

ORIGINAL RESEARCH

Building design features and wind effects on rabbits in cages

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Abstract

Rearing rabbits in the tropics has been discovered to be a lucrative alternative to providing white meat to the populace. While red meat is available, evidence reveals that they are more expensive; hence, the need to increase rabbit production especially as they can be conveniently reared at home backyards and as they can easily convert family's leftover foods into meat. However, rabbits' comfortability during rearing cannot be compromised, thus the research was borne out to investigate their welfare through their respiratory and pulse rates when reared in different housing designs. Buildings were constructed: width = 1.2 m; length = 4.8 m; height = 1.2 m, all at 0.5 m height from the ground, each with pens in accordance with desired building openings and building orientations, all were for a pen per doe. Factors considered were the season of the year at two levels: dry and rainy seasons; building orientations at three levels: 0°, 45°, and 90° to the prevailing wind's direction and ventilation side openings: four levels of 50 %, 60 %, 70 %, and 80 %, all replicated thrice to be 2 x 3 x 4 x 3 factorial design. Measured were pulse and respiratory rates at 10.00 h and 14.00 h daily. Interactions between different openings, orientations and seasons were significant at $p \leq 0.01$ on the pulse rate of does. The range of wind speed was between 3.61 and 5.04 km/h, this falls within the thermo-comfort range for does. There were higher R^2 values which depicted high correlations between the animals' and the wind directions or wind speeds. The low wind speeds recorded cumulatively resulted in normal pulse rates and respiratory rates in does at all orientations. The effects of all building designs did not change the normalcy in both respiratory and pulse rates in the rabbits' lives in the reared environment.

Keywords: Pulse Rate, Respiratory Rate, Openings, Orientation, Thermo-comfort

Introduction

Wind's effects are felt on man, animals and objects, such as trees or other inanimate objects. The intensity of any wind on any object depends on the weather in that environment which is a function of temperature or temperature changes, humidity, wind motion, directions of the wind flow, the season of the year, type of wind etc. Wind can be primary, secondary or tertiary in nature (Aakash, 2022; Lamidi, 2011). Tertiary winds blow only during a particular period of the day or year in a small area, it can also be referred to as local wind, it can be of different types, like hot, cold, ice-filled, dust-rich, by local characteristics of the area. Primary winds constantly blow throughout the year in a particular direction known as prevailing winds and then it becomes the prevailing wind's direction (Lamidi and Ola, 2021; Lamidi *et al.*, 2019).

It is a known fact that animals do generate heat from their bodies which are made up of tissues. Functions of all organs and systems ultimately depend upon absorption and nutrition. The food taken in by the animal is used in constructing new tissue while some are broken down such that they are oxidized by tissue cells to produce heat and energy. The heat produced by oxidation processes can be measured which will determine the metabolic rate. The metabolic rate of animals is, therefore, an indicator of their nutritive and productive status. It is also very much influenced by environmental variables such as temperature, humidity, air velocity and radiation, (Lamidi, 2011). The heat and moisture released through respiration are simple and this heat must be dissipated out to the environment. Thus, animal life depends so much on their envi-

ronment and their housing that may be conditioned to adapt to the environment for more productivity.

Rabbits reared in cages should be able to stretch out fully when lying down, with a secure living environment, they should be able to exercise and stand up with their ears not touching the roof of the building (Agri4Profits, 2022). Also, their environment can be managed through the use of a housing system since all categories of animals may be integrated into an environment through the use of premeditated housing system designs. This is because the correlations between environmental housing and the farm animals' reactions to thermal and environmental factors are interesting and if the knowledge and correlations are tapped, they are useful for animals when integrated into their environment for their good welfare. For instance, the building receives ventilation to the fullest capacity depending on the openings in the building, the orientation of the building to the wind movements and the wind speed and prevailing wind's direction (Lamidi *et al.*, 2019).

Buildings can be perpendicular to the direction of the prevailing wind or parallel to it, it can also be at any other angle, that is, at a skew to the prevailing wind (Lamidi *et al.*, 2016). But the designer of the house should be sure about which orientations/ and openings would be able to reduce the animal stress through their pulse and respiratory activities especially now when the global climate is not at any level of mercy to both man and animals. Of recent, new building designs may be needed to complement the efforts of other animal scientists (breeders) to ensure higher productivity to mitigate the effects of climate change in the world. Therefore, a question may be asked on whether animal housings at different orientations and openings could affect the comfortability of these animals or not.

