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# Effects of natural building ventilation on live weights performance of does during reproduction

**Lamidi W. A.[1]*, Osunade J. A.[2] and Ogunjimi L. A. O.[2]**

[1]Department of Agricultural Education, Osun State College of Education, Ila-Orangun, Osun State, Nigeria.
[2]Department of Agricultural Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria.

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**Four identical adjoining buildings, each with eight pens (number of does = 32) of dimensions 1.2 × 0.6 × 1.2 m were constructed with floor area per pen (1.2 × 0.6 m). Three factors were considered in the study; building orientations (Or.45° and Or.90° to wind directions) and ventilation openings (Op.20, Op.40, Op.60 and Op.80% side openings) and seasons (dry and rainy). Ventilation rates inside each pen were estimated using opening effectiveness and magnitudes of prevailing winds' speed measured. Rabbits were mated to produce litters at two consecutively times per season. Significant ($p< 0.05$) differences due to season were observed for the weight gains during and after conception and also for size at birth. Or.90° with Op.60% had mean weight of 14.0 g day$^{-1}$, highest recorded in does weight gain before conception but conception rate (CR) of 32.81% and gestation period (GP) of 31.19 days. CR was highest for Op.80% (42.18) with lower GP of 31.38 days. Litter size (Ls) was high for higher openings Op.60, Op.80 and Op.100. Increasing side building ventilations increases weight gain and CR with 30 to 31 days GP and high Ls in does before, during and after conception.**

**Key words:** Conception, gestation, litters, orientation, openings.

## INTRODUCTION

Ventilation systems in building may be natural or artificial (mechanical) and are installed to maintain a comfortable indoor environment for the animals occupying it. Natural ventilation can be generated by wind pressure and/or thermal buoyancy due to stack effect. The natural ventilation allows a chimney effect due to buoyant forces to be created, as well as creating a suction force while wind blows across the building (Nicol, 2004). The natural ventilation opening acts as an exhaust to allow warm, moist air to exit the building. This is very important for hot climate when outdoor air temperature is extremely high (Humphreys and Nicol, 1998).

In rabbits' building, ventilation systems continuously remove the heat, moisture and odours created by rabbits, solar heat gain through the building envelope and casual heat from equipment and artificial lighting (Patial et al., 1991; Bassuny, 1999). All these replenish the oxygen supply by bringing in drier and clear outside air (Gugliermetti et al., 2004). Adequate air exchange also removes gases such as ammonia ($NH_3$), hydrogen sulphide ($H_2S$) and methane ($CH_4$) which are generated in the pen via their wastes and which can be harmful to the rabbits (Shove et al., 2008). The merit of ventilation is how such polluted proportion of air within the enclosed space should be continuously withdrawn and replaced by fresh air. This must be drawn in from a clear external source, as high as elevation and as practical (Lamidi, 2011). Thus, ventilation is needed to maintain air purity.

*Corresponding author. E-mail: lwasiuagunbiade@yahoo.com. Tel: +2348062085175.

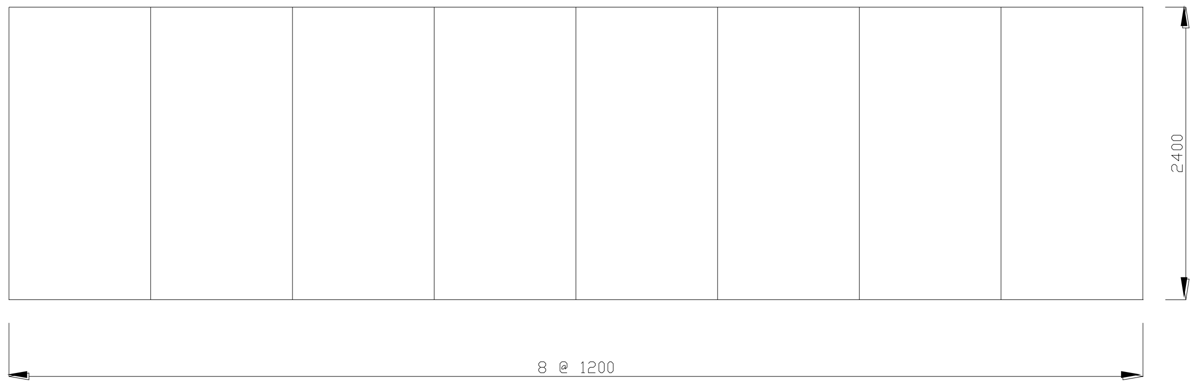


**Figure 1.** Plan view of the experimental building for 45 and 90° orientations.

Building shape or geometry may greatly influence air movement into and around the building and it accounts for increase or decrease in heat and its accompanying stress. The geometry of the building determines to a large extent the size and shape of the eddy, it should be realized that building height, width and depth determine the size of the eddy, or the calm area for the airflow. However, a small change in both building form and shape or feature arrangement may create large changes in air movement. As ventilation can never be compromised in building, building configuration assists in cross-ventilation, if, however, due to poor design and therefore compromised, air movement may not reach deep down into building's space depending on the level of the design and the distance (or height) between the floor and the ceiling (Sherman and Matson, 2008; Steemers, 2003; Chappells and Shovel, 2005). The objectives were to determine the effects of building ventilation opening resulting from variations in temperature and humidity inside the building on the weights and carcass development in does at different stages (before, during and after conception) of their reproductive lives.

## MATERIALS AND METHODS

### Experimental design

The study was carried out at the rabbitry section of the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife. Ile-Ife is in the rain forest zone of Nigeria, situated at longitude 14° 33'E and latitude 07° 28'N. Four identical adjoining buildings with dimensions 1.2 × 4.8 × 1.2 m (width × length × height, respectively) were constructed with floor area per pen (1.2 × 0.6 m). Each of the building housed eight pens for 32 does altogether. Another building, 100% open at all sides housed four pens of 1 doe each and with dimension 1.2 × 0.6 m each was used as control experiment.

