Production performance and temperature-humidity index of broilers reared in naturally ventilated houses in Botswana

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ABSTRACT
Production performance of straight-run Cobb 500 broilers under commercial management practices was investigated and their temperature humidity index developed. Birds were raised in three non-insulated naturally ventilated houses over a 6-week period. One trial was undertaken in winter and the other in summer. The environmental parameters measured were indoor and outdoor air temperature and relative humidity. Production responses measured were specific feed intake, average body mass and mortality while those derived were body mass gain and feed conversion. Due to lack of environmental control, the broiler house temperatures fell outside the thermoneutral temperature zone of the birds for a significant period which negatively affected their welfare and production performance. The mean specific feed intake ranged from 152 to 279 g feed/kg body mass while mean feed conversion ranged from 1.82 to 3.29 kg feed/kg body mass gain. The live weight of the birds at six weeks of age ranged from 1.8 to 2.3 kg while mortality ranged from 3.8 to 9.3%. Temperature humidity index developed at 3 to 4 and 5 to 6 weeks of age was $THI_{3\text{-}4wk} = 0.62T_{db} + 0.38T_{wb}$ or $THI_{5\text{-}6wk} = 0.71T_{db} + 0.29T_{wb}$. This index can now be represented graphically and farmers can use it as a handy look-up management chart that guides them on proper strategies to employ to relieve the birds of heat stress.
Keywords: Broilers, temperature humidity index, feed conversion, feed intake, temperature

INTRODUCTION
The environment in which birds are raised constitutes a decisive factor in the success or failure of a poultry operation (Tinoco et al, 2003). Among all possible environmental factors, air temperature, relative humidity, thermal radiation, and air movement most directly affect broiler production because they affect maintenance of homoeothermy. Out of the thermal comfort zone, birds must make more drastic physiological adjustments to maintain constant core body temperature. This in turn reduces production performance, because dietary energy and nutrients are not used for growth and development, but rather to produce or dissipate heat (Penz, 1991).

Some widely used animal production performance indicators are feed conversion, feed intake, mortality and, body mass gain. The environmental parameters mentioned above as well as nutrition play a pivotal role in determining bird performance and should thus be monitored continuously.
The temperature humidity index (THI) has been widely used by researchers to assess effects of hot and humid environments on humans and animals. The THI indicates an animal's response to temperature and humidity and thus the relative importance of the sensible and latent thermal components (Xin et al., 1992). The THI is usually expressed by assigning different weighting factors to the dry bulb (T_{db}) and wet bulb (T_{wb})

temperatures. It has been developed for different animal species including cows (Bianca, 1962; Kabuga, 1992), pigs (Ingram, 1965), laying hens (Zulovich Chepete et al. and DeShazer, 1990), hen turkeys (Xin et al., 1992), and tom turkeys (Brown-Brandl et al., 1997). Gates et al. (1995) used the THI of laying hens to assess broiler production in response to heat stress for lack of information on THI for broilers.

Naturally ventilated (NV) broiler housing system with no insulation is common in Botswana and the performance of broilers under local conditions and management practice has not been investigated. Due to harsh environmental conditions, especially the long hot season, broiler producers have indicated a need to investigate bird performance and develop a management tool that could be used to guide farmers on how to mitigate heat stress on the birds. Hence, the objectives of this study were to investigate the production performance of Cobb 500 broilers reared in NV houses and develop the THI at different growth stages under typical low-scale commercial production setup.

Materials and Methods

Housing Facilities

The study was conducted at the Botswana College of Agriculture's (BCA) Student Enterprise Project (SEP) broiler houses. The management ractices were typical of small-scale commercial production. Birds were raised in three identical NV houses measuring 16.0 m L × 7.6 m W × 2.5 m H oriented east-west. The end wall and dwarf sidewalls (0.8 m high) were made of unplastered 11 cm thick single course concrete masonry. A 15 mm diameter thin wire mesh covered the sidewall openings to a height of 1.7 m. Polyethylene plastic curtains were fitted along the entire sidewall and could manually be opened or closed whenever necessary. Reflective corrugated iron sheets were used as roofing material with no insulation and no ceiling. There was a 35 cm ridge opening along the entire length of the roof which was also covered with thin wire mesh. The floor was made of 75 mm poured concrete. Three fluorescent light bulbs (58 W each) were used in each house to provide lighting. About 1700 day-old straight-run (mixed male and female) Cobb 500 broiler chicks weighing 0.04 kg/chick were brought into each of the three houses (House 1, 2, and 3) at two-week lapse period during each of the two trials (Trial 1 and 2). That is, when house 1 was stocked, house 2 would be stocked 2 weeks later, and house 3 another 2 weeks after house 2. Prior to chick arrival, the floor was covered to a depth of 5 cm with wood shavings over a 42.6 m^2 floor area for brooding. Small feeders and trough drinkers were used during brooding. When chicks arrived, they were group-weighed (100 chicks per box) and put into the brooding area with the gas brooder turned on.

