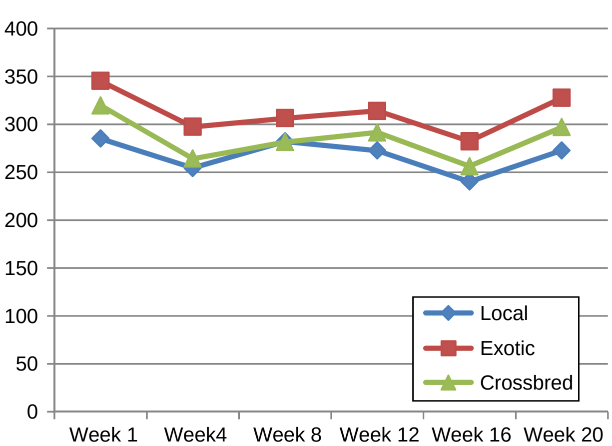


Figure 3. Mean PR (beats/min) of turkeys as affected by genotype and age (weeks).

Genetic variation was observed in the haematological and biochemical contents of the birds. The GLU concentration revealed that the local turkey exhibited the best adaptive performance. Etches et al. (2008) reported that when young chickens were exposed to high ambient temperatures, plasma corticosterone increased within 30 min, but dropped below pre-exposure levels within 120 min with the drop in circulatory level accompanied by low plasma concentrations of glucose, phosphate, sodium ion and elevated plasma pH. However, the lower GLU value especially of the exotic turkeys might be due to the fact that they are heavier than their local counterparts. El-Dlebshany et al. (2009) reported that high body weight caused decrease in GLU concentration. Serum parameters are important in

Downloaded by [41.222.42.218] at 02:27 30 November 2012

Table II. Least squares means, standard errors (±SE) and coefficients of variation (CV) (%) of blood parameters as influenced by genotype.

	Genotype					
Traits	Local	CV	Exotic	CV	Crossbred	CV
GLU (mg/dl)	214.96 ± 8.13^a	16.05	178.51 ± 7.11^b	16.92	184.44 ± 6.90^b	15.87
Na^+ (mmol/l)	156.78 ± 2.82^a	7.62	160.33 ± 2.84^a	7.51	157.83 ± 2.72^a	7.32
K^+ (mmol/l)	2.84 ± 0.17^c	25.35	3.32 ± 0.07^b	9.34	3.74 ± 0.13^a	14.71
Cl^- (mmol/l)	106.72 ± 1.26^{ab}	5.03	109.28 ± 1.31^a	5.10	105.22 ± 1.13^b	4.57
PCV (%)	42.67 ± 1.48^a	14.69	44.67 ± 1.55^a	14.73	43.06 ± 1.16^a	11.43
Hb (g/dl)	14.05 ± 0.47^b	14.23	15.08 ± 0.53^a	14.85	14.13 ± 0.36^b	10.90
WBC ($\times 10^9$)	21.24 ± 0.69^a	13.84	19.68 ± 0.52^{ab}	11.13	19.06 ± 0.59^b	13.22
RBC ($\times 10^{12}$)	4.67 ± 0.19^a	17.34	4.94 ± 0.22^a	18.62	4.75 ± 0.20^a	17.89
H/L ratio	0.16 ± 0.01^b	37.50	0.21 ± 0.02^a	28.57	0.14 ± 0.01^b	35.71

GLU, glucose; Na^+, sodium; K^+, potassium; Cl^-, chloride; PCV, packed cell volume; Hb, haemoglobin; WBC, white blood cell counts; RBC, red blood cell counts; H/L, heterophyl/lymphocyte ratio; values with different superscripts are significantly different ($P < 0.05$).

Downloaded by [41.222.42.218] at 02:27 30 November 2012

the proper maintenance of the osmotic pressure between the circulating fluid and the fluid in the tissue spaces so that the exchange of materials between the blood and cells could be facilitated. They also contribute to the viscosity and maintenance of normal blood pressure and pH (Ladokun et al., 2008). The results of K^+ and Cl^- concentration in this study suggested that heat stress decreased serum electrolytes especially the cations with increase in body temperature. During acute heat stress, as the body temperature rises, haemodilution occurs, some of the tissue K exits into the bloodstream apparently due to altered membrane permeability. When this K translocation phenomenon abates during or after acute heat stress, or due to adaptation to chronic heat stress, and excess K is excreted, plasma K concentrations return to normal or below (Borges et al., 2004). Yahav et al. (1995) reported that a range of 11.4–11.7 g/dl in Hb in Israelian Turkeys, which are lower than the values obtained in the current study. Exotic turkeys had the highest ratio of H/L. Zulkifli et al. (2003), Huff et al. (2005) and Aksit et al. (2006) reported that the H/L ratio was a reliable indicator of avian stress; and this can be used as a selection criterion for heat tolerance in birds (Al-Murrani et al., 1997; Peters et al., 2011). The local and the crossbred turkeys had lower H/L ratios suggesting better adaptability to the tropical environment. This is an indication that the local turkeys could have accumulated genes for better adaptation at the expense of genes for better growth performance. The analysis of domestic animal genetic resources is imperative in order to assist management decision-making on which resources to preserve and possibly improve for fitness-adaptability traits (Barker, 2009). Therefore, the present findings open possibilities for associating high growth rate with better heat performance.