Three factors were considered in the study; building orientations (Or.45° and Or.90° to the directions of the wind), ventilation openings (Op.20, Op.40, Op.60 and Op.80% side openings) and seasons of the year (dry and rainy seasons). The Op.100% opening with four rabbits served as control. The experimental set up was a 2 × 2 × 4 design with the effects of orientation and ventilation openings investigated during the dry and rainy seasons; each treatment was replicated four times. The does were mated to produce two sets of offspring consecutively per season. All the experimental animals were obtained from the same population and therefore the influence of genetic factors should be minimal. In addition pure rabbits breeds are not available in Nigeria on demand because there are no pure breed parent materials in the country. The available rabbit stocks in Nigeria are made of several generations of crosses of about 4 different breeds imported into the country several years back and therefore the influence of genetic factors should be minimal.

Figures 1 to 5 show the experimental plans of the building and some rabbits in their pens. Thirty-two rabbits with age range 32 weeks to 34 weeks were allocated to each of the 4 pens at Op.20%; each of 4 pens at Op.40%, each of 4 pens at Op.60%, each of 4 pens at Op.80% in Or.45° and these were all repeated in pens in Or.90° orientations. The Op.100% opening had only Or.90° orientation with 1 rabbit doe in each of its four pens. Their individual concentrate feeds and water were equally weighed and given the same time in individual pot daily throughout the period of the experiment. The parameters measured for the determination of growth performance in the gestating rabbits were weight of the doe before conception, during gestation period and weight of does during breastfeeding (before weaning kits). Litter size was also measured. Triple beam balance MB with a capacity of 2610 ± 0.01 g was used to measure the weekly weight gain of does. Ventilation rates (the quantity of air) inflow into each constructed pen were estimated using approximate results based on empirical data as given by ASHRAE (1997) and ASHRAE/HVAC&R (2004) written as

$$Q = E\,Av \tag{1}$$

where Q= wind or airflow rate, $m^3/s$, A = area of inlet opening; $m^2$ (the outlet openings are assumed to be equal in area, which is true in the case of the experiment), v = wind or air velocity, m/s; and E = opening effectiveness and it is a function of $\rho$, v, $\mu$, l, z, $\phi$ and $\theta$, $\rho$ = air density / ($kg/m^3$) = 1.65 $kg/m^3$ at 30°C, v = air or (prevailing) wind velocity, m/s, $\mu$ = absolute air viscosity $Ns/m^2$ = 0.0000248 $Ns/m^2$ at 30°C, $\phi$ = wind flow angle of incidence, z / l = ratio of opening height to opening length, $\theta$ = roof slope.

Then, according to Naas et al. (1998), effectiveness of the building openings (E) varies according to direction of the prevailing wind relative to the opening and is given as:

$$E = 16.33\left[\frac{0.21\rho v}{\mu}\right]^{-0.3515} \times \mathrm{Sin}(\phi)^{1.201} \times \left(\frac{4z}{l}\right)^{-0.1213} \times (\mathrm{Sin}\ \theta)^{-0.153} \tag{2}$$

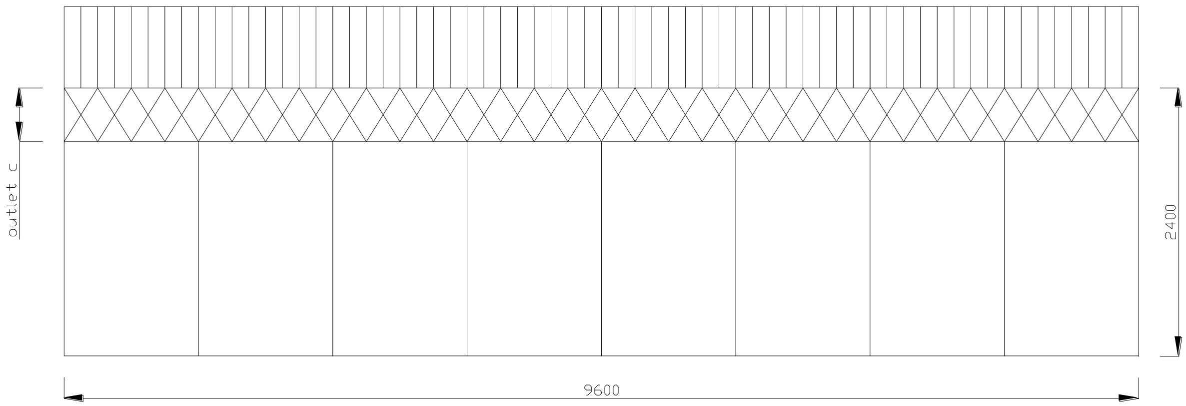


**Figure 2.** Side view of the experimental building for 45, 90° orientation and at leeward openings c = 20%: At 45° and 90°, whether inlet a = 20% or inlet b = 40% or inlet a = 60% or inlet b = 80%, outlet c = 20% constant throughout.

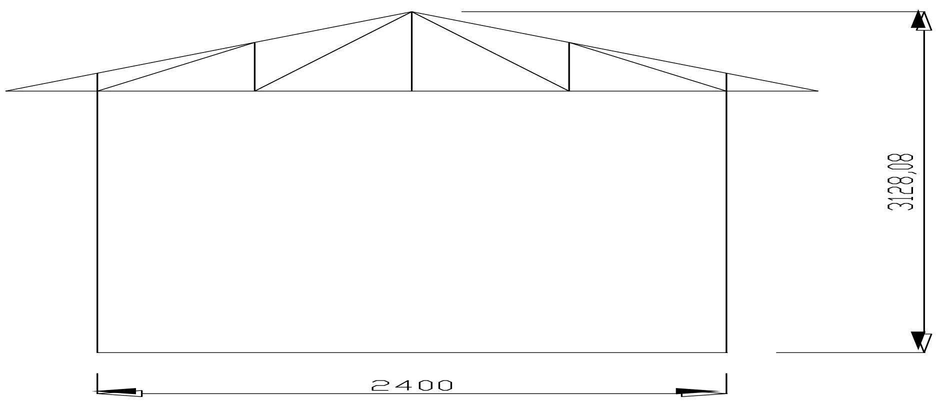


**Figure 3.** End view of the experimental building for 45 and 90° orientation and at different openings; roof slope = 30°.


**Figure 4.** Two of the four experimental housing built with wood showing pens in the 45° (background) and 90° (foreground) orientations buildings.


**Figure 5.** Experimental housing built with wood showing rabbits in their individual pens in 100% side opening building used as control, present conventional building.

**Table 1.** p-values showing interactions of seasons, building orientation and opening on the weekly weight gain by does at various stages in dry and rainy seasons.

| Parameter (kg) | Source | p-values | |
|---|---|---|---|
| | | Dry season | Rainy season |
| Wt.g.bCR | Or. | 0.523 | 0.123 |
| | Op. | 0.356 | 0.236 |
| | Or. * Op. | 0.0001** | 0.012* |
| | Season * Or. * Op. | 0.278 | 0.059 |
| Wt.g.dCR | Or. | 0.034* | 0.043* |
| | Op. | 0.207 | 0.005* |
| | Or. * Op. | 0.0001** | 0.013* |
| | Season * Or. * Op. | 0.00204* | 0.007* |
| Wt.g.p | Or. | 0.007* | 0.021* |
| | Op. | 0.021* | 0.015* |
| | Or. * Op. | 0.021* | 0.015* |
| | Season * Or. * Op. | 0.002* | 0.002* |

Or.*Op.; Season*Or.*Op = interactions; Wt.g. bCR – weight gain by doe before conception; Wt.g. dCR – weight gain by does during conception; Wt.g. p – weight gain by does during post-natal.

**Statistical analysis**

Data concerning the doe's liveweights before, during and after conception were statistically analysed by 2 × 2 × 4 factorial design according to the following experimental mixed model:

$$Y_{ijk} = \mu + S_i + Or_j + Op_k + S_i.\ Or_j + S_i.\ Op_k + Or_j.\ Op_k + S_i.\ Or_j.\ Op_k + e_{ijk}$$

where, $Y_{ijk}$ = observation on ijk$^{th}$ weights of doe due to all factors; $\mu$ = overall mean effect; $S_i$ = the fixed effect of i$^{th}$ season (i = dry, rainy); $Or_j$ = the fixed effect of j$^{th}$ orientation (j = 45$^0$, 90$^0$); $Op_k$ = the fixed effect of k$^{th}$ opening (k = 20, 40, 60 and 80%); $S_i.\ Or_j.$ = interaction effect between the i$^{th}$ season and j$^{th}$ orientation; $S_i.\ Op_k$ = interaction effect between the i$^{th}$ season and k$^{th}$ opening; $Or_j.\ Op_k$= interaction effect between the j$^{th}$ orientation and k$^{th}$ opening; $S_i.\ Or_j.\ Op_k$ = interaction effect between the i$^{th}$ season, j$^{th}$ orientation and k$^{th}$ opening and $e_{ijk}$ = random error.

## RESULTS AND DISCUSSION

### Weight gain by doe before conception

Significant differences ($p < 0.05$) due to the interactions between building orientations and openings were observed on the weight gain by the does before conception in the dry and rainy seasons (Table 1). In contrast, the interaction

**Table 2.** Means depicting body weights (± SE) of Does as affected by seasons, orientations and openings before conception (n = 30 days).

| Items | Body wt (g) | | Daily wt mean (g) | Weekly wt gain/loss (g) | Carcass wt (g) |
|---|---|---|---|---|---|
| | Initial | Final | | | |
| Effect of season | | | | | |
| Dry | 1540 ± 13[a] | 1656 ± 6[a] | 7.2 ± 0.1[a] | 11.6[a] ± 0.4[a] | 1480 ± 6[a] |
| Rain | 1550 ± 12[a] | 1690 ± 6[a] | 7.5 ± 0.2[a] | 14.0[a] ± 0.6[a] | 1500 ± 10[a] |
| Significance | NS | NS | NS | NS | NS |
| Effect of orientation | | | | | |
| Or.45° | 1535 ±11[a] | 1623± 10[b] | 5.8± 0.8 [a] | 8.8 ± 0.4[a] | 1500 ± 6[a] |
| Or.90° | 1540 ± 7[a] | 1696± 6[a] | 6.5± 0.6 [a] | 15.6 ± 0.4[a] | 1540 ± 16[a] |
| Significance | NS | NS | NS | NS | NS |
| Effect of opening (%) | | | | | |
| Op.20 | 1487 ± 2[b] | 1647± 10[a] | 6.3 ± 0.5[a] | 6.0 ± 0.4[a] | 1400 ± 4[a] |
| Op.40 | 1480 ±11[b] | 1580± 6[a] | 4.0 ± 0.6 [a] | 10.0 ± 0.2[a] | 1480 ± 16[a] |
| Op.60 | 1600 ± 2[a] | 1935 ± 10[b] | 14.0 ± 0.5[b] | 33.5 ± 1.4[b] | 1400 ± 4[a] |
| Op.80 | 1580 ± 10[a] | 1728 ± 16[a] | 5.8 ± 1.2[a] | 14.8 ± 1.3[a] | 1480 ± 16[a] |
| Op.100 | 1700 ±10[a] | 1731± 11[a] | 8.8 ± 1.2[a] | 12.8 ±1.3[a] | 1420± 3.1[a] |
| Significance | NS | * | NS | * | NS |