Water was provided to the chicks immediately for two hours after which chick starter mash was fed. The 5.0 kW gas brooder (Model CE 0085 Type M8, Gasolec, Bodegraven, The Netherlands) was turned on for 16 hours continuously in winter (6 pm to 10 am) and for 12 hours in summer (8 pm to 8 am) for 10 to 12 days. When birds reached two weeks of age, the floor space was increased to 85.1 m^2. From the third week to point of slaughter (sixth week), the entire floor space of 121.6 m^2 was used. At the end of each trial, the houses were rested for two weeks before commencement of the next trial to allow for cleaning and disinfecting. Feeding schedule during the rearing period is indicated in Table 1. After brooding, feed and water were provided *ad libitum* via suspended feed troughs and automatic bell drinkers. Similar management schemes and chick quality were maintained in all houses and trials.

Table 1. Nutrient composition of *ad libitum*-fed feed for the broilers

Ingredient (%)	Starter mash (week 1)	Starter crumbles (week 2 - 3)	Grower pellets (week 4 to 5)	Post finisher pellets (week 6)
Crude protein	17.24	16.36	16.63	13.53
Total Phosphorus	0.71	0.91	0.98	0.81
Magnesium	0.21	0.28	0.35	0.23
Calcium	0.97	1.18	1.21	0.98

Data Collection

The environmental parameters measured were indoor and outdoor temperature and relative humidity (RH) using temperature and RH sensors built into IceSpy RL-TT radio transmitters. The temperature and RH signals from all the houses were transmitted to a data logging IceSpy Radio Collection Unit (Model 4374, A.W.R. Smith Process Instrumentation CC, South Africa) located in house 2. Four transmitters were used per house - two inside and two outside. Transmitters in the house were placed at bird level while those outside were placed at the mid height of the sidewall opening. The data were recorded on an hourly basis for the entire rearing period and were downloaded once every week for analysis.

Daily mean air velocity data were recorded using an anemometer (Model Casella W 1208/2, England, UK) at a meteorological station located within 100 m from the experimental site. Mortality and feed consumption were recorded daily. The average body mass (BM) of the birds was measured once every week by group-weighing a sample of the birds on an electronic scale. The sample consisted of 500, 100, 100, 60, 50 and 40 birds during week 1 to 6, respectively. Feed conversion (FC) was calculated on weekly basis as the unit weight of feed per unit live body weight of birds.

THI Development

Procedures outlined by Xin et al. (1992) and Brown-Brandl et al. (1997) were used in THI development. The bird physiological responses used were daily feed intake (FI), body mass gain (BMG) and mortality while environmental parameters were daily mean indoor dry bulb and wet bulb temperatures.

Data Analysis

Analysis of variance (ANOVA) was used to determine variability of mean indoor environmental conditions (temperature and RH) among the houses within and between trials. Multiple linear regression analysis was used in the development of THI. In both cases, Statistical Analysis Software (SAS, SAS Institute 2001) was used.

RESULTS AND DISCUSSIONS

Environmental Conditions

There were significant differences ($P = 0.0001$) in mean temperature and RH between trials 1 (winter, May - July 2003) and 2 (summer, August - October, 2003) as well as among the houses within each trial. Thus, the discussion of bird performance is presented separately for each trial and for each house within trial since the mean environmental conditions greatly influence the production performance of the birds (Penz, 1991).