Conclusion

Genetic differences accounted for variations in heat tolerance traits and blood parameters of the turkeys. The local and crossbred turkeys appeared to exhibit better adaptability to the Nigerian humid tropical environment than their exotic counterparts. The present findings in line with global initiative could assist in the design of long-term genetic improvement programme for turkey production in the tropics characterized by high temperature and relative humidity. The attendant effect will be increase in the number of birds, thereby assisting in bridging the animal protein gap in poor developing countries.

References

Adenkola, A. Y. & Ayo, J. O. (2009). Effects of ascorbic acid on rectal temperature fluctuations in indigenous turkeys during the hot-dry season. *International Journal of Poultry Science*, *8*, 457–461.

Aksit, M., Yalcin, S., Ozkan, S., Metin, K., & Ozdemir, D. (2006). Effects of temperature during rearing and crating on stress parameters and meat quality of broilers. *Poultry Science*, *85*, 1867–1874.

Al-Murrani, W. K., Kassab, A., Al-Sam, H. Z., & Althari, A. M. K. (1997). Heterophil/lymphocyte ratio as a selection criterion for heat resistance in domestic fowls. *British Poultry Science*, *38*, 159–163.

Barker, J. S. F. (2009). Defining fitness in natural and domesticated populations. In J. H. J. van der Werf, H.-U. Graser, R. Frankham, & C. Gondoro (eds.) *Adaptation and Fitness in Animal Populations. Evolutionary and Breeding Perspectives on Genetic Resource Management*. Dortrecht: Springer.

Borges, S. A., Fischer da Silva, A. V., Majorka, A., Hooge, D. M., & Cummings, K. R. (2004). Physiological responses of broiler chickens to heat stress and dietary electrolyte balance (sodium plus potassium minus chloride, milliequivalents per kilogram). *Poultry Science*, *83*, 1551–1558.

Blokhuis, H. J., Veissier, I., Miele, M., & Jones, B. (2010). The Welfare Quality® project and beyond: Safeguarding farm animal well-being. *Acta Agriculturae Scandinavica, Section A – Animal Science*, *60*, 129–140.

Downloaded by [41.222.42.218] at 02:27 30 November 2012

Brown-Brandl, T. M., Beck, M. M., Schulte, D. D., Parkhurst, A. M., & DeShazer, J. A. (1997). Physiological response of tom turkeys to temperature and humidity change with age. *Journal of Thermal Biology*, *22*, 43–52.

Castanheira, M., Paiva, S. R., Louvandini, H., Landim, A., Fiorvanti, M. C. S., Dallago, B. S., Correa, P. S., & McManus, C. (2010). Use of heat tolerance traitss in discriminating between groups of sheep in central Brazil. *Tropical Animal Health and Production*, *42*, 1821–1828.

Edingston, G. M. & Gilles, H. M. (1981). *Pathology of Haemonchus contortus in the Tropics* (2nd Edn). London: Edward Arnold Publisher Ltd.

El-Dlebshany, A. E., El-Tahawy, W. S., & Amin, E. M. (2009). Inheritance of some blood plasma constituents and its relationship with body weight in chickens. *Egyptian Poultry Science*, *29*, 465–480.

Etches, R. J., John, T. M. & Verrinder Gibbins, A. M. (2008). Behavioural, physiological, neuroendocrine and molecular responses to heat stress. In: N.J. Daghir, (ed.) *Poultry Production in Hot Climates*, 2nd Edn. (CABI), pp. 61–65.

Hermes-Lima, M., Storey, J. M., & Storey, K. B. (1998). Antioxidant defences and metabolic depression. The hypothesis of preparation for oxidative stress in land snails. *Comparative Biochemistry and Physiology, Part B*, *120*, 437–448.

