Full Paper

THERMAL COMFORT STATUS IN A NATURALLY VENTILATED TROPICAL LIVESTOCK BUILDING: COMBINED EFFECT OF ORIENTATION AND AMOUNT OF OPENING ON RABBIT PRODUCTION

L.A.O. Ogunjimi
Department of Agricultural Engineering
Obafemi Awolowo University
Ile-Ife Nigeria
laogunjimi@yahoo.com

G. A. Ogunwande
Department of Agricultural Engineering
Obafemi Awolowo University
Ile-Ife Nigeria

J.A. Osunade
Department of Agricultural Engineering
Obafemi Awolowo University
Ile-Ife Nigeria

ABSTRACT

The effect of orientation and amount of opening (vent) using two buildings orientations and two opening levels in a rabbit house under a naturally ventilated condition was studied in this research. Sixteen (16) rabbits of same age bracket were used, distributed randomly into four (4) partitioned pens each. The rabbits were fed with commercial pellet feed and given water *ad libitum* for 91 days. The two orientations and openings (inlet) were 90° and 45° to the direction of the prevailing North-south wind and 50% and 30% of 1.44 m^2 area, respectively, and also a control building having 100% opening but oriented in east-west direction. Temperature and relative humidity of the buildings were observed twice daily through a period of thirteen weeks. Feed intake, weight gain (WG), feed efficiency (FE), pulse rate (PR), rectal temperature (RT) and respiration rate (RR) of the rabbits were equally taken for each week of the experiment. From the results of the experiment it was observed that building orientation and amount of opening greatly affect the internal comfort level of animal buildings. The 50% opening/90^0 orientation building provides the least Temperature-Humidity Index (THI = 32.49 ^{0}C) and hence the highest thermal comfort situation for the rabbits corresponding to the highest WG and FE of 76.88 gm and 0.68; lowest RT and RR of 38.85 ^{o}C and 41.08 rpm, respectively. Hence it was observed that rabbits' performances characteristics of WG and feed utilization efficiency of the rabbit are significantly correlated with the comfort levels of the pen; the correlation coefficient, R^2, ranges between 0.92 and 0.98.

Keywords: *Environmental modification; microclimate; ventilation apparatus; natural ventilation; environmental stress; thermal comfort level.*

1. INTRODUCTION

Intensive livestock production is greatly influenced by the environmental stresses which are mainly due to temperature and humidity; the combination of which is considered to be the major limiting environmental factor high against livestock productivity, [1, 2, 3, 4]. These factors apart from affecting feed consumption of the animals also offers favourable conditions for the development of various disease causing micro-organisms [5, 6]. However, these conditions are not usually taken into consideration while designing animal buildings in the tropical region, particularly in Nigeria; hence the need for this study.

Farm building microclimate depends mainly on the material of construction, location, orientation, the level of vent that is available and nature of animal housed, [1, 7]. While the material of construction affects the heat and moisture transfer characteristics, types of animal housed influences both heat and moisture production while all other factors influence the ventilation rate and airflow pattern, [7]. All these factors affect the microclimate by influencing temperature and humidity distribution within the livestock building. Temperature and humidity inside a livestock house are usually higher than that of the outside environment due to the amount of heat and moisture produced by the animals and possibly water spillage within; however, all these can be lowered by proper ventilation. In another study it was concluded that the thermal environment of farm buildings are mostly considered under the control of the major factors of temperature, humidity and air movement and in most cases air circulation pattern (ventilation) is having a dominating influence on the mixture, temperature and humidity gradient of the air [3].

Some other authors [7, 8] in different works also observed that ventilation affects the control of the internal thermal environment of a building, on the other hand, [9, 10, 11] stated that both configuration and orientation of a building provide a range of effects on the air movement pattern and velocity. These alter the interior and exterior environment of a structure; so also, the energy consumption by the occupants of the building is greatly impaired.

Externally, landforms, vegetation and buildings influence air movement by altering the velocity and pattern of airflow. Buildings situated too close to each other can cause undesirable wind current through the lot, creating wind passage way or tunnel [12].