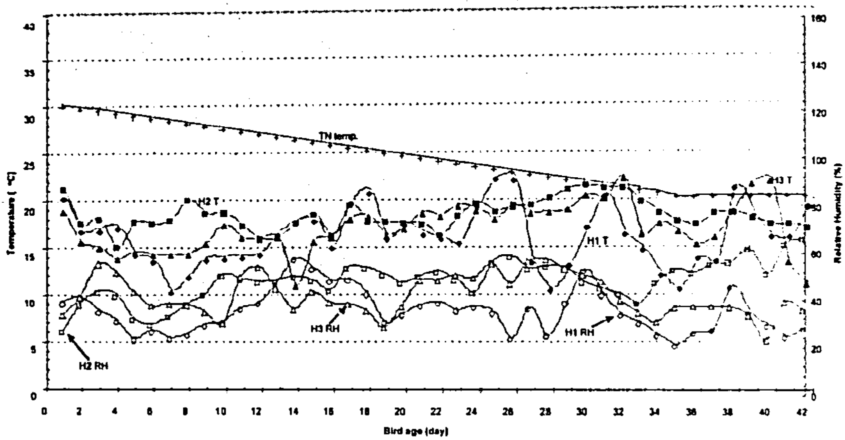
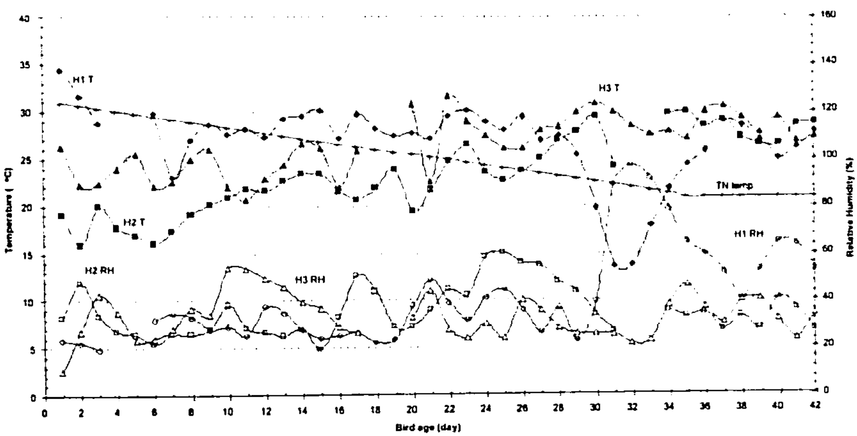


Figure 1. Daily mean indoor temperature (T) and relative humidity (RH) of three broiler houses (H1, H2, H3) during trial 1. The experiment was staggered as such: H3 started 14 days after H2 and H1 started 28 days after H2. TN temp is thermoneutral temperature as per Cobb 500 Broiler Management Guide (1993).

The mean daily air velocity measured outside the houses ranged from 1.3 to 1.6 m/s and 2.0 to 2.3 m/s during trial 1 and 2, respectively.

Figure 1 shows the daily mean indoor temperature and RH during trial 1 over a 42-day growth period. The mean temperature ranged from 10.8 to 22.7°C, 15.5 to 22.0 °C, and 11.6 to 23.0 °C, for house 1, 2, and 3, respectively. The corresponding mean RH was 22 to 59%, 28 to 67%, and 25 to 59%. Figure 2 depicts similar results for trial 2 with mean temperature ranging from 13.7 to 34.5°C, 16.0 to 30.0 °C, and 20.8 to 31.8 °C, for house 1, 2, and 3, respectively. The corresponding mean RH was 20 to 98%, 20 to 61%, and 11 to 55%. The peak RH of 98% in trial 2 for house 1 corresponds to a period when it had rained (Fig. 2). The gaps in the graphs in figure 2 are a result of unrecorded data due to temporary data logger failure. Thermoneutral temperature (TN) for broilers ranges from 21 to 30°C (Chepete & Xin, 2002) and the set point temperature depends on bird age. For example, the Cobb 500 Broiler Management Guide (1993) recommends a temperature of 31.0 °C for day old chicks that should be reduced by 0.29 °C per day until it reaches 21 °C at 35 days of age where it remains constant until slaughter. This TN is plotted in both figures 1 and 2. The mean temperature range was 10.8 to 23.0 °C during trial 1 which suggests that the birds were mostly exposed to cold stress and is evidenced by house temperatures being below TN temperature (fig. 1). Lack of insulation and supplemental heating

Figure 2. Daily mean indoor temperature (T) and relative humidity (RH) of three broiler houses (H1, H2, H3) during trial 2. The experiment was staggered as such: H3 started 14 days after H2 and H1 started 28 days after H2. TN temp is thermoneutral temperature as per Cobb 500 Broiler Management Guide (1993).



made it impossible to maintain the desired indoor temperature. Birds tend to feed more when they feel cold and use the valuable energy in keeping themselves warm at the expense of meat production (Penz, 1991) and this increases the costs of feed.