*p < 0.05; NS- not significant, Means bearing different supercripts in the same classification differ significantly.

among the season, the orientation and the openings as at then was not significant (p>0.05). Table 2 showed that in the rainy season, Or.90°and Op.60% were with mean weights respectively of values 7.5, 6.5 and 14.0 g day$^{-1}$, highest recorded in does' weight gain before conception. There were statistical differences among the weights (daily and weekly) in their respective classifications. Differences between initial and final weights was 140 g in rainy season compare with 116 g in dry season, 156 g in Or.90° and 335 g in Op.60 when compared with other openings, it was the highest (Table 2). In both dry and rainy seasons, the mean values from multiple range test showed building opening Op.40% had the lowest daily weight gain of 0.004 kg day$^{-1}$, whereas, Op.60% had 0.014 kg day$^{-1}$.

## Weight gain by doe during conception

Significant differences ($p < 0.05$) due to (i) building orientation, (ii) the interaction between building orientation and opening and (iii) interactions between the seasons, orientations and openings were observed on the weight gains by the does at the conception period during the dry and rainy seasons (Table 1). Effect of opening was significant in the rainy season on the weight gain by doe. The season, orientation and the openings were statistically different from each other according to their classifications. Differences between initial and final weights of does during conception show higher weight in Op.60% (220 g) and Op.100 (141 g), (Table 3). The higher weight and weight gain recorded at rainy season in Or.90° at Op.80% (16.2, 10.0 and 4.8 g week$^{-1}$); Table 3, were due to lower Temperature-Humidity Index (THI) recorded (23.00 ± 0.05) in the pen, lower THI value implied lesser heat stress on the animal (Figure 7a), this was in agreement with Finzi et al. (1995) and Ogunjimi et al. (2008) that rabbits have increased weight at lesser heat load. The study showed that mean weight's increment was highest for Or.90° (10.6 g week$^{-1}$). Conception rate (CR) was highest for Op.80% (42.18) with lower gestation period (GP) of 31.38 days compare to 33.38 days in Op.60%.

## Weight gain by doe during pre-weaning (post-natal) period

The significant effects ($p < 0.05$) due to building orientation, opening and their interactions and interactions between the season, orientation and opening were observed in the does' weight gain at post-natal (pre-weaning) period during the dry and rainy seasons (Table 1). Statistical means showed 60% opening with highest litter size of 2.92, the 90° orientation with litter size of 2.45 (45° orientation, 2.15) and in the rainy season, 2.53 (dry season, 1.60). There were statistical differences among the same parameters in the same classifications. There was significant ($p< 0.05$) effect due to season on litter size at birth (Table 4). Randi (1982) and Patial et al.

**Table 3.** Means (± SE) depicting some Does' parameters as affected by seasons, orientations and openings during conception (n = 35 days).

| Items | Body wt (g) Initial | Body wt (g) Final | Daily wt mean (g) | Weekly wt gain/loss (g) | Conception rate (%) | Gestation period (days) |
|---|---|---|---|---|---|---|
| Effect of season | | | | | | |
| Dry | 1550 ± 2[a] | 1666 ± 6[a] | 4.2 ± 0.1[a] | 15.4 ± 4[a] | 34.60 ± 0.6[a] | 34.30 ± 0.2[b] |
| Rain | 1570 ± 10[a] | 1685 ±16[a] | 5.1 ± 0.2[a] | 16.2 ± 6[a] | 35.40 ± 1.0[a] | 32.13 ± 0.6[a] |
| Significance | NS | * | * | * | * | ** |
| Effect of orientation | | | | | | |
| Or.45$^0$ | 1520± 14[a] | 1628 ± 1[a] | 1.1 ± 0.15[a] | 9.0[b] ± 0.6[a] | 35.41 ± 1.0[a] | 32.31 ± 0.6[a] |
| Or.90$^0$ | 1582 ± 6[b] | 1688 ± 1.5[b] | 1.3 ± 0.1[a] | 10.0[b] ± 0.6[a] | 35.26 ± 2.3[a] | 32.13 ± 0.6 |
| Significance | NS | * | * | * | * | ** |
| Effect of opening, % | | | | | | |
| Op.20 | 1540 ± 2[a] | 1646 ± 10[a] | 2.3 ± 0.5[a] | 6.0 ± 0.2[a] | 33.91 ± 1.3[a] | 33.07 ± 0.2[a] |
| Op.40 | 1580 ±16[a] | 1684 ± 6[a] | 4.0 ± 0.6[b] | 5.5 ± 0.3[a] | 32.27 ± 2.4[a] | 33.38 ± 0.7[a] |
| Op.60 | 1690 ± 2[c] | 1910 ± 8[b] | 1.4 ± 0.5[a] | 3.6 ± 1.4[a] | 32.81 ± 4.2[a] | 31.19 ± 0.2[a] |
| Op.80 | 1620 ±10[c] | 1731 ± 11[a] | 1.8 ± 1.2[a] | 4.8 ± 1.3[a] | 42.18 ± 3.1[b] | 31.38 ± 0.1[a] |
| Op.100 | 1580 ±10[c] | 1721 ± 11[a] | 2.8 ± 1.2[a] | 5.8 ± 1.3[a] | 32.00 ± 2.1[a] | 31.00 ± 0.1[a] |
| Significance | NS | * | * | * | * | ** |

*p < 0.05; **p< 0.001; NS- not significant, Means bearing different supercripts in the same classification differ significantly.

(1991) also found that seasons significantly affect litter size in Himachal Pradesh (India). This result however contrasted Nasr (1994) findings in Egypt (a sub-saharan tropical country) that effect of season was not significant on the litter size at birth. Litter size was high for higher openings Op.60, Op.80 and Op.100% respectively with mean values 2.92, 2.29 and 2.92. Figures 6 and 7 showed how the weights of doe before their conception varied in their different pens; there were gains and losses in their weights during the lactation (or pre-weaning) period. It was generally observed that as the building opening size increases, the weight gain by doe after conception increases as shown by openings Op.20, Op.40 and Op.60% in the rainy seasons (Table 2). No mortality was recorded from the does during the seasons at both orientations and openings.

Maximum weight gain of 5.8 and 0.45 kg week$^{-1}$ was recorded for Op.80% ventilation opening and 7.8g week$^{-1}$for Or.90° orientation in the rainy season. The differences between initial and final doe's weight after conception period were higher at Or.90 (120 g), Op.60 (170 g) and Op.100 (180 g) (Table 4). Tables 5 and 6 revealed that there was linear relationship between the THI values and the weight gains in does as shown by the linear model equations respectively for the dry and rainy seasons. In all, the high $R^2$ values shown that there was positive correlation between the THI, weights and weight gains in the does during the post natal period (Tables 5 and 6). At Op.60, Op.80 and Op.100% openings, the correlations were stronger. The combined effects of different orientations and openings, Figures 8 and 9 show that the does' weights were not increasing but fluctuate non-linearly throughout the periods. This may be due to the fluctuations in the THI values calculated from measured temperatures and humidities (Marai and El-Kelawy, 1999). It may also be as a result of the combination of different openings and different orientations [these led to different ventilation rate ($m^3$/s) in the individual pens] that had significant effect ($p < 0.05$) on the weights of the does and by extension on their metabolic activities and reproductive performances.

## Airflow rates in the pens

The ventilation rates in $m^3$/s calculated from Equations 1 and 2, 100% opening had 0.00577 $m^3$/s; Op 80. 90° Or. had 0.00417 $m^3$/s, Op 80. 45° Or. had 0.00303 $m^3$/s (37.62% increase of 90° Or. over 45° Or. at 80% opening); Op 60. 90° Or. had 0.00279 $m^3$/s, Op 60. 45° Or. had 0.00330 $m^3$/s (18.27% increase of 45° Or. over 90° Or. at 60% opening) during the dry season. During the rainy season, Op 80. 90° Or. had 0.00492 $m^3$/s, Op 80. 45$^0$ Or. had 0.00307 $m^3$/s (60.26% increase of 90° Or. over 45$^0$ Or. at 80% opening); Op 60. 90° Or. had 0.00427 $m^3$/s, Op 60. 45° Or. had 0.00201 $m^3$/s (112.43% increase of 90° Or. over 45° Or. at 60% opening). It can be seen that for the same opening at different orientations, there were appreciable, significant differences in their magnitudes. These different airflows in different

**Table 4.** Means (± SE) depicting weight, litter size, does' mortality as affected by seasons, orientations, openings after conception (n = 30 days).

| Items | Body wt (g) | | Daily wt mean (g) | Weekly wt gain/loss (g) | Wt. of litter (g) | Litter size | Mortality of does (%) |
|---|---|---|---|---|---|---|---|
| | Initial | Final | | | | | |
| Effect of season | | | | | | | |
| Dry | 1650 ± 2 [a] | 1730 ± 16[b] | 0.8 ± 0.01[a] | 2.4 ± 0.03[a] | 114 ± 0.6 [a] | 1.60 ± 0.02[a] | Nil |
| Rain | 1672 ± 10[a] | 1756 ± 16 [b] | 0.5 ± 0.02[a] | 2.0 ± 0.06[a] | 134 ± 1.0 [b] | 2.53 ± 0.06[a] | Nil |
| Significance | NS | * | * | * | * | ** | NS |
| Effect of orientation | | | | | | | |
| Or.45[0] | 1618± 1.4[a] | 1724 ± 1[b] | 2.4 ± 0.15[b] | 6.0 ± 0.6 [b] | 126 ± 1.0 [a] | 2.15 ± 0.02[a] | Nil |
| Or.90[0] | 1680 ± 6[a] | 1800 ± 1.5[c] | 1.3 ± 0.1[a] | 7.8 ± 0.03 [b] | 133 ± 2.3[b] | 2.45 ± 0.12[b] | Nil |
| Significance | NS | * | * | * | * | * | NS |
| Effect of opening (%) | | | | | | | |
| Op.20 | 1635± 2.4[a] | 1742 ± 10[b] | 2.3 ± 0.5 [b] | 6.0 ± 0.2[b] | 136 ± 1.3[b] | 2.10± 0.02[a] | Nil |
| Op.40 | 1570 ±16[a] | 1680 ± 6[a] | 2.0 ± 0.6[b] | 5.5 ± 0.3[b] | 117 ± 2.4[a] | 1.83 ± 0.17[a] | Nil |
| Op.60 | 1710 ± 10[a] | 1890 ± 8.3[ab] | 1.3 ± 0.05[a] | 3.6 ± 1.4[a] | 127 ± 4.2[a] | 2.92 ± 0.2[a] | Nil |
| Op.80 | 1700 ±6[a] | 1806±10.5[c] | 1.8 ± 0.2[b] | 5.8 ± 1.3[b] | 140 ± 3.1[b] | 2.29 ± 0.11[a] | Nil |
| Op.100 | 1600 ±6 [a] | 1780± 12.5[c] | 2.8 ± 0.2[b] | 7.8 ± 1.3[b] | 144 ± 3.1[b] | 2.92 ± 0.11[a] | Nil |
| Significance | NS | * | * | * | * | * | NS |

*p < 0.05; **p< 0.001; NS- not significant, Means bearing different supercripts in the same classification differ significantly.

pens provided different thermo-comfort conditions for the rabbits and thereby may likely contribute to their reproductive performance.

The different resulted weight gains and losses in does at various periods of the experiment as shown in Figures 6a and b to 11a and b led to the different cumulative weights of does at the end of each period. Though all the rabbits were reared in their different pens at the weight bracket of 1.54 ± 0.20 kg, their weights at the end of the first week of rearing were no longer within the same weight brackets and at the subsequent weeks, they continued to be different and far from same weight brackets (Figure 6a and b). This shows that their weights were affected by the prevailing conditions inside their individual pens as a result of the different orientations and openings. The Op.60, Op.80 and Op.100% openings respectively had higher cumulative weights' values of 2.22 ± 0.08, 2.20 ± 0.17 and 2.04 ± 0.25 kg at Or.90° orientation. At Or.45° orientation, the Op.60 and Op.80% openings respectively had 1.93 ± 0.20 and 1.97 ± 0.32 kg cumulative weights' values for the does in the rainy season. The lowest final weight of doe recorded was 1.11 ± 0.26 kg for Op.60% opening in the Or.45° orientation in the dry season, Figure 3a. The fluctuations in the does' weights were as a result of the fluctuations in both temperature and humidity that have effects on the animal physiological and metabolic activities.

Figures 6 to 11 show weight gains/losses in does before, during and after conception periods. However, there were more weight gains than losses at openings Op.60 and Op.80% and especially, at the Or.90° orientation than other openings.

## Conclusions

Seasons affect weight and weight gain in does at different ventilation openings and different orientations. The interaction between season, building orientation and opening significantly affected ($p < 0.05$) the weight gain by the does

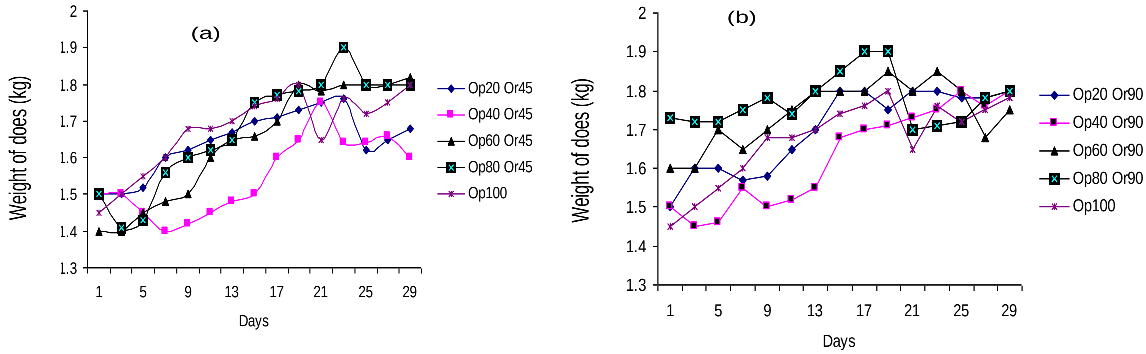


**Figure 6.** Weight of doe in every other day before conception during the dry season (a) Or.45°(b) Or.90°.

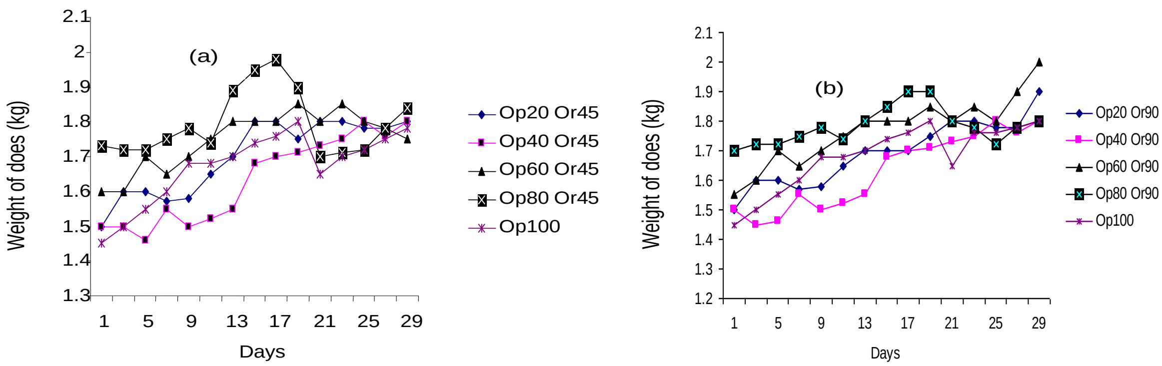


**Figure 7.** Weight of doe in every other day before conception during the rainy season (a) Or.45° (b) Or.90°.

**Table 5.** Regression analysis between building openings, THI values and weights of doe after gestation (during lactation) at both orientation (dry season), n = 35 days.

| **Orientation- Or.45°** | | | | |
|---|---|---|---|---|
| **Op.%** | **Linear model** | | **Quadratic model** | |
| | **Regression equation** | **$R^2$ values** | **Regression equation** | **$R^2$ values** |
| Op.20 | w = -0.224 t + 25.55 | 0.42 | w = 0.0203 $t^2$ - 0.548 t + 26.48 | 0.72 |
| Op.40 | w = -0.194 t + 25.41 | 0.32 | w = 0.0103 $t^2$ - 0.359 t + 25.88 | 0.42 |
| Op.60 | w = -0.163 t + 25.53 | 0.51 | w = 0.0241 $t^2$ - 0.549 t + 26.63 | 0.61 |
| Op.80 | w = -0.191 t + 25.40 | 0.62 | w = 0.0137 $t^2$ – 0.411 t + 26.022 | 0.72 |
| Op.100 | w = -0.213 t +25.004 | 0.42 | w = 0.0223 $t^2$ - 0.148 t + 26.48 | 0.72 |
| **Orientation-Or.90°** | | | | |
| **Op.%** | **Linear model** | | **Quadratic model** | |
| | **Regression equation** | **$R^2$ values** | **Regression equation** | **$R^2$ values** |
| Op.20 | w = -0.218 t + 25.54 | 0.32 | w = 0.012 $t^2$ - 0.537 t + 26.43 | 0.62 |
| Op.40 | w = -0.141 t + 25.209 | 0.71 | w = 0.011 $t^2$ - 0.314 t + 25.70 | 0.91 |
| Op.60 | w = -0.213 t + 25.61 | 0.62 | w = 0.012 $t^2$ - 0.410 t + 26.17 | 0.82 |
| Op.80 | w = -0.158 t + 25.48 | 0.82 | w = 0.025 $t^2$ - 0.552 t + 26.59 | 0.72 |
| Op.100 | w = -0.213 t + 25.004 | 0.42 | w = 0.0223 $t^2$ - 0.148 t + 26.48 | 0.73 |

w = weight of doe, t = THI.

**Table 6.** Regression analysis between building openings, THI values and weights of doe after gestation (during lactation) at both orientation (rainy season).

**Orientation- Or.45°**

| Op.% | Linear model | | Quadratic model | |
|---|---|---|---|---|
| | Regression equation | $R^2$ values | Regression equation | $R^2$ values |
| Op.20 | w = -0.182 t + 25.71 | 0.92 | w = -0.0079 $t^2$ - 0.056 t + 25.35 | 0.92 |
| Op.40 | w = -0.091 t + 24.99 | 0.21 | w = 0.0079 $t^2$ + 0.0029 t + 24.65 | 0.31 |
| Op.60 | w = 0.0920 t – 23.66 | 0.33 | w = 0.0027 $t^2$ + 0.049 t + 23.78 | 0.43 |
| Op.80 | w = -0.214 t + 25.16 | 0.93 | w = 0.0157 $t^2$ – 0.464 t + 25.87 | 0.82 |
| Op.100 | w= -0.113 t + 24.004 | 0.42 | w = 0.0023 $t^2$ - 0.448 t + 25.41 | 0.72 |

**Orientation- Or.90°**

| Op.% | Linear model | | Quadratic model | |
|---|---|---|---|---|
| | Regression equation | $R^2$ values | Regression equation | $R^2$ values |
| Op.20 | w = -0.191 t + 25.84 | 0.41 | w = -0.020 $t^2$ + 0.127 t + 24.94 | 0.64 |
| Op.40 | w = -0.078 t + 24.94 | 0.70 | w = 0.0210 $t^2$ - 0.411 t + 25.89 | 0.41 |
| Op.60 | w = 0.140 t + 25.57 | 0.72 | w = -0.010 $t^2$ + 0.011 t + 25.15 | 0.92 |
| Op.80 | w = -0.110 t + 25.52 | 0.61 | w = 0.0027 $t^2$ - 0.152 t + 25.65 | 0.61 |
| Op.100 | w = -0.113 t + 24.004 | 0.42 | w = 0.0023 $t^2$ - 0.448 t + 25.41 | 0.72 |

w = weight of doe, t = THI.

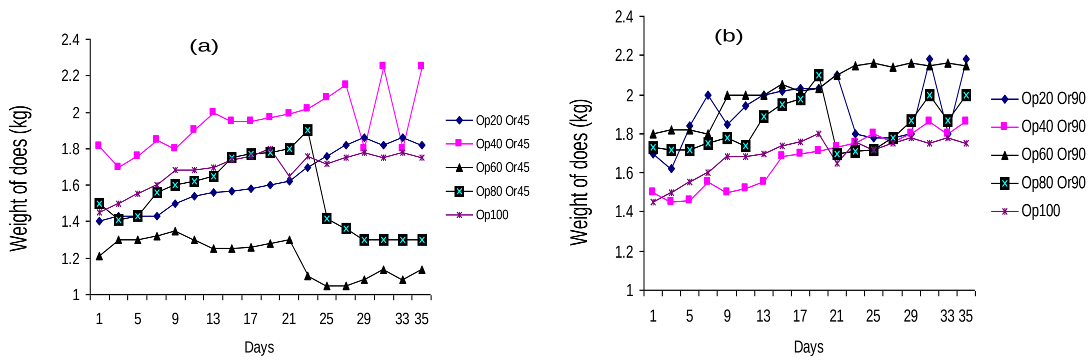


**Figure 8.** Weight gain by Doe (kg) in every other day during conception in dry season (a) Or.45° (b) Or.90°.

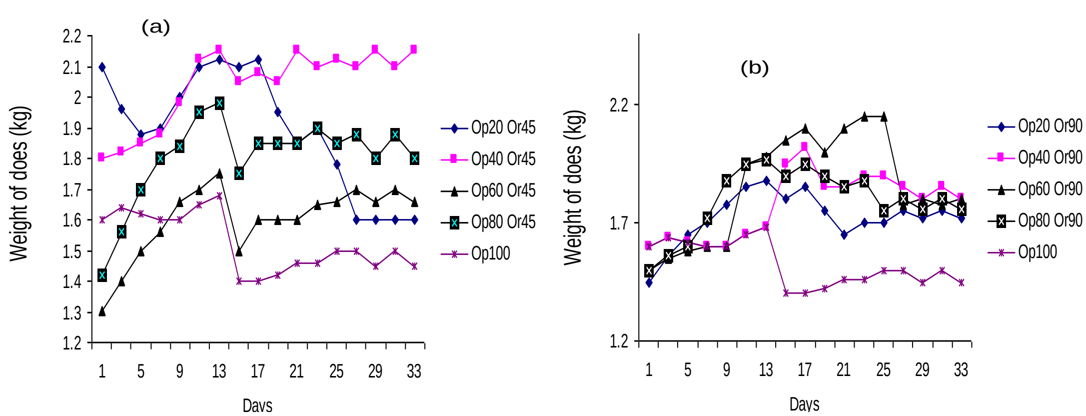


**Figure 9.** Weight gain by Doe in kg in every other day during conception in rainy season (a) Or.45° (b) Or.90°.

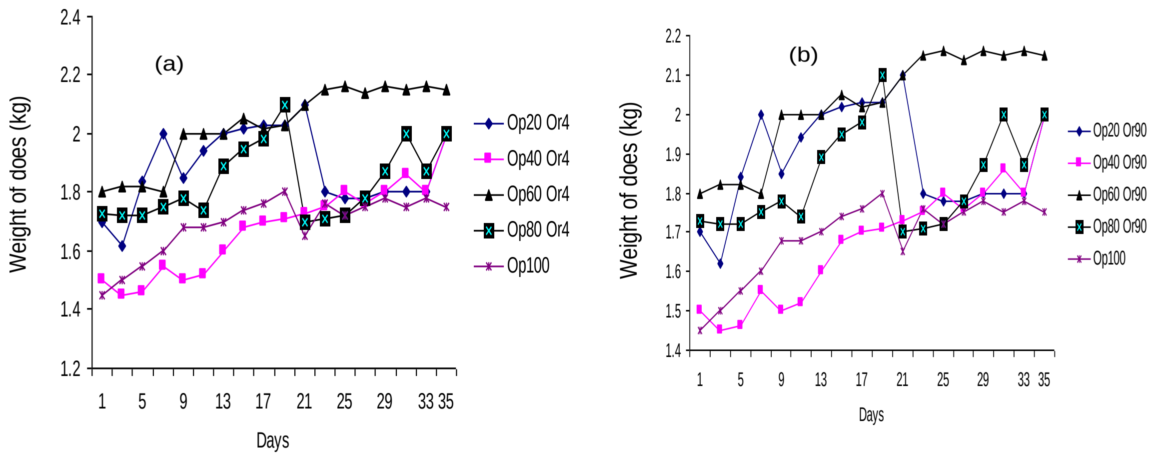


**Figure 10.** Weight gain by Doe in kg in every other day at post-natal in dry season (a) Or.45° (b) Or.90°.

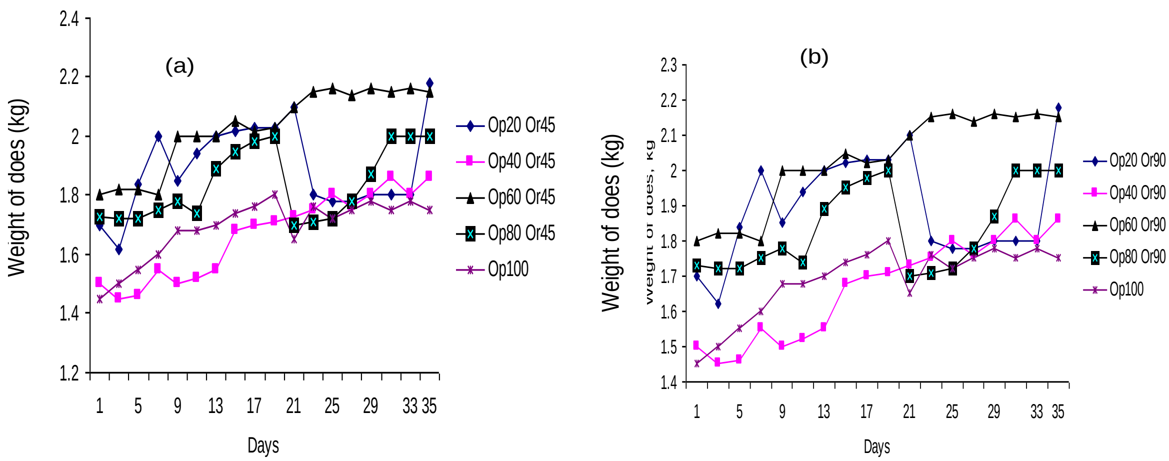


**Figure 11.** Weight gain by Doe in kg in every other day at post-natal in rainy season (a) Or.45° (b) Or.90°.

during and after conception. Building opening Op.40% had the lowest daily weight gain of 0.004 kg day$^{-1}$, whereas, Op.60% had 0.014 kg day$^{-1}$. The study also revealed that mean weight's increment was highest for Or.90° (10.6 g week$^{-1}$). It was generally observed that as the building opening size increases, ventilation rate increases and the weight gains by doe after conception increases as shown by openings Op.40, Op.60 and Op.80 in the rainy seasons. CR was highest for Op.80% (42.18) with lower GP of 31.38 days in Op.60%. There was linear relationship between the THI values and the weight gains in does. In all, the high $R^2$ values shown that there was positive correlation between the THI and weights and weight gains in the does during the post natal period. At Op.60, Op.80 and Op.100% openings, the correlations were stronger. Seasons significantly ($p< 0.05$) affected the litter size at birth. Litter size was high for higher openings Op.60, Op.80 and Op.100%. No mortality was recorded for the does at both seasons.

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