An earlier experiment done on the building openings and building orientations on how they would affect the reproductivity and weights metrics in rabbits does reveal that some of their reproductive parameters and carcass weights were affected by both the orientations to the prevailing wind and openings on the

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building (Lamidi *et al.*, 2015; Lamidi and Osunade, 2015). However, information on the welfare of the animals in terms of respiratory and pulse rates when interacting with various building designs on the farm was still few.

Besides, the normal respiration rate in an adult rabbit is 30 – 60 per minute, but their respiratory rate may be faster than this if they are hot or stressed. A rabbit's resting heart rate ranges between 140 and 180 beats per minute, and stress caused by a visit to the veterinary doctor can raise this to well over 300 beats per minute, that is, more than five beats per second (McNitt 2009). Because of the recent cold and heat stresses experienced around the globe due to high temperatures of 40 °C in some countries and below room temperature at other times in other countries, rabbits' production could have been affected and therefore a need to investigate their welfare, especially via pulse and respiratory rates through different housing designs to extend the knowledge if any to the farmers.

Since does' reproductive performances and weight metrics were affected by building designs as found out by Lamidi *et al.* (2015), could pulse and respiratory rates in the animals have been parts of what led to these cumulative effects in their reproductive parameters and weight metrics? Were they in or out of their normal physiological limits or welfare during their rearing's managements in their pulse and respiratory rates that could have affected their reproductive performances? This research was to evaluate rabbit does' respiratory and pulse rates as indices for their comfortability when reared in different natural housing systems comprising different design orientations to an environmental prevailing wind's direction.

Materials and Methods

A rabbit house was constructed on a farm in Okinni via Osogbo, longitude 4°32'9''E and latitude 7°48'56''N, in the rainforest zone of Nigeria. Similar buildings were constructed at 0.5 m from the ground level at width = 1.2 m; length = 4.8 m and height = 1.2 m. Each building housed pens (in accordance with desired building openings and building orientations), each pen housed a doe. The reason why does were used was that they are females that can procreate. Just like other pens around the area, they were constructed with wood, wire mesh and galvanized steel gauze as flooring and iron roofing sheets. A doe has a floor geometry of 1.2 m × 0.6 m, the building has varying side

inlet openings at the windward side according to the procedures of the research and a constant 20 % outlet opening runs through at the leeward side. The roofing design was flat (with no gable) to make the experimental procedure not to be influenced by the change in height of 1.2 m. There was no odour in the area.

Three factors were considered in this study; (i) seasons (S) of the year at two levels of dry and rainy seasons, (ii) building orientations (O) at three levels of 0°, 45° and 90° to the prevailing wind direction (Figure 1) and (iii) ventilation openings (P) at four levels of 50 %, 60 %, 70 % and 80 % side openings at the windward side (Figure 2 [i-iv]). Assuming the cage's total height was ten units, then, for 50 % cage opening, half of the cage's height, that is, five units of the ten units total height of the cage was covered, for 60 %, six units of the ten units total height of the cage's height was covered, for 70 %, it was seven units out of ten units and for 80 %, eight units of the ten units total cage's height was covered. Each arrangement was replicated thrice to have a 2 × 3 × 4 × 3 factorial design. Like building openings' pens were not allowed to follow each other consecutively, so also, same went for like building orientations' pens, thus the whole arrangement was completely randomised.

A similar building with three pens was built close to the experimental buildings as control with 100% side opening all along the length at both the leeward and windward directions. The control building was at 90° orientation to wind direction (because of fire outbreaks, building is usually at 90° orientation to the prevailing wind). A simple geographic compass (name: Universe Today) was used with long metre ruler in the siting of correct variations in the orientation of the cages.

Healthy rabbits were all introduced into the cages at the same weights bracket mean value of 0.84 ± 0.23 kg and same age bracket of 5 weeks when they were just weaned from their mothers. They were in their cages a week before parameters were measured to make them integrate with the surroundings. They all have uniform sizes and weight brackets at the time of introduction into their different cages. Besides, all the animals were fed equally, watered equally *ad libitum* and they were of the same common heterogeneous breeds since pure breeds are not common in the country. They were reared for six months: three months for each of the two seasons, dry and rainy seasons between August to October 2020 and December 2020 to February 2021. The buildings were completely sanitised by health