During trial 2, the mean temperature range was 13.7 to 34.5 °C which suggests that birds were at times cold (mostly at 0 to 14 days of age, fig. 2) or too warm (mostly at 15 to 42 days of age, Fig. 2). Under uncontrolled environment, the comfort of the birds cannot be guaranteed. Such large temperature fluctuations may aggravate the physiological stress on the birds as they adjust to cope with the ever-changing environment. Yunis and Cahaner (1999) reported that growth rate, feed efficiency, and meat yield are significantly decreased when broilers are reared at high ambient temperature. Reductions of 23 to 33% in body weight gain have been reported by Yalcin et al. (1997) in commercial broilers raised during a hot summer. Therefore, there is need to have some supplementary heating and cooling mechanism fitted in NV houses to mitigate incidents of adverse weather. Provision of insulation on the walls and roof would reduce heat loss and help maintain better indoor temperatures.

Production Performance

Table 2 shows mean specific FI, FC, body mass and mortality of birds during trials 1 and 2. Specific FI generally decreased with increasing bird age due to increasing body mass and the overall average ranged from 152 to 257 and 157 to 279 g feed/kg body mass for trials 1 and 2, respectively. On the other hand, FC did not seem to follow any pattern probably due to the fluctuating environmental conditions (figs. 1 and 2) that tremendously influenced the feeding habits of the birds as well as physiological utilization of consumed feed. The corresponding FC values ranged from 1.83 to 2.83 and 1.82 to 3.29 kg feed/kg BMG. High FC is not desirable as it is indicative of low efficiency in converting feed into meat and results in low body mass as is the case for house 3 trial 2. Under controlled environment, Proudfoot and Hulan (1987) obtained significant linear trends for FC as well as significant quadratic and cubic contrasts that provided evidence that the FC trends tended to be erratic and they partially attributed this to temperature × diet interaction. Similarly, Xin et al. (1994) reported increasing linear trend of FC for Cobb × Cobb male broilers raised under controlled environment. The average body mass at the end of the six-week growth period ranged from 2.2 to 2.3 and 1.8 to 2.3 kg/bird during trials 1 and 2, respectively.

Overall total mortality by the end of the six-week growth period ranged from 4.3 to 9.3 and 3.8 to 7.0 %, respectively during trials 1 and 2. During trial 1 (winter), daily mean temperatures were up to 18.5°C lower than TN 93 to 98% of the time (fig. 1) thus, mortality may have been caused largely by cold stress. On the other hand, daily mean temperatures during trial 2 (summer) were up to 9°C higher than TN 36 to 74% of the time (fig. 2) hence, heat stress may have contributed significantly to mortality. Commonly, local producers consider 5% mortality as acceptable and sometimes they register up to 10% during extreme conditions. Under controlled environment, mortality of 2 to 3% is common and 5% is considered high.

Temperature Humidity Index (THI)

Since THI is for thermally challenging conditions, only mean daily dry bulb temperatures that were higher than TN (fig. 2) in the different houses were selected and used in the THI development together with their corresponding bird production responses. This occurred only in trial 2. Birds tended to lie down, spread their wings out, and/or panted during this period due to heat stress. The mean temperature and RH used ranged from 21.9 to 31.8°C and 22 to 79%, respectively. THI was developed for birds at the age groups of 3 to 4, and 5 to 6 weeks to account for changes in birds' physiology, size and surface area which influence their reactions to effects of temperature and RH (Brown-Brandl et al., 1997). THI was not developed for birds during brooding (0 to 2 weeks of age) due to few data points that represented stressful conditions (fig. 2) and thus would not yield meaningful THI equations.

The results of THI development are depicted in Table 3. The significant effect of temperature and RH on the different production responses of the birds appeared to vary between the age groups. For example, for 2 to 4-week old birds, specific FI and BMG were significantly (P = 0.0147 and 0.0053, respectively) affected by temperature and RH while mortality was not (P = 0.6533) and at bird age of 5 to 6 weeks, specific FI and mortality were significantly affected (P = 0.0004 and 0.0334, respectively) but BMG was not (P = 0.1107).