Huff, G. R., Huff, W. E., Balog, J. M., Rath, N. C., Anthony, N. B., & Nestor, K. E. (2005). Stress response differences and disease susceptibility reflected by heterophil to lymphocyte ratio in turkeys selected for increased body weight. *Poultry Science*, *84*, 709–717.

Ilori, B. M., Peters, S. O., Ikeobi, C. O. N., Bamgbose, A. M., Isidahomen, C. E., & Ozoje, M. O. (2010). Comparative assessment of growth in pure and crossbred turkeys in a humid tropical environment. *International Journal of Poultry Science*, *9*, 368–375.

Justin, E. & Stephen, E. (2004). Heat Stress in Poultry-solving the Problem (ADAS). Accessed 8 February 2009, available at: www.adas.co.uk/LinkClick.aspx?fileticket = jup96ObjlnQ%3D&tabid. . .

Ladokun, A. O., Yakubu, A., Otite, J. R., Omeje, J. N., Sokunbi, O. A., & Onyeji, E. (2008). Haematological and serum biochemical indices of naked neck and normally feathered Nigerian indigenous chickens in a sub-humid tropical environment. *International Journal of Poultry Science*, *7*, 55–58.

Lake, P. E. (1962). Artificial insemination in poultry. In J. P. Maile (ed.) *The Semen of Animals and Artificial Insemination*, pp. 331–335. Bucks: Commonwealth Agricultural Bureau.

Lin, H., Jiao, H. C., Buyse, J., & Decuypere, E. (2006). Strategies for preventing heat stress in poultry. *World's Poultry Science Journal*, *62*, 71–85.

Lin, H., Zhang, H. F., Du, R., Gu, X. H., Zhang, Z. Y., Buyse, J., & Decuypere, E. (2005). The thermoregulation response of broiler chickens to humidity at different ambient temperatures 1. Four-week-age. *Poultry Science*, *84*, 1173–1178.

Mashaly, M. M., Hendricks, G. L., Kalama, M. A., Gehad, A. E., Abbas, A. O., & Patterson, P. H. (2004). Effect of heat stress on production parameters and immune responses of commercial laying hens. *Poultry Science*, *83*, 889–894.

Mirkena, T., Duguma, G., Haile, A., Tibbo, M., Okeyo, A. M., Wurzinger, M., & Solkner, J. (2010). Genetics of adaptation in domestic farm animals: A review. *Livestock Science*, *132*, 1–12.

Oladimeji, B. S., Osinowo, O. A., Alawa, J. P., & Hambolu, J. O. (1993). Estimation of average values for pulse rate, respiratory rate and rectal temperature and development of heat stress index for adult Yankassa sheep. *Bulletin of Animal Health and Production in Africa*, *45*, 105–107.

Oluyemi, J. A. & Roberts, F. A. (2000). *Poultry Production in Warm Wet Climates*, pp. 88–117. Ibadan: Spectrum Books.

Peters, S. O., Gunn, S. S., Imumorin, I. G., Agaviezor, B. O., & Ikeobi, C. O. N. (2011). Haematological studies on frizzled and naked neck genotypes of Nigerian native chickens. *Tropical Animal Health and Production*, *43*, 631–638.

Ramnath, V., Rekha, P. S., & Sujatha, K. S. (2008). Amelioration of heat stress induced disturbances of antioxidant defence system in chicken by Brahma Rasayana. *Evidence-based Complementary and Alternative Medicine*, *5*, 77–84.

Robert, A. V. (1994). *Raising Healthy Goats Under Primitive Conditions, Overview of General Information* (Washington, DC: Christian Veterinary Mission), pp. 12–18.

SAS. (2007). *SAS Users Guide: Statistics Released Version 8.2*. (Cary, NC: Statistical Analysis System Institute Inc.).

Wilson, R. T. (2009). Fit for purpose – the right animal in the right place. *Tropical Animal Health and Production*, *41*, 1081–1090.

Yahav, S., Goldfield, S., Plavnik, I., & Hurwitz, S. (1995). Physiological responses of chickens and turkeys to relative humidity during exposure to high ambient temperature. *Journal of Thermal Biology*, *20*, 245–253.

Yakubu, A., Gwaska, J. A., & Salako, A. E. (2009). Strain and placement density effect on welfare, haematological and serum biochemical indices of broilers in north central Nigeria. *Acta Agriculturae Slovenica*, *94*, 153–158.

Zulkifli, I., Liew, P. K., Israf, D. A., Omar, A. R., & Hair-Bejo, M. (2003). Effect of early age feed restriction and heat conditioning on heterophil/lymphocyte ratios, heat shock protein 70 expression and body temperature of heat-stressed broiler chickens. *Journal of Thermal Biology*, *28*, 217–222.