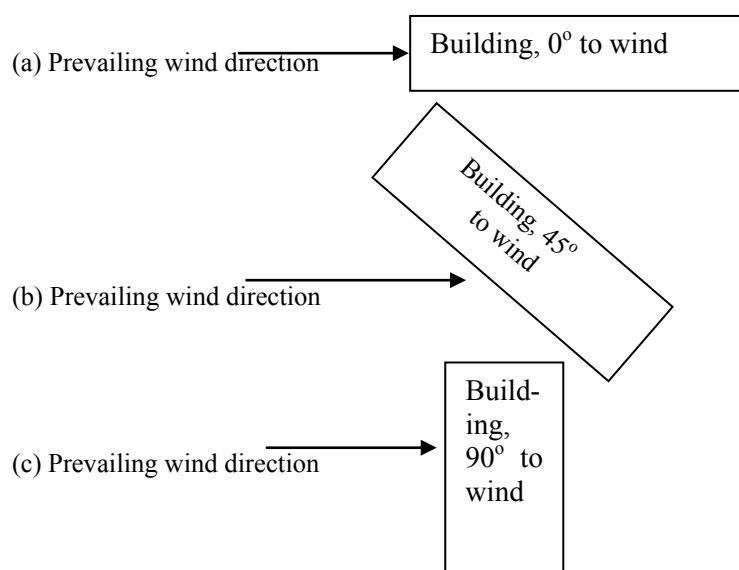


Figure 1 Diagrammatic sketches of the building orientations

officer after the rainy season rearing experiment before the pens were restocked with the same animals for the dry season experiment.

The pulse and respiratory rates in the rabbits at 10.00 h and 14.00 h were measured each day starting from when they were introduced into the cages. Respiratory rates in the rabbits were measured by counting the number of breaths for an entire minute by using a digital fingertip pulse oximeter overall (Hesley Pulse Oximeter Fingertip imported from Hesley Inc, Bangalore, India) which provides an accurate measurement of respiratory rate (Figure 3). Pulse rate was measured by putting a pulse oximeter fingertip on the left side of the rabbit's chest where the elbow meets the chest, that is, on the ribs right behind the rabbit's left or right elbow. At that location, the heart beating was felt. The heartbeat and respiratory pulse were recorded (Figure 3).

Data analysis

The characters were subjected to a 2-way analysis of variance using SPSS 16 and the means were separated using DMRT at a 5 % level of significance.

Results and Discussion

The opening P variable in the research was found to be significant at $p \leq 0.01$ on the pulse rate of the rabbit does, whereas the orientation of the building was not significant at $p \leq 0.01$ on the pulse rate. Both openings and orientations were not significant on respiratory rate for the same does at the same period, Table 1. The season was not significant on both the pulse and respiratory rates also. The interactions between (1) the different side openings of the building and the orientation of the building and (2) the different side openings of the building and the seasons of rearing were also found to be significant at $p \leq 0.01$, on the does' pulse rates, refer to Table 1. Besides, the interactions between the different side openings of the building and the orientation of the building and the seasons of rearing were also significant at $p \leq 0.01$ on the same pulse rate of rabbits whereas, the interaction among the three was not significant on the respiratory rate. Also, the interaction between the openings and orientations was not significant at ($p \leq 0.05$; $p \leq 0.01$) on the respiratory rate.

Since all the animals were fed, and watered equally and were of the same common heterogenous breeds (that have been



Figure 2 Varying percent side opening at the windward of the cage



Figure 3 Measuring pulse rate using a digital fingertip pulse oximeter

in rearing in the country for a long number of years), the reasons that can be adduced behind these significant effects of opening and orientations with their interactions on why the pulse rates could be so affected significantly on these does could be because of their metabolic rates which is an indicator of their nutritive and productive statuses. It could also be very much influenced by other environmental variables such as temperature, humidity, air velocity and radiation which could have been affected by wind's movements and directions. This is also because of the fact that both the pulse and the respiratory rates influence each other and are related, the heat and moisture released through respiration are always simple and since this heat must be dissipated, thus the pulse rate was affected significantly by the designed housing systems. This is in agreement with how orientations and openings affected the weights and some reproductive parameters in the rabbit does especially the 90° orientation and 80 % opening in an earlier experiment as reported by (Lamidi et al., 2015). For respiratory rate not to have been affected implies the status quo was maintained in the animals at the period. All along, the site of the research was not disturbed by any obnoxious noise or crowd of people or odour; this could be a reason to infer why the respiratory rate was not affected but was normal in the period.

There was good ventilation inside their cages, especially in the 90° orientation and higher openings (though not statistically different from others) because of the undisturbed moderate winds of less than 20 km/h recorded in the site throughout the period of the research. The ambient temperature was also 55 °F (30.5 °C) on average during the period making the ideal environment but there was general cloudiness that usually has with its rains, be in the rainy period in the southwestern part of the country where the research took place. Besides, the range of wind speed in the dry season, 3.61 and 5.04 km/h, was recorded as shown in Figure 4.

The ventilation inside their cages, especially in the 90° orientation and higher openings (though not statistically different from others) could be responsible for their good well-being because urine and faeces that could have produced ammonia that would have caused them irritating eyes and noses (and that could have raised their respiratory and pulse rates) were ejected down to the ground surface from their wire-gauzed floor geometries (Borso *et al.*, 2016; McNitt, 2009). The ambient temperature was also 30.5 °C on average during the period making the cages an ideal environment for their good performance and a normal feed rate was observed. The effects of the breed and

size of the does could also be factors that were responsible for these significances in their metabolic activities and especially why the animals were healthy throughout the months of the research.

The statistical differences among the pulse rates of does in the dry season only could be so because of the change in the climatic condition as trade winds prevailed over all other tropical winds during the dry season, especially the harmattan wind. The closeness of the values of the respiratory rate values signifies that the rabbits' conditions were almost not different, their respirations could not have been so significantly affected in their different cages. The contrast to this which was recorded for the pulse rates in the dry season could be surmised to be because of the effects of the openings and the orientations of the building to the prevailing wind which were significant in the dry season. In all these, the rabbits' health status was confirmed by veterinary doctors during and after the research, especially in their pulse and respiratory terms. The animals were comfortably healthy within these thresholds of both respiratory and pulse rate values in the building and even in the control experiment (Table 2).

Moreover, there were no statistical differences ($p \leq 0.05$; $p \leq 0.01$) among various mean values for all the respiratory rates in both dry and rainy seasons, however, there were statistical differences among the pulse rates of does in the dry season but not in the rainy season as depicted in Table 2. The contrast to this was recorded for the pulse rates in the dry season. The reason why there were no significant differences in the rainy season could be adduced to the general cloudiness that is usually with the rainy period in the southwestern part of the country where the research was done. But the reason why the respiratory rates were not significant when the pulse rates were, (since they are related), could be because of some other factors like size of the animals and breeds. Also, the reason could be a result of the building or wind effects on the animals' metabolic activities. Besides, the building orientations and openings that were experimented upon made the does to be comfortably healthy.

The low level of all the CV values could only indicate that there were lesser levels of dispersions in the mean values which implies that the values obtained for respiratory and pulse parameters were not too staggered apart nor too close to each other. The wind speeds' values that were less than 10 km/h could be because they were local/planetary and tertiary in nature and may not be too significant like tropical trade wind, especially in

Table 1 ANOVA of parameters in rabbit does at different building factors and measured parameters

Source	Df	Respiratory rate, %	Pulse rate, %
Opening (P)	3	0.5809ns	0.0200**
Orientation (O)	2	0.7422ns	0.2154ns
Season (S)	1	0.7186ns	0.7661ns
P × O	6	0.4311ns	0.0400**
P × S	3	0.4174ns	0.0153**
O × S	2	0.5333ns	0.3551ns
P × O × S	6	0.3098ns	0.0033**
Error	48	3.7333	1.4152
Total	71		
CV%		7.5	3.9

*Significant at $p \leq 0.05$, **significant at $p \leq 0.01$; ns- no significant; Df = Degree of freedom; CV% = Coefficient of variation.

Table 2 Mean values of respiratory and pulse rates in dry and rain seasons

Parameters		Dry season		Rainy season	
		Respiratory rate, %	Pulse, %	Respiratory rate, %	Pulse, %
Openings	50%	148.29 ± 0.74 ^a	112.46 ± 2.27 ^f	148.85 ± 0.28 ^a	113.78 ± 0.88 ^a
	60%	148.33 ± 0.80 ^a	112.47 ± 1.33 ^e	148.71 ± 0.58 ^a	113.14 ± 0.93 ^a
	70%	148.11 ± 0.77 ^a	111.75 ± 1.36 ^d	148.75 ± 0.60 ^a	113.41 ± 0.95 ^a
	80%	148.11 ± 0.80 ^a	111.91 ± 1.34 ^d	148.56 ± 0.55 ^a	113.48 ± 0.91 ^a
Orientations	0°	148.43 ± 0.52 ^a	113.91 ± 0.80 ^c	148.77 ± 0.28 ^a	113.40 ± 0.74 ^a
	45°	148.09 ± 0.77 ^a	113.84 ± 1.79 ^b	148.61 ± 0.62 ^a	113.00 ± 0.97 ^a
	90°	148.32 ± 0.79 ^a	113.87 ± 2.78 ^a	148.58 ± 0.97 ^a	113.00 ± 0.62 ^a
Control		148.25 ± 0.70 ^a	111.67 ± 1.89 ^d	148.36 ± 0.67 ^a	113.20 ± 0.72 ^a

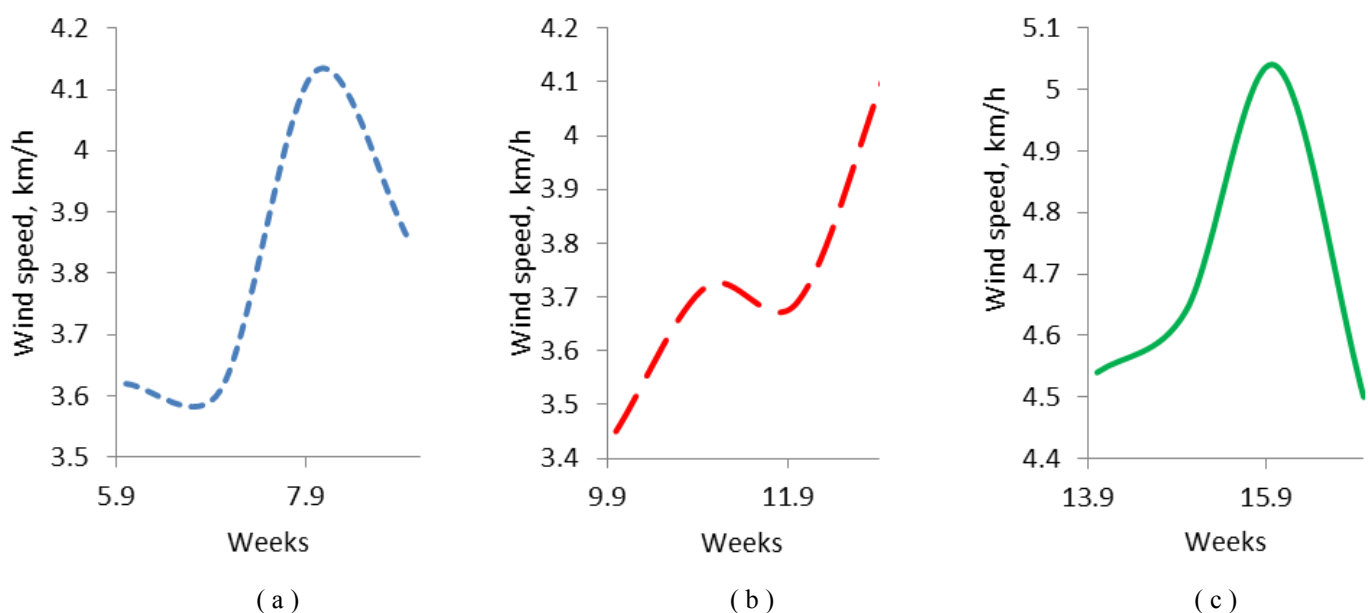
Mean values with the different superscripts on the same column are significantly different ($p < 0.05$).

the rainy season. However, for the fact that they were low could be good to these small animals (does), especially in this artificially 'stress-free' environmental building that was created (Philips and Piggins, 1992). The reason had been that 10 mph (16.09 km/h) is a rather moderate air velocity inside a building and would be particularly non-annoying except if conditions happened to be dusty (Lamidi *et al.*, 2019; Cleugh *et al.*, 1998). The 50 km/h could be too bad for the rabbit does inside the building as it was bad for fragile farm crops like tomatoes (Bang *et al.*, 2010).

The favourable effect of increased airflow at high temperatures is due if there is an increase in evaporative heat loss, but since the period in the rainy season was cloudy. The temperatures taken during the periods were all at room temperature and as well as moderate humidity values of range 70-90 %. Therefore, evaporative losses on the does could have been minimal and thus this summarised the reason why they were healthy

throughout the period as confirmed by the health specialist. This could help them to be capable of yielding more carcasses (Pinheiro *et al.*, 2011). Besides, their health status was also confirmed from their same age bracket after the 12 weeks of rearing in the experiment. Their weights increased by almost 100 % to the same weights bracket of 1.69 ± 0.21 kg, which also depicted their healthiness in growth.

The wind speeds and directions between the weeks in the first month to the third months of rearing in the experiment, in both the dry and rainy seasons, were not uniform on the average as there were wind fluctuations as expected in a natural system (Figures 2 – 5). The values were, however, very low at the period and all were less than 10 km/h because they were local and tertiary in nature, and may not be too significant like trade wind in other areas. However, the fact that they were low could be good for these small animals (Philips and Piggins, 1992).

**Figure 4** Average wind speeds, km/h during various dry season months

$$y_a = -0.2217x^3 + 4.92x^2 - 35.818x + 89.29 \quad R^2_a = 0.99 \quad (1)$$

$$y_b = 0.1283x^3 - 4.385x^2 + 49.877x - 185.15 \quad R^2_b = 0.99 \quad (2)$$

$$y_c = -0.2067x^3 + 9.45x^2 - 143.54x + 729.04 \quad R^2_c = 0.99 \quad (3)$$

where y = wind speeds in the dry season; x = does' whole metabolic activities (which define its welfare characteristics) in the dry season

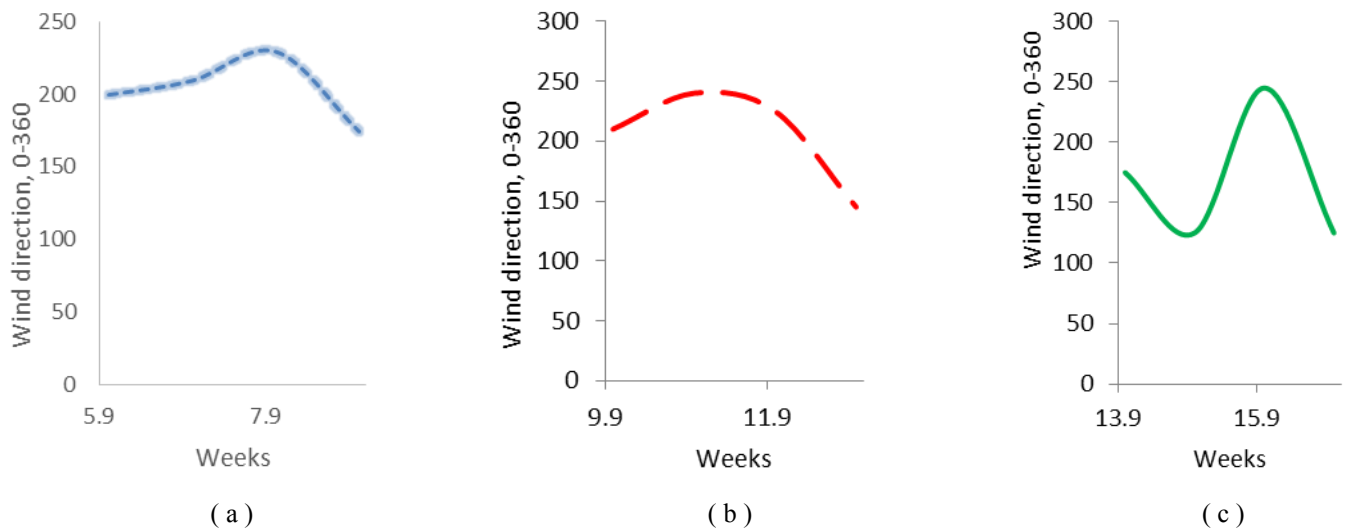


Figure 5 Average wind directions (0-360°), during various dry season months

$$z_a = -14.167w^3 + 302.5w^2 - 2123.3w + 5110 \quad R^2_1 = 0.99 \quad (4)$$

$$z_b = -3.3333w^3 + 87.5w^2 - 704.17w + 1835 \quad R^2_2 = 0.99 \quad (5)$$

$$z_c = -68.333w^3 + 3160w^2 - 48572w + 248325 \quad R^2_3 = 0.99 \quad (6)$$

z = wind directions (dry season); w = does' whole metabolic activities (which define its welfare characteristics) in the dry season

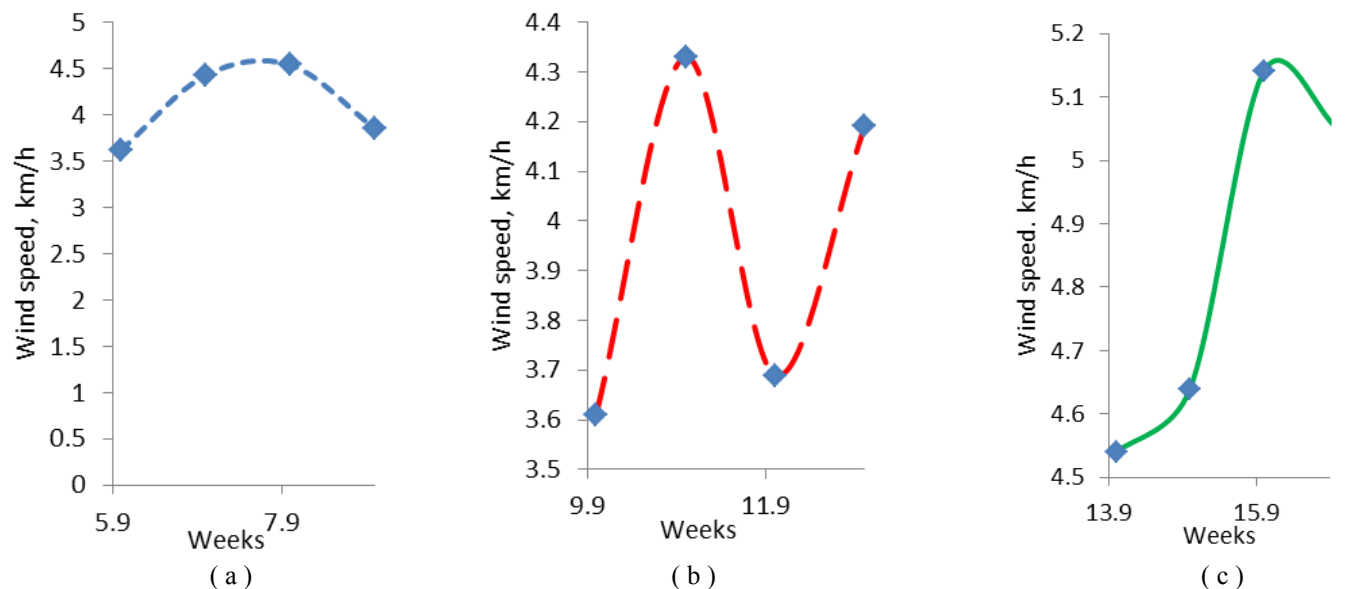


Figure 6 Average wind speeds, during various rainy season months

$$p_a = -0.0167v^3 - 3E-13v^2 + 2.9267v - 10.34 \quad R^2_{pa} = 0.99 \quad (7)$$

$$p_b = 0.4167v^3 - 14.43v^2 + 165.83v - 628.39 \quad R^2_{pb} = 0.99 \quad (8)$$

$$p_c = -0.165v^3 + 7.625v^2 - 116.91v + 599.54 \quad R^2_{pc} = 0.99 \quad (9)$$

where p = wind speed (rainy season); v = does' whole metabolic activities (which define its welfare characteristics) in the rainy season

The mean wind directions from 0 degrees to 360 degrees varied between 175-230° (E 85° S-S 50° W) in the first month, 145-240° (E 55° S-S 60° W) in the second month and 125-245° (E 35° S-S 75° W) in the third month in the dry season. These were however very low in the rainy season: between 180-210° (E 90° S-S 30° W) in the first month, 160-225° (E 70° S-S 45° W) in the second month and 125-230° (E 35° S-S 50° W) in the third month in the rainy season. The does' environment with their metabolic energy for activities in each of the three months of rearing at both dry and rainy seasons have the same $R^2 = 0.99$ (Equations 4-12, Figures 4-7) which depicted high coefficient of determination, R^2 , between the animals' and the wind direc-

tions and wind speeds recorded which means stronger linear relationship exist between these two variables. The fluctuating wind directions' average values as shown in Figures 5 to 7 were also the results recorded. This effect could also have been contributed to by other weather parameters like temperature and humidity.

The high R^2 between the animals' respiratory and pulse rates and the wind speeds recorded in the period could be because the wind speeds were low and the animals could have been comfortable with them in those times or it could be that the does have been in their thermo-comfort zone. This could only be explained in the sense that since man and rabbit does

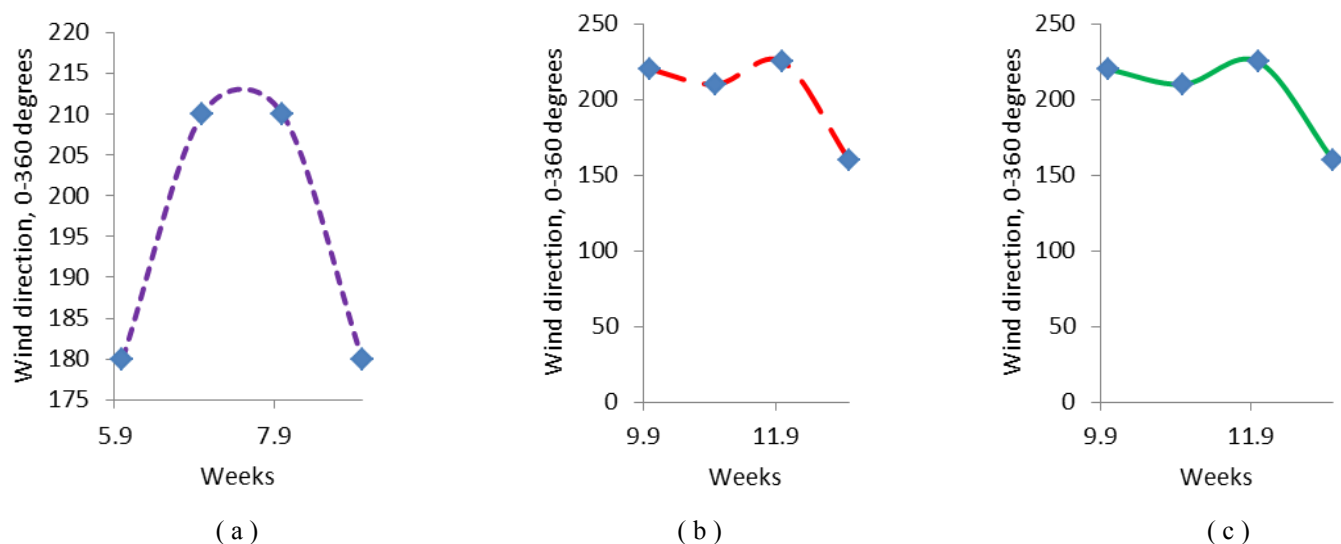


Figure 7 Average wind directions (0-360°) during various rainy season months

$$s_a = -15t^2 + 225t - 630 \quad R_{at}^2 = 0.99 \quad (10)$$

$$s_b = -17.5t^3 + 590t^2 - 6607.5t + 24795 \quad R_{bt}^2 = 0.99 \quad (11)$$

$$s_c = -59.167t^3 + 2747.5t^2 - 42408t + 217750 \quad R_{ct}^2 = 0.99 \quad (12)$$

s = wind direction (rainy season); t = does' whole metabolic activities (which define its welfare characteristics) in the rainy season

do enjoy the same homothermic inclinations and that wind direction appeared to be related to the man's energy levels and that since such is significantly lower when the wind blew from the southeast by Bos et al. (2012), then the rabbit does could also have been affected by this prevailing southwest wind's direction. Therefore, the fluctuating wind's directions average values were the results recorded. This effect could also be contributed to by other weather parameters like temperature and humidity that could have resulted from the wind's directions and speeds.

However, another report by Sun (2013) says that although winds can devastate communities and buildings, most animals are not affected too much except stray animals because they have no home or shelter. But since these rabbits were not stray animals, this result of Sun (2013) could also be the reason why their respiratory rates were not significantly affected as the pulse rates were significantly affected by the building openings and orientations because of the house they were kept.

Since the overall objective in animal housing systems design is to create environments in which the animals approach thermo-neutrality while simultaneously thinking of an appropriate balance between the productive value of thermo-neutrality and the cost of systems to maintain it. It could therefore be inferred from the research that any of the openings and orientations above could give good housing during this period of global warming that has made many places on the globe lose their usual climatic inclinations. These were not the same results obtained from earlier experiments on the influences of the building orientations and openings on the reproductive performances of rabbits (Lamidi and Ola, 2015; Lamidi, 2011). In those experiments, does' and litters' weights and reproductive parameters of does were highly affected by the building parameters.

Conclusions

This research evaluated rabbit does' respiratory and pulse rates as indices for their comfortability when reared in different natural housing systems comprising different design orientations to an environmental parameter namely wind. Factors considered

in the study were the season of the year at two levels of dry and rainy seasons; building orientations at three levels of 0°, 45° and 90° to the prevailing wind's direction and ventilation openings at four levels of 50 %, 60 %, 70 % and 80 % side openings at the windward side. The range of wind speed recorded was within the normal range for the rabbit does and this was the reason why they were healthy throughout the period of the research.

The high correlation between the animals' welfare and the wind directions and speeds recorded shows the reason why southwest wind direction and low wind speed significantly affected the pulse rates in the does. All the orientations and openings in the building for rabbits produced normal pulse and respiratory rates in the does. The effects of the buildings have not really affected does' respiratory rates. The building affected the pulse rates but the values were still within the normal, implying apparently no changes in their reactions to the ambient conditions. The effects of all the designs did not change the normalcy in the animals' lives.

Acknowledgement

All the neighbouring farmers who have to tolerate the incessant visits to the area and as well participated in the safety of the does are appreciated.

Conflict of Interest Declaration

There is no declaration of interest or conflict.

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