Table 2. Specific feed intake, feed conversion, body mass and mortality of broilers during trials 1 and 2

House	Production Response	Overall mean Trial 1 (winter)	Overall mean Trial 2 (summer)
	Specific feed intake	221 (139)	157 (64)
1	Feed conversion	2.47 (1.12)	1.82 (0.41)
	[1]Body mass (kg/bird)	2.3	2.2
	[2]Mortality (%)	9.3	3.8
	Specific feed intake	152 (66)	170 (77)
2	Feed conversion	1.83 (0.45)	1.86 (0.46)
	[1]Body mass (kg/bird)	2.2	2.3
	[2]Mortality (%)	4.3	7.0
	Specific feed intake	257 (142)	279 (154)
3	Feed conversion	2.83 (1.18)	3.29 (1.22)
	[1]Body mass (kg/bird)	2.3	1.8
	[2]Mortality (%)	4.3	4.3

Specific feed intake in g feed per kg body mass; Feed conversion in kg feed per kg body mass gain. Figures in parenthesis are standard deviations. Overall mean is averaged over a 6-week growth period.[1] = Mean weight at point of slaughter
[2] = Total mortality throughtout the 6-week growth period. Standard deviations for average body mass were negligible

All the production responses have been included in each age group because the effects of T_{db} and T_{wb} on production performance were relevant even though the model did not always account for significant portions of the response statistically (Brown-Brandl et al., 1997). THIs obtained from this study are:

$$THI_{3\text{-}4wk} = 0.62T_{db} + 0.38T_{wb} \quad [1]$$

$$THI_{5\text{-}6wk} = 0.71T_{db} + 0.29T_{wb} \quad [2]$$

THI for broilers at 3 to 4 weeks of age agreed closely to that of White Leghorn laying hens which have THI = $0.60T_{db} + 0.40T_{wb}$ (Zulovich and DeShazer, 1990). For 5 to 6 weeks of age, THI agreed closely to that reported by Xin et al. (1992) for pre-fasted 15- to 16-wk old hen turkeys whose THI was THI = $0.74 T_{db} + 0.26T_{wb}$. Tao and Xin (2003) reported Temperature Humidity Velocity Index (THVI) of $(0.85T_{db} + 0.15T_{wb})$ _ $V^{-0.058}$ for male Ross _ Ross broilers aged 46 ±3 days under acute heat exposure. In general, broilers responded more to T_{db} than T_{wb}. THI results of this study provide substantial information for broilers reared under non-controlled semi arid environment in real commercial production setup.

Table 3. Standardized coefficients, regression model assessment, and weighting factors used in developing the THIs for broilers at 3 to 4 and 5 to 6 weeks of age during trial 2

Production Response	Standardized Coefficients		Regression Model Assessment		Individual Weightings	
	T_{db}	T_{wb}	R^2	*P value	T_{db}	T_{wb}
3 to 4 weeks old				(n=24)		
Specific FI	0.59645	-0.24051	0.3307	0.0147	0.86	0.14
BMG	-0.63886	0.04856	0.3926	0.0053	0.99	0.01
Mortality	-0.02930	0.20580	0.0397	0.6533	0.02	0.98
				Average	0.62	0.38
5 to 6 weeks old				(n=36)		
Specific FI	0.39382	-0.49384	0.3771	0.0004	0.39	0.61
BMG	-0.34934	0.07628	0.1249	0.1107	0.95	0.05
Mortality	0.39504	-0.19733	0.1862	0.0334	0.80	0.20
				Average	0.71	0.29

FI = Feed intake (g feed/kg body mass); BMG = Body mass gain (kg);
* P values less than or equal to 0.05 are considered statistically significant for the significance of the regression (R^2)

CONCLUSIONS

Due to lack of environmental control, the broiler house temperatures fell outside the thermoneutral temperature zone of the birds almost all the time which negatively affected bird welfare and production performance. The mean specific feed intake ranged from 152 to 279 g feed/kg body mass while mean feed conversion ranged from 1.82 to 3.29 kg feed/kg body mass gain. The live weight at six weeks of age ranged from 1.8 to 2.3 kg while mortality ranged from 3.8 to 9.3%. The temperature and humidity index (THI) for broilers at different growth stages is $THI_{3\text{-}4wk} = 0.62T_{db} + 0.38T_{wb}$ or $THI_{5\text{-}6wk} = 0.71T_{db} + 0.29T_{wb}$. This index can now be represented graphically and farmers can use it as a handy look-up management chart that guides them on proper strategies to employ to relieve the birds of heat stress.

RECOMMENDATIONS

There is need to have auxiliary heating and cooling equipment installed in broiler houses to help attain indoor temperature within thermoneutral temperature zone in order to optimize bird comfort and productivity. This would significantly reduce mortality due to extreme weather. Future studies may have to be undertaken under controlled environment to permit coverage of awide array of conditions and ensure sufficient data for THI development.

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