EFFECT OF CAGE DENSITY ON GROWTH AND CARCASS PERFORMANCE OF FATTENING RABBITS UNDER TROPICAL HEAT STRESS CONDITIONS

Villalobos O.*, Guillén O.*, García J.†

*Departamento de Zootecnia, Facultad de Agronomía, Universidad del Zulia. Maracaibo, Venezuela.
†Departamento de Producción Animal, E.T.S.I. Agrónomos, Universidad Politécnica de Madrid, Ciudad Universitaria, 28040 Madrid, Spain.

ABSTRACT: Three hundred crossbred New Zealand, California, Butterfly, Dutch, and Satin rabbits, weaned at 30 d and weighing 535±8 g (standard error) were assigned randomly to four treatments: 6, 12, 18 and 24 rabbits/m² (3, 6, 9 and 12 rabbits/cage, respectively, each cage measuring 0.5 m²) resulting in 10 cages/treatment. During the experimental period (from weaning to 2.2 kg body weight) weekly individual live weight, cage feed intake, incidence of diarrhoea, ringworm, and injured rabbit data was recorded. The maximum temperature-humidity index ranged from 31 to 35, and so indicating severe heat stress. At the end of the experimental period 10, 20, 30 and 30 rabbits under densities of 6, 12, 18 and 24 rabbits/m², respectively, were slaughtered and carcass performance recorded. Average daily gain and feed intake from weaning to the end of the experimental period decreased by 0.31±0.070 and 1.20±0.25 g, respectively, for each unit that the density increased at the beginning of the experiment (P=0.001). The length of the fattening period increased by 0.91±0.16 d (P=0.001) for each unit of increment of density. However, rabbit production (expressed in kg/m²) increased linearly and quadratically with density (P<0.008). Cage density did not affect feed efficiency, which on average was 0.214 g/g (P=0.37). Animals housed at the highest density, compared to the average of those caged at lower densities, tended to show higher incidence of ringworm (68.9 vs 39.4%; P=0.075) and injury (16.8 vs 3.03%; P=0.12), and showed higher mortality (20.5 vs 9.63%; P=0.043). Density did not alter the dressing out percentage nor chilled carcass weight. The proportion of scapular fat (P=0.042) increased linearly with increasing levels of density, but perirrenal fat was unaffected (P=0.22). Increasing density reduced dorsal length linearly (P=0.001), and reduced drip loss percentage linearly and quadratically (P=0.097 and 0.018, respectively). Based on these results, under our heat stress conditions, avoiding densities higher than 18 rabbits/m² or 34 kg/m² at the end of fattening is recommended.

Key words: cage density, growing performance, carcass performance, heat stress.

INTRODUCTION

Cage density during rabbit fattening is an important factor that influences labour, investment cost, performance, and accordingly, profitability. In Europe, cage density varies in commercial farms from 14 to 23 rabbits/m² (or from 720 to 425 cm²/rabbit) (Trocino and Xiccato, 2006). Densities higher than 19 rabbit/m² reduce feed intake and growth rates, with no effect on feed efficiency or mortality (Maertens and De Groote, 1984; Aubret and Duperray, 1992). The European Food and Safety Authority (2005) recommended a minimum surface of 625 cm²/rabbit and not more than 40 kg/m² at the end of fattening, in order to avoid disturbances in rabbit behaviour. However, the behaviour of rabbits depends on their age. Rabbits just after weaning (at 21 d) tend to huddle together, increasing the stocking density up to 31-61 rabbits/m² for the first two weeks after weaning, while older animals prefer lower densities and when caged at high densities spend less time eating (Morisse and Maurice, 1997; Matics et al., 2004).
The results of these studies cannot be extrapolated to tropical conditions, where it is difficult to apply adequate environmental control, and consequently an increase in cage density can more negatively affect rabbit growth performance. In these conditions, an increase in cage density reduces feed intake and impairs growth rates, but it also seems to increase mortality (Nieves et al., 1996; Mbanya et al., 2004). The cage density recommended by these authors ranges between 5 and 16 rabbits/m², but they do not give any information regarding environment temperature and relative humidity.

The aim of this work is to study the effect of cage density under the heat stress conditions found in Maracaibo, Venezuela (average temperature 28ºC and relative humidity 76%; Peters et al., 1983), by measuring growth performance, mortality, and animal injury rates and carcass performance.

