Temperature-Humidity Index (THI) in rabbits' pens at different building orientations and openings: a measure of animal comfortability in Ile-Ife, Nigeria

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Abstract

Natural ventilation for rabbits' comfortability when subjected to different building orientations and side openings when stocked and when unstocked were studied. It was 3 x 2 x 3 factorial design. There were 3 factors: season at two levels (dry and rainy seasons); building orientations (Or) [two levels: 45^o and 90^o to the directions of prevailing wind] and ventilation openings (Op) [four different levels: 20%, 40%, 60% and 80% side openings]. Two phases in the experiment were the monitoring of the outside climate (temperature, relative humidity) and in-building climate conditions at stocked and unstocked. The measurements were taken two times a day at 10.00 hr and 14.00 hr. There was interaction among the Or, Op and THI inside stocked building (THI_{in}) but the interaction between Or and Op did not significantly affect THI_{in} at stocking. This interaction accounts for why 90^0 Or have low THI values. The Or significantly affected ($p \leq 0.05$) temperature, humidity and THI_{in} during rainy seasons. There were higher concentrations of air moving in from surrounding of the building especially in the 90^o Or pens and especially with higher percentage of openings like 60% and 80% and therefore rabbits in those pens could be adjudged to be in thermo-comfort zone.

Key words: *Climate, conformability, rabbits, stocking, openings, orientation, Nigeria.*

1. INTRODUCTION

THI is an index that evaluates the effects comfort of temperature and humidity levels on humans and animals, it is a measure depicting the level of discomfort the average person or animal is thought to experience due to combine effects of the temperature and humidity of ambient air. Thus, THI is an index of measurement on the comfort of man and animals via temperature and humidity levels (Lamidi and Afolabi, 2016). Temperature Humidity Index (THI) depends wholly on temperature and humidity, it accounts for the cumulative effect of both and is straightforward and accurate to assess the risk of heat stress (Barre *et al.*, 1988). THI values vary between and within different livestock species of interest, for different classes of animals and also vary from different building designs to another. THI value provides a set of categories that indicate heat stress of animals.

Rabbits are small herbivorous animals that feed only on plants and that live together in-groups. The exotic types do eat plants and concentrates specially formulated for them to improve food security (Lamidi, 2011; IFPRI 2004). Cold and heat stresses in rabbits' buildings are results of THI. Temperature changes result in either cold or heat stresses and generally brought about decrease in production in animals (Bruce, 1999; Barre *et al.*, 1988). Animal comfort is determined by the followings: temperature of movement, relative humidity and ambient thermal conditions which are all summed up to THI; velocity of air movement and level of fur, their psychological state and nature of their building. The minimum specification of rabbit pen was given by USDAFRD (1992) as 0.75 m by 0.67 m, this is in the temperate region, for tropical regions, there have not been any followed standard by the farmers. The objective of this research was to determine the effects of THI on rabbits' comfortability via different building orientations while the building is stocked.

2. MATERIALS AND METHODS

The research was done at Rabbitry Division of the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Nigeria (latitude 07^o 28' N; longitude 04^o 33' E). Four similar adjoined buildings, width, 1.2 m; length 2.4 m and height 1.2 m were built. Each building consisting of four pens was built via orientations and openings as in the procedures of the research. Floor area of each pen was 1.2 m x 0.6 m with 30^o roof slope. There were openings on long sides of the building at windward side (inlet) and at the leeward side (outlet) made up of thick wire net.

Three factors at different levels were considered in the research: (1) season of the year at two levels of dry and rainy season, (2) building orientations (Or) at two levels of 45^o and 90^o to the directions of the wind and (3) ventilation openings (Op) at four levels of 20%, 40%, 60% and 80% side openings. These factors were considered at two different seasons of the year. The experimental set up was a 3 x 2 x 4 factorial experiment; 3 factors of treatment, 2 seasons of research and 4 replicates. There were two phases in the experiment. Phase 1 was the monitoring of the immediate-outside-of-the-building climatic conditions (temperature, relative humidity). Phase 2 involved measuring climatic conditions (temperature, relative humidity and THI_{in} and calculations of the ventilation rates inside the building) when the building was stocked. Temperatures (using digital thermometer (model SW-1189, made by Uniscope, Nigeria Ltd) and relative humidities (using hygrometer model M50.60101, 023460 made in France) were measured two times a day; 08.00 h and 10.00 h at both seasons. A 100% open-at-all-sides at 30 m × 10 m housing rabbits at the same place was used as control experiment. THI was calculated using the temperature-humidity index equations:

$$THI = db^{o}\,C - \{[0.31 - 0.31 \left[\frac{RH}{100}\right]](db^{o}C\text{-}14.4)\} \quad \ldots \ldots \quad \ldots \qquad (1)$$

where $db^{o}C$ = dry bulb temperature in Celcius and

RH = relative humidity in %

THI relates the combined effects of dry-bulb temperatures and humidity to animal comfort and performance (Marai *et al.*, 2001a, b). For the ventilation rate calculation, where:

g = acceleration due to gravity, m/s^2;

(y –z) is difference in height, (assuming two different levels inside the pen to establish ventilation), where y = z/2, metres, it is the height of the pen at the neutral plane level

z = is any height from the pen's floor where there was no any pressure differential, metres, from symmetry, effects of wind is felt mostly at z/2 (ASAE,1999);

Q = ventilation rate, m^3/s;

T= Temperature, ^{0}C; ΔT = change in Temperature, ^{0}C;

A = Area, m^2;

l = length of the pen, metres;

b = width of the pen, metres; and

l_c = local loss coefficient for material of construction, dimensionless.

Since wire net was used in the building to cover the opening; for wire net, l_c = 1; for wood, l_c = 1.2 and for wall, l_c = 1.5; (ASAE, 1999; Bruce, 1999). Then

$$Q = -\{2g \frac{\Delta T}{T}\} l_c^{-½} \frac{2A}{3}\left(\frac{z}{2} - z\right)^2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad ... \quad (2)$$

solving;

$$Q = \frac{A}{3} \{gz \frac{\Delta T}{T}\} l_c^{-½} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

Solving equation 3 for Q where l_c = 1 for wire net; the equation is now reduced to

$$Q = \frac{A}{3} \frac{\Delta T}{T} [g\ z]^{1/2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

Equation (4) gives the ventilation rate, m^3s^{-1}, inside the pen, at a particular time in seconds. If $\frac{A}{3}$ $[gz]^{1/2}$ is a constant k of the product of some parameters of the pen, Q = is the slope of the graph of ventilation against the natural logarithm of fraction of the temperature inside the pen to the temperature, T_o outside of the pen (Lamidi and Ola, 2021).

From equation 4:

$$Q = k\ (T_1 - T_0) / T_1 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

2.1 Data analysis

Two way ANOVA was used in the analysis using SAS (2008), the means were separated using Duncan Multiple Range Test of significance at 0.05 confidence level. Where mean values were not statistically different from each other, Least Significant Differences (LSD) was used to separate them.

3. RESULTS

3.1 THI_{in} in unstocked pens

Table 1 shows that all building orientations and building openings were within the same range of mean temperatures; no opening was statistically different from one another at both seasons, however, only 100% opening was statistical different from others in rainy season.

The 90^0 building orientation has lowest THI_{in} of 25.14 in pen 80% Op (the lowest) and the highest THI_{in} as 28.23 in 100% Op during the rainy season. Since, rabbits do not need high temperature or THI, this range of 25.14 to 26.91 (60% Op. in dry season) is far below room temperature and therefore could be adjudged to be good for the animals in both seasons. There were high mean values in 60% and 100% pens inside the building than other pens, Table 1. The LSD values show that the mean values are close as the LSD values are smaller, less than 20% in both seasons, and at different Or and Op and this also shows that the tests performed are uniform and reliable.

Table 1: *Mean values of climatic conditions (THI_{in} in ^oC) of unstocked pens during dry and rainy seasons*

Season	Or. (º)		Op. (%)					LSD (%)
	45	**90**	**20**	**40**	**60**	**80**	**100**	
Dry	26.83^a	26.78^a	26.86^a	26.79^a	26.91^a	26.64^a	27.87^a	10
Rainy	25.45^a	25.29^a	25.42^a	25.54^a	25.38^a	25.14^a	28.23^b	13

***** Superscripts with same letter along the same row are not statistically different at $p \leq 0.05$.

THI_{in}- THI inside pen

3.2 THI_{in} in stocked pens

The p-values in Table 2 reveal that season affected the THI_{in} of the pen during rainy season only and these are the results of statistical differences recorded in Table 1. This shows that building parameters have effects on the THI inside the building as there was interaction among building openings, building orientations and THI inside rabbits' building. The R^2 values were high, 0.847 and 0.857, highest for 40 and 20% openings respectively and in dry and rainy seasons respectively (Table 3a and 3b). However, Table 4 which shows the ventilation rates, Q calculated from Equations 1-5 above ranging from 0.24×10^{-3} to 4.57×10^{-3} m^3/s. These values confirm that Q values were generally low in the dry season in all the pens except 60% at 90^0 orientation and at both orientations in 80% opened pens. Comparing these Q values to 0.4×10^{-3} m^3/s per 100 g body weight which is a ventilation rate for small animals to be in their thermo-comfort zones as recorded in NIH (2012) for small animals like rabbits, it can be show that these Q values in Table 4 are moderate since they are well above the 0.4×10^{-3} m^3/s and with the Q per body weights as show in Table 4, the higher the Q values in Op.60 Or 90, the more the mean weights of the rabbits in the pens.

Table 2: *p-values showing interaction between Or, Op on climatic condition (THI_{in} in ^oC) of the stocked pens during dry and rainy seasons*

Source	Dry season (Pr>F)	Rainy season (Pr>F)
Or.	0.1085	0.0323*
Op.	0.6121	0.0495*
Or.*Op.	0.4186	0.9827

Table 3a: *Regression models among Or, Op and THI_{in} inside stocked pens with 45^0 and 90^o orientation in the dry season*

	Quadratic equations, 45^0 Or.		Quadratic equations, 90^0 Or.	
Op.%	**Regression**	**R^2**	**Regression**	**R^2**
20	$Q = -0.184\ t^2 + 2.028\ t + 24.13$	0.789	$Q = -0.188\ t^2 + 2.056\ t + 23.88$	0.829
40	$Q = -0.177\ t^2 + 1.972\ t + 23.94$	0.847	$Q = -0.165\ t^2 + 1.827\ t + 24.60$	0.777
60	$Q = -0.108\ t^2 + 1.31\ t + 25.40$	0.757	$Q = -0.186\ t^2 + 2.043\ t + 23.90$	0.827
80	$Q = -0.099\ t^2 + 1.024\ t + 26.64$	0.528	$Q = -0.086\ t^2 + 1.003\ t + 25.87$	0.447
100	$Q = -0.125\ t^2 + 1.52\ t + 24.59$	0.641	$Q = -0.125\ t^2 + 1.518\ t + 24.59$	0.641

*Q = Ventilation inside the pen; t = THI; Op.= Building Opening; Or. = Building Orientation

Table 3b: *Regression models among Or, Op and* THI_{in} *inside stocked pens with* 45^0 *and* 90^o *orientation in the wet season*

Op.%	**Quadratic equations, 45^0 Or.**		**Quadratic equations, 90^0 Or.**	
	Regression	**R^2**	**Regression**	**R^2**
20	$Q = -0.185\ t^2 + 1.598\ t + 22.54$	0.857	$Q = -0.184\ t^2 + 1.618\ t + 22.47$	0.826
40	$Q = -0.142\ t^2 + 1.24\ t + 22.72$	0.679	$Q = -0.106\ t^2 + 0.877\ t + 23.41$	0.564
60	$Q = -0.137\ t^2 + 1.149\ t + 23.435$	0.754	$Q = -0.156\ t^2 + 1.315\ t + 23.24$	0.810
80	$Q = -0.167\ t^2 + 1.485\ t + 22.54$	0.817	$Q = -0.137\ t^2 + 1.142\ t + 23.47$	0.760
100	$Q = -0.159\ t^2 + 1.426\ t + 22.57$	0.841	$Q = -0.159\ t^2 + 1.426\ t + 22.57$	0.841

Table 4: *Ventilation rate, Q, as a measure of animal comfortability in their pens*

Treatments	**Dry season Q, m^3/s**	**Rainy season Q, m^3/s**	**Mean weights of rabbits g**
Op.20. Or 45.	2.83×10^{-3}	1.27×10^{-3}	1,840 ± 0.111
Op.40. Or 45.	2.78×10^{-3}	0.24×10^{-3}	1,720 ± 0.142
Op.60. Or 45.	3.30×10^{-3}	2.01×10^{-3}	1,425 ± 0.065
Op.80. Or 45.	3.03×10^{-3}	3.07×10^{-3}	1,300 ± 0.000
Op.20. Or 90.	2.99×10^{-3}	1.77×10^{-3}	1,698 ± 0.209
Op.40. Or 90.	2.86×10^{-3}	0.62×10^{-3}	1,890 ± 0.090
Op.60. Or 90.	2.79×10^{-3}	4.27×10^{-3}	1, 978 ± 0.190
Op.80. Or 90.	4.17×10^{-3}	4.92×10^{-3}	1,730 ± 0.025
100%	5.77×10^{-3}	3.98×10^{-3}	1,788 ± 0.025

4. DISCUSSION

There were no significant differences at $p<0.05$ between building orientations or building openings and THI_{in} at unstocked pens at both dry and rainy seasons, this shows that the effects of seasonal changes had no significant effects on the unstocked pens. This could be so since there were no any rabbits inside the pen that may have its respiratory activities to alter the climatic conditions in the pens (Ayyat and Marai, 1998). However, reason(s) for the significant effects of the seasonal changes upon the unstocked pen could be because of the outside climate that could not be different from the 100% control building since it is open at all side both in the leeward and windward sides. It could also be due to the fact that, its internal temperature was slightly different from temperature in outside since it was only cover with wire net of 1 inch diameter.

The lower mean values of the THI_{in} in the building recorded especially in the rainy season which was as low as 25.14^0C which were obviously as a result of low temperatures and relative humidities were because of wind effects with humidified air (high relative humidity mean of 68.75% was recorded in 80% Op.). The higher THI_{in} recorded in the 80% (27.87) and the all-side-opened building (28.23) was also as a result of low humidity and low temperature values recorded that led to low computed THI_{in}. This could also be the reason why the values of the ventilation rates values were generally low in the dry season in all the pens, and this could be helpful for rabbits to have stayed in the thermo-comfort zone in their pens. Also, the higher the Q values in the pens especially in pen Op.60 Or 90, (Table 4), the more the mean weights of the rabbits are revealing. All these culminate into moderate Q, m^3s^{-1}/100 g body weight of rabbit and are evidence of the animals being in their thermo-comfort zone. The smaller LSD percent values at different Or and Op depict that these mean values were products of more reliable uniform research/test which show that the mean values even though, they are not significantly different from each other but they are depicting that they are real. And, further, that they do not exist because of chance but because of the building parameters in research/test or because of animal physiological characteristics since climatic parameters (Temperature, Relative Humidity) are already without significant differences.

The low mean THI_{in} values in 60% and 80% pens were because of high ventilation, (Table 4, as show in the rainy season) inside the building than other pens because of their increased size building openings. The higher THI_{in} recorded in the 100% at both dry and rainy seasons was due to high temperature at the immediate outside of the pen when compare to other pens of lesser side openings and since it was not constant, it might be due to sudden changes in the moving air in and around.

The mean THI_{in} values in 90^o building orientation were low in the rainy season. This could be because the building is normal (90^o) in its orientation to the direction of the wind which would allow more airflow in it than pen that was inclined at acute angle 45^0 to the wind direction. This was as a result of moving air that may have a bombarding characteristic at that period especially during the rainy season whenever rain was about to fall (Cleugh et al., 1998).

This significant difference among the orientation and openings in the rainy season agrees with what was stated by Ogunjimi *et al.* (2008) and Bodman and Gerald (2006) that there was correlation among the building openings, building orientations and the THI inside the rabbits' building at full loading. This could be depicted to have been emphasized as shown by high R^2 values of 0.847 and 0.857 recorded.

There were higher concentrations of air moving in from surrounding of the building especially in the 90^o orientation pens and especially with higher percentage of openings like 60% and 80%, compare to n pens of lesser longer side openings. Also, there could have been heat generated inside the pens by the animal themselves through breathing which were unable to leave the pens especially the 45° Or pens. This could explain the range of ventilation values in Table 4 and hence the resulted differences in their body weights, although other factors may contribute to these differences.

5. CONCLUSION

The following conclusions were made:

There were interactions among the building openings, building orientations and THI inside the rabbits' building. Season affects the THI_{in} of the pen when stocked but not when unstocked.

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REFERENCES

ASAE.1999. CIGR Handbook in Agricultural Engineering, Animal Production and Aquacultural Engineering, Ed: CIGR-The Int'l Commission of Agricultural Engineering. *Pub by ASAE- American Society of Agricultural Engineering*, Niles Rd, MI, USA.

Ayyat, M.S. & Marai, I.F.M. 1998. Evaluation of Application of the intensive rabbit production system under the subtropical conditions of Egypt. *Journal of World Rabbit Science* 6: 213-217.

Barre, H.J., Sammet, L.L. & Nelson, G.L. 1988. *Environmental and Functional Engineering of Agricultural Buildings.* New York, AVI Book.

Bodman, A. & Gerald, R. 2006. *Non-Mechanical Ventilation-Designing forFunction.* Proceedings of the 2nd National Dairy Housing Conference, Madison, WI, ASAE, pp. 122-129.

Bruce J.M. 1999. Environmental Control of Livestock Housing. *In: CIGR Handbook of Agricultural Engineering – Animal Production & Aquacultural Engineering*. ASAE Publisher: p 54-67.

Cleugh, H.A, Miller, J.M. & Bõhm, M. 1998. Direct mechanical effects of wind on crops. *Agroforestry systems* 41(1):85-112

IFPRI 2004. Assuring Food and Nutrition Security in Africa by 2020. Proceedings of an All-African Conference (Ed: Ketema, S.) *International Food Policy Research Institute -IFPRI 2020 vision*, April 1-3, 2004, Kampala, Uganda. Washington D.C. p 116.

Jedele, D.G. 1985. *Dairy Housing and Equipment Handbook*, MWPS-7. MidWest Plan Service

Lamidi, W. A. & Ola, S. I. 2021. Modelling of the Temperature-Humidity Index (THI) and Ventilation patterns in the rabbits' pens. *Ethiopian Journal of Environmental Studies and Management* 14 (4): 487- 499.

Lamidi, W. A. & Afolabi M. S. 2016. Influence of some environmental factors on maize productivity in Osun State, Nigeria**.** *Ethiopian Journal of Environmental Studies and Management 9*(2), Supplementary 2, 1009-1021. doi.org/10.4314/ejesm.v9i2.7S.http://www.ajol.info/index.php/ejesm/article/view/150117/139683.

Marai, I.F.M., Ayyat, M.S. & Abd El-Monem, U.M. 2001a. Growth Performance and Reproductive Traits at first parity of NZW female Rabbits as affected by Heat Stress and its Alleviation, under Egyptian conditions. *Journal of Tropical Animal Health and Production* 33: 1-12.

Marai, I.F.M., Ayyat ,M.S. & Abd El-Monem, U.M. 2001b. Growth Performance and Reproductive Traits at first parity of NZW female Rabbits as affected by Heat Stress and its Alleviation, under Egyptian conditions. *Journal of Tropical Animal Health and Production* 33: 13-15

National Institute of Health (NIH) 2012. *Ventilation Design Handbook in Animal Research Facilities,* orf.od.ih.gov

Ogunjimi, L.A.O., Oseni, S.O. & Lasisi, F. 2008. Influence of temperature Humidity Interaction on Heat and Moisture Production in Rabbits. 9th World Rabbit Congress, June 10-13, 2008, Verone, Italy. *Management and Economy* 1579-1583.

SAS 2008. *Statistical Analysis Software. Guide for Personal Computers*. Release 8.1.SAS Institute Inc. Cary, North Carolina, USA

USDAFRD 1992. *United States Department of Agriculture, Food and Rural Development, Minimum Specification for Rabbit Housing*, March 1992.