Openings that allow air to enter the space (inlet) and those that allow air to exit the same space (outlet) are the ventilating devices of the building. However, an inlet may become an outlet and vice versa, depending on the direction of the airflow and season. The size, location and configuration of the air inlets, the size, and ratio of inlet to outlet apparatus are most important in designing the air distribution system [10, 13], they both concluded that the larger the ventilating opening (VO) and proper orientation to the prevailing wind, the more the comfort level for both animal and man in a livestock building. The essential function of air movement within a building is to provide comfort for the occupants who essentially are expected to benefit directly [9]. The orientation of a building are generally based on the prevailing wind direction and its magnitude with a view to minimizing the damaging effect of the wind on them [14]. On the other hand, it was observed that proper location of a building with respect to prevailing winds and surrounding trees, structure and land formations is essential to the success of natural ventilation system [15]. There is an optimum orientation for different location and temperature ranges and that there is variation in the ventilation rate for different building orientation (BO) within the same location [16]. Hence, by building livestock shelters in the preferred orientation, the breeder should expect some period during which the ventilation rate will not meet that requirement for a particular period and prevailing temperature.

The most obvious limitation to rabbit production in hot climate area is the susceptibility of this species to heat stress, which evokes a series of drastic changes in their biological functions that lead to impairment of production and reproduction [20, 21, 22, 23]. In tropical climates for rabbits, temperature seems to be the dominant factor, but variations in length of daylight cannot be excluded. In subtropical climate (such as in Egypt), the ambient temperature, relative humidity and diurnal light seemed to be involved [4]. Growth involves a complex set of metabolic events which are genetically and environmentally controlled; and hence the exposure of rabbits to high ambient temperature decreases embryonic weight; length and growing live body weight [24, 25, 26, 27, 28]. The adverse effect of high ambient temperature on rabbits may lead to decrease in feed consumption, dehydration of animals, tissue metabolism and the low metabolic energy left for growth, since more energy is consumed by the increase in respiratory frequency that occurs in hot ambient temperature [10, 13, 24]. Puberty in rabbits within the same breed and sex is affected by such factors as temperature, relative humidity and photoperiod of which ambient temperature is the most important [20, 26, 27]. While considering environmental factors of temperature and relative humidity of an enclosure, a relationship that can be used in the determination of the thermal comfort level for rabbits was developed as [27]:

$$THI = T - \left[\left(0.31 - 0.31\left(\frac{RH}{100}\right)\right)(T - 14.4)\right]$$

Where: THI is Temperature-Humidity Index (°C); T (°C) is dry bulb temperature and RH, relative humidity expressed in percentage of the enclosure under consideration.

2. Materials And Methods

An investigation was carried out using three different rabbit buildings at the Rabbitry Unit of the Teaching and Research Farm of the Obafemi Awolowo University, Ile-Ife, Nigeria (Latitude 07° 28'N and Longitude 04° 33'E) between the months of January and April 2006. Two of the buildings were with two different inlet openings A of 50% and B of 30% of 1.44 m^2 the sides (i.e. 0.72 m^2 and 0.48 m^2), respectively; while the outlet opening was 20% of the side (i.e. 0.288 m^2). One of the buildings was oriented perpendicular (90°) and the other skewed at 45° to the direction of the north-east prevailing wind throughout the period of experiment. The two openings for these buildings are denoted as A_{90} (0.72 m^2 for 50% opening/90° orientation); A_{45} (0.72 m^2 for 50% opening/45° orientation); B_{90} (0.48 m^2 for 30% opening/90° orientation) and B_{45} (0.48 m^2 for 30% opening/45° orientation).

The experimental animals comprised of 16, 12-week old New Zealand White rabbits which were randomly allotted to the two buildings, with two rabbits in each pen. The two animals were however separated with chicken wire to prevent physical contact, while providing same environment condition for them. There were three treatments replicated twice in a complete randomized block design. The rabbits were acclimatized for two weeks in their individual environment before the experiment commenced. All animals were fed with the same commercial pelletted feed and fresh water *ad libitum* throughout the period of the experiment that lasted 13 weeks (91 days). The initial weight of the animals was taken at the first day of the experiment, while subsequently this was repeated every week throughout the period. The measurements were taken using a Triple Beam Balance, MB – 2610 with a capacity of 2610 ± 0.10 g. Weekly feed intake and body weight changes in individual rabbits were then observed for the evaluation of average daily WG, and FE.

Physical characteristics of RT, respiratory and PRs were observed in the mornings (7.30 – 8.30 hrs) and afternoons (12.30 – 13.30 hrs) throughout the period of the experiment as in previous works [10, 11, 28]. Environmental parameters of temperature and relative humidity of both the inside and outside of the experimental buildings were monitored two times daily to obtain the direct effect of orientation, percent opening and their interaction on the thermal comfort levels of the rabbit building; all these were taken using the methods described by previous authors [10, 11, 13, 28]. The wind speed at the location was collected from the Teaching and Research Farm (TRF) meteorological station for the period.

2.1. Statistical Analysis

In order to better understand the effects of the different treatments and their interactions, data were subjected to statistical analyses using Statistical Analysis Systems [29] software. Two-way Analysis of Variance (ANOVA) was performed to compare variations in performance characteristics of rabbits' production and physiological behaviours. Where significance was indicated at $p \leq 0.05$, Duncan's Multiple Range test was used to separate the means.

3. Results And Discussion

Table 1 shows the ANOVA results on the effect of ventilating opening (VO), building orientation (BO) and the interaction between ventilation opening and building orientation (VO*BO) on the rabbit building thermal comfort level and the rabbit's production and physiological performances. It was observed that VO and BO were not significant ($p > 0.05$) on feed intake and RT but significant ($p \leq 0.05$) on WG, FE, RR and pulse rate. The combined effect was significant ($p \leq 0.05$) on WG, FE and RR. The Duncan's multiple range test (Table 2a) showed that 90° orientation had higher effect on WG and FE while 45° had on RR and PR. Opening of 50% had higher effect on WG and FE while 30% opening had on RR and PR. The combined effect showed that at 45° BO, the rabbits had higher WG, FE and lower PR with 50% VO. It was also observed at 90° BO,

Table 1. The ANOVA results showing the effects of orientation and ventilation opening on rabbit's production and physiological performances

Parameter	Source of variation	Df	Sum of Squares	Mean of Square	*F*-value	Pr > F
Feed Intake	VO	1	294.679	294.679	1.75	0.189
	BO	1	569.593	569.593	3.38	0.069
	VO*BO	1	8.940	8.940	0.19	0.661
	Error	96	16173.727	168.476		
Weight gain	VO	1	2188.329	2188.329	27.37	<0.0001
	BO	1	1469.708	1469.708	18.38	<0.0001
	VO*BO	1	368.781	368.781	4.61	0.034
	Error	96	7676.667	79.965		
Feed efficiency	VO	1	0.246	0.246	243.53	<0.0001
	BO	1	0.0316	0.031	31.81	<0.0001
	VO*BO	1	0.019	0.019	19.22	<0.0001
	Error	96	0.095	0.001		
Rectal temperature	VO	1	0.031	0.0309	0.01	0.925
	BO	1	10.801	10.800	3.03	0.084
	VO*BO	1	3.867	3.867	1.09	0.300
	Error	96	341.887	3.561		
Respiration rate	VO	1	1201.560	1201.560	917.5	<0.0001
	BO	1	1114.810	1114.810	850.94	<0.0001
	VO*BO	1	18.194	18.194	13.89	0.0003
	Error	96	125.769	1.310		
Pulse rate	VO	1	15012.021	15012.021	8898.13	<0.0001
	BO	1	1276.560	1276.560	744.81	<0.0001
	VO*BO	1	6.252	6.252	3.71	0.057
	Error	96	161.961	1.687		

VO: ventilation opening; BO: building orientation

Table 2a. Duncan Multiple Range test showing the effects of orientation and opening on the parameters measured

Parameter	BO		VO	
	45 ^{o}	90 ^{o}	30%	50%
Feed intake	113.802^a	118.482^a	117.826^a	114.459^a
Weight gain	69.355^b	76.873^a	68.527^b	77.701^a
Feed efficiency	0.612190^b	0.647102^a	0.581346^b	0.677947^a
Rectal temperature	39.2829^a	38.6384^a	38.9434^a	38.9779^a
Respiration rate	50.6058^a	44.0577^b	50.7308^a	43.9327^b
Pulse rate	192.3846^a	185.4327^b	200.9231^a	176.8942^b

**Superscripts with the same letter across the row are not significantly different at p ≤ 0.05; VO: ventilation opening; BO: building orientation*

Table 2b. Duncan Multiple Range test showing the interaction effects of orientation and opening on the parameters measured

BO	45^o		90 ^{o}		Control
VO	30%	50%	30%	50%	
Feed intake	115.1894^a	112.412^a	120.4595^a	116.5065^a	117.8025
Weight gain	62.8846^b	75.825^a	74.1692^b	79.5774^a	74.7269
Feed efficiency	0.55032^b	0.674060^a	0.61237^b	0.68183^a	0.63302
Rectal temperature	39.45845^a	39.4973^a	38.4282^b	38.8485^a	38.9838
Respiration rate	54.4231^a	46.7885^a	47.0385^b	41.0769^b	44.2308
Pulse rate	204.1538^a	180.6154^b	197.6924^a	173.1731^b	177.3269

**Superscripts with the same letter across the row are not significantly different at p ≤ 0.05; BO: building orientation; VO: ventilation opening*

the rabbits had higher WG, FE, RT and lower PR with 50% VO. It was observed that the combination A_{90} (1.2 m × 0.6 m opening, 90^o orientation pens) showed a significant difference ($p \leq 0.05$) with far lower THI value distinct from all other combinations of B_{90} (1.2 m × 0.4 m opening, 90^o orientation pens); A_{45} (1.2 m × 0.6 m opening, 45^o orientation pens) and B_{45} (1.2 m × 0.4 m opening, 45^o orientation pens). The combination B_{45} provides the highest THI value and the lowest comfort level while the combination A_{90} has the least THI value and hence the highest comfort level. This is in accordance with the conclusion that stated that the higher the THI of an enclosure, the more stressful is the environment [27].

In all cases, the A_{90} combination pens provided on the average the best performance from the rabbits, the highest WG (76.88 g) and FE (0.68) while they have the least values of 41.087 rpm for RR and 173.17 bpm for PR all for the THI value of 32.68 ^{o}C that correspond to the highest comfort level for the rabbits in this experiment, Tables 1. On the other hand, the B_{45} combination pens with the highest THI value of 35.40 ^{o}C and hence the lowest comfort level provides the lowest WG of 62.88 g and FE of 0.55 while they provide the highest RT (39.50 ^{o}C); RR (54.42 rpm) and PR of 204.50 bpm, all these are in accordance with earlier findings [11, 13, 27, 28]. The rabbits in these pens (B_{45} pens) consume their feeds sparingly; this confirms earlier researchers' findings for which animals are found to reduce their feed intake under a heat stressed environment [1, 23, 24]

4. Conclusion

The experiment showed that the larger the opening, the higher the difference between the height to length ratio and the closer the orientation of the building is to 90^o (i.e. perpendicular to direction of the prevailing wind) which implied that the closer is the comfort level of the pen to the optimum. This situation will result in better performance of the rabbits as was seen in the levels of the various production parameters of WG; feed intake and the physiological characteristics of studied.

References

[1] Esmay, M. L., Dixon, J. E., 1986. Environmental control for agricultural buildings. The AVI Publishing Company, Inc. Westport, Connecticut.

[2] Barre, H. J.; Sammet, L.L.; Nelson, G. L., 1988. Environmental and Functional Engineering of Agricultural Buildings. Van Nostrand Reinhold Company.

[3] Lokhorst, C., van Ouwerkerk, E. N. J. And Voskamp, J. P., 1995. Management support and climate control. In: Aviart Housing for Laying Hens. Blokhusis H. J. And Metz, J. H. M. (Editors). Published by agricultural Reseach Department, institute for Animal Science and Health, ID-DLO,Lelystad; and Institute of Agricultural and Environmental Engineering, IMAG-DLO, Wageningen; pp 131-153.

[4] Marai, *I. F. M., Ayyat, M. S., Gabr, H. A. and Abdei-Monem, U. M,.* 1996. Effect of summer heat stress and its amelioration on production performance of New Zealand White adult female and male rabbits under Egyptian conditions. 6th World rabbit congress, 2, 233-243.

[5] Froeechlich, O. P.; Hellickson, M. A., Young, H. G., 1975. Ridge vent effect on model ventilation characteristics. *Transactions of the ASAE*; 18 (4): 690 – 693.

[6] Ayoade, J. O., 1998. Introduction to climatology for the tropics. Spectum Books Limited, Ibadan, Nigeria.

[7] Grool Koerkamp, P. W. G., 1998. Review of emissions of ammonia from huosing systems for laying hens in relation to sources, processes, building design and nature of handling. *Journal Agricultural Engineering Research*, 59: 73 – 87.

[8] Boulard, T.; Baille, A., 1995. Modelling of air exchange rate in a greenhouse equipped with continuous roof vents. *Journal of Agricultural Engineering Research*; 61: 37 – 48.

[9] Boutet, T. S., 1987. Controlling air movement - A Manual for Architects and Builders. McGraw-Hill Book Company, New York.

[10] Ogunjimi, L. A. O., Osunade, J. A. and Alabi, F. S., 2007. Effect of ventilation opening levels on thermal comfort status of both animal and husbandman in a naturally ventilated rabbit occupied building. *International Agrophysics, 21, 261-267.*

[11] Ogunjimi, L. A. O., Oseni, S. O. and Lasisi, F., 2008b. Influence of temperature-humidity interactions on heat and moisture production in rabbit. Presented at the 9th World rabbit Congress; 11 – 13 June 2008.

[12] Don, D. J.; William, H. F.; Sherwood, S. D., 2000. Wind and snow control for the farmstead. AE – 102 Purdue University Cooperative Extension Service, West Lafayette, IN 47907.

[13] Ogunjimi, L. A. O., 2007. Optimization of thermal comfort in a naturally ventilated building livestock. Ph. D. Thesis; Agricultural engineering department, Obafemi awolowo University, Ile-Ife, Osun state, Nigeria.

[14] NwokonobI, I. V., Idike, F. I. And Echiegu, E. A., 2003. Determination of prevailing wind direction for farmstead planning and layout in Makurdi, Benue State. *Journal of agricultural Engineering and technology*, 11, 29-35.

[15] Jones, *D. D.*, Friday, W. H. And DeForest, S. S., 2005. Principles of natural ventilation for livestock housing. Purdue University Cooperative Extension Service, Paper AE-97 (Electronic version).

[16] Barrington, S. F.; Zemanchik, N.; Choiniere, Y., 1994. Orientating livestock shelters to optimize natural summer ventilation. *Transactions of the SAE*; 37 (1): 251 – 256.

[17] Barrington, S. F.; Mackinnon, I. R., 1990. Modelling of ventilation duct performance. *Transactions of the ASAE*; 33(4): 1329 – 1336.

[18] Nääs, I. A., Moura, D. J., Buckin, R. A. and fialho, F. B., 1998. An algorithm for determining opening effectiveness in natural ventilation by wind. *Transactions of the ASAE*, 41(3), 767-772.

[19] Adre, N., Albright, L. D., 1994. Criterion for establishing similar airflow pattern (Isothermal) in slotted-Inlet ventilated enclosures. *Transactions of the ASAE*; 37(1): 235 – 250.

[20] Marai, *I. F. M., Abd El-Samee, A. M. and El- Gafarry, M. N.*, 1991. Criteria of response and adaptation to high temperature for reproductive and growth traits in rabbits. *Option Mediterraneennes, Serree A*, 17, 127 – 134.

[21] Fernandez, C. I.; Blas, E.; Concha, C., 1994. Growth and some carcass traits of adult rabbits under high ambient temperature. *World Rabbit Science*; 2:147 – 151.

[22] El–Raffa, A. M., 2005. Rabbit production in hot climates. http://www.google.com/search

[23] Habeeb, A. A.; Marai, I. F. M., Kamal, T. H., 1992. Heat stress. In Farm Animals and the environment; edited by C. Phillips and D. Piggins. C.A.B. International. UK, pp 27 – 47.

[24] Habeeb, A. A.; Aboul-Naga, A. I.; Yousef, H. M., 1993. Influence of exposure to high temperature on daily gain, feed efficiency and blood components of growing male Californian rabbits. *Egyptian Journal of Rabbit Science.* 3: 73 – 80.

[25] Marai, I. F. M., El-Masry, K. A. and Nasr, A. S. 1994. Heat stress and its with nutritional, buffering, hormonal and physical techniques for new Zealand White rabbits maintained under hot summer conditions of Egypt. *Options Mediterraneennes*, 8 (supplement), 457-487.

[26] Marai, *I. F. M., Ayyat, M. S. And El-Monem, U. M.*., 2001. Growth performance and reproductive traits at first parity of New Zealand White female rabbits as affected by heat stress and its allivation under Egyptian conditions. *Tropical Animal Health and Production*, 33, 451-564.

[27] Marai, I. F. M., Habeeb, A. A. M., and Gad, A. E., 2002. Rabbits' productive, reproductive and physiological performance traits as affected by heat stress: a review. Livestock Production Science, 78, 71-90.

[28] Ogunjimi, L. A. O., Ogunwande, G. A. and Osunade, J. A., 2008a. Rabbit weight gain, feed efficiency, rectal temperature and respiration rate as affected by building thermal environment in the humid tropical climate of Southwestern Nigeria. *Agricultural engineering International: the Ejournal.* Manuscript BC 07 008. Vol. X. January 2008.

[29] SAS (2002). Statistical Analysis Systems Technique. Guide for personal computers. Release 8.1. SAS Institute Inc. Cary, NC. USA.