**MATERIAL AND METHODS**

**Animals and housing**

Three hundred crossbred New Zealand, California, Butterfly, Dutch, and Satin rabbits, weaned at 30 d, were transported just after weaning from a commercial farm (located in Barinas: average 26ºC and 74% relative humidity) to our facilities (seven hours distant) in Maracaibo (Venezuela). Animals were housed in flat-deck cages measuring 500×100×500 mm (0.5 m²) equipped with one nipple drinker and one hopper feeder (30 cm available) in each cage. Water was filtered before storage in the farm water-tank. The farm is an open-air building equipped with a ventilator to recycle air and a mesh (80% shade) on the windows to avoid animals being exposed to the sun. The regional climate in Maracaibo is very dry tropical forest (Holdrige, 1978). The temperature-humidity index (THI) was calculated according to Marai et al. (2001):

\[
\text{THI} = db^\circ C - [(0.31 - 0.031 \text{ RH}) \times (db^\circ C - 14.4)],
\]

where \( db^\circ C \) is dry bulb temperature in Celsius degrees, and RH is the relative humidity as a percentage. According to Marai et al. (2002) there is heat stress when THI is higher than 28.9, while under 27.8 there is no heat stress.

**Experimental procedure**

Rabbits were caged at 6, 12, 18 and 24 rabbits/m² (or 3, 6, 9 and 12 rabbits/cage) and they were assigned randomly to one of these four treatments (10 cages/treatment). The average weaning weight was 535±8.0 g (standard error) and rabbits were identified by a number written in their ears. A commercial diet was offered *ad libitum* to the animals containing (g/kg dry matter (DM)): 918 DM, 97.8 ash, 164 crude protein (CP), 36.2 ether extract, 124 crude fibre, 361 neutral detergent fibre (NDF), 186 acid detergent fibre (ADF) and 44.6 acid detergent lignin (ADL), and an estimated digestible energy value of 11.1 MJ/kg (De Blas et al., 1992). Individual animal weights, cage feed intake, and mortality were recorded weekly. Dead animals were not substituted. The average number of rabbits per cage and week was used to calculate growth rate and feed intake per cage and animal. Mortality, diarrhoea incidence, and injured animals were expressed in percentage per cage. During the experiment an outbreak of diarrhoea appeared just after weaning. An intramuscular injection with Diarrex H (Aldor C.A., Venezuela) for 3-4 d was used to control the infection. It contained dimetridazol, sulphamethacine, trimetoprin and tretracycline. Animals diagnosed with ringworm (Trichophyton spp.) were treated orally with ketazol (Laboratorios Vargas, Venezuela) containing ketoconazol. The experiment finished when the average weight of the rabbits in the cage reached 2.2 kg/rabbit. Then 10, 20, 30 and 30 rabbits corresponding to rabbits caged at 6, 12, 18 and 24 rabbits/m², respectively, were slaughtered at between between 9.30 and 11.00 am. Rabbits were stunned by a neck hit and then bled. Afterwards, they were dissected according to Blasco et al. (1993).
Chemical analysis

AOAC (2000) procedures were used to determine the concentrations of DM (934.01), ash (967.05), CP (968.06), ether extract (including acid hydrolysis, 920.39), and crude fibre (932.09). Dietary NDF, ADF, and ADL were determined sequentially using the fibertec system (Foss, Danemark) according to the methods of Mertens (2002), the AOAC (2000; procedure 973.187) and Van Soest et al. (1991), respectively.

Statistical analysis

The results obtained in this study for growth performance (expressed per cage) were analyzed as a completely randomized design with the average weaning weight per cage as a linear covariate and cage density was included as a linear and quadratic covariate, by using the SAS General Linear Model procedure (SAS Inst. Inc., Cary, NC). We studied the individual growth rate, and the interaction between cage density and fattening period (considering four fattening periods: weaning (30-44 d, 44-58 d, 58-85 d, 85 d-2.2 kg BW) for the animals that finished the experiment. This interaction was analysed as a repeated measurement analysis by using a mixed model (CS covariance structure) that included weaning weight as a linear covariate, cage density as a linear and quadratic covariate, and fattening period (time effect) as classified effect. Interactions among cage density and fattening period were also included. In this model, the cage is considered as a random effect. The model used to study carcass traits included the sex as a classified effect, slaughter weight as a linear covariate, and cage density as a linear and quadratic covariate – using the SAS General Linear Model procedure. The maximum/minimum was calculated and commented when quadratic effects were significant, except if it was out of the range studied. All data is presented as least-square means.

RESULTS AND DISCUSSION

Inside the farm the relative humidity ranged from 67 to 94% and the minimum temperature varied from 21 to 29°C (corresponding to the night, when animals eat most of the feed). According to the review of Cervera and Fernández-Carmona (1998), these temperatures would be lower than the upper critical temperature of weaned rabbits (30°C), but higher than the value for adult rabbits (25°C). The calculated THI ranged between 21 and 28, and according to Marai et al. (2002) this would not cause heat stress. At the maximum temperatures (recorded around 15:00 h, and varying from 24 to 35°C) THI ranged from 31 to 35, and this implies a very severe heat stress which would impair growing performance.

Feed intake and growth rate (both expressed per day and rabbit) from weaning to the end of fattening was impaired by 1.20±0.25 and 0.31±0.070 g, respectively, for each unit that cage density (rabbits/m²) increased at the beginning of the experiment (P<0.001) (Table 1). This negative effect was recorded in all the fattening stages. However, cage density had no effect on feed efficiency – which was on average 0.214 g/g (P=0.37). Accordingly, the reduction in growth rate when cage density increased is directly related to the reduction of feed intake as previously observed (Maertens and de Groote, 1984; Aubret and Duperray, 1992; Nieves et al., 1996; Mbanya et al., 2004). As a consequence, the length of the fattening period increased by 0.91±0.16 d (P=0.001) for each unit that cage density increased. The single growth rate for rabbits that finished the fattening period decreased by 0.25±0.035 g/d for each unit of increase in cage density (P<0.001) (Table 2). In these animals, the effect of cage density varied depending on the fattening period (P=0.022). During the first two weeks after weaning (from 30 to 44 d of age) the effect of cage density was worse (−0.30±0.080 g/unit of density increment; P<0.001) than those of the 44-58 and 58-85 day periods (−0.13±0.057 and −0.12±0.047 g/unit of density increment, respectively; P<0.024). These results differ from those reported by Maertens and de Groote (1984) and Aubret and Duperray (1992) who did not observe any effect on density during the 10-14 day period after weaning, or even with
| Initial density, rabbits/m² | 6  | 12 | 18 | 24 | SEM¹ | L² | P² |
|----------------------------|----|----|----|----|------|----|----|
| Initial density, cm²/rabbit| 1667 | 833 | 555 | 417 |      |    |    |

30 (weaning)-44 d

|                        | 30 (weaning)-44 d | 44-58 d | 58-85 d | 85 d-2.2 kg | 30 d (destete)-final |
|------------------------|-------------------|---------|---------|-------------|----------------------|
| Body weight at 44 d, g/rabbit | 922 | 886 | 865 | 831 | 12.2 | 0.001 | 0.001 |
| Daily gain, g/rabbit×d  | 22.1 | 20.3 | 18.8 | 14.3 | 2.08 | 0.025 | 0.001 |
| Feed intake, g/rabbit×d | 58.6 | 53.3 | 50.3 | 46.6 | 2.43 | 0.003 | 0.001 |
| Feed efficiency, g/g    | 0.361 | 0.363 | 0.365 | 0.295 | 0.033 | 0.26 | 0.011 |
| Mortality, %             | 8.79 | 8.84 | 7.70 | 12.2 | 3.52 | 0.63 | 0.015 |
| Body weight at 58 d, g/rabbit | 1262 | 1198 | 1176 | 1129 | 20.1 | 0.001 | 0.001 |
| Daily gain, g/rabbit×d  | 24.6 | 21.5 | 21.4 | 18.3 | 1.19 | 0.003 | 0.014 |
| Feed intake, g/rabbit×d | 83.4 | 75.7 | 74.7 | 73.0 | 2.83 | 0.032 | 0.001 |
| Feed efficiency, g/g    | 0.297 | 0.294 | 0.289 | 0.243 | 0.020 | 0.11 | 0.75 |
| Mortality, %             | 0.18 | 1.63 | 1.00 | 4.64 | 1.41 | 0.090 | 0.18 |
| Body weight at 85 d, g/rabbit | 1848 | 1747 | 1700 | 1643 | 27.9 | 0.001 | 0.001 |
| Daily gain, g/rabbit×d  | 20.9 | 19.5 | 18.6 | 17.4 | 0.76 | 0.005 | 0.079 |
| Feed intake, g/rabbit×d | 109 | 105 | 93.1 | 86.6 | 4.79 | 0.002 | 0.16 |
| Feed efficiency, g/g    | 0.196 | 0.188 | 0.200 | 0.199 | 0.0098 | 0.67 | 0.81 |
| Mortality, %             | 0.072 | 0.12 | 0.13 | 1.85 | 0.57 | 0.077 | 0.24 |
| Final body weight, g/rabbit | 2178 | 2233 | 2100 | 2170 | 37.8 | 0.35 | 0.35 |
| Daily gain, g/rabbit×d  | 17.3 | 20.2 | 12.8 | 14.4 | 1.71 | 0.057 | 0.46 |
| Feed intake, g/rabbit×d | 114 | 113 | 93.7 | 80 | 4.93 | 0.001 | 0.81 |
| Feed efficiency, g/g    | 0.150 | 0.183 | 0.138 | 0.172 | 0.016 | 0.88 | 0.52 |
| Mortality, %             | 0.37 | 0.00 | 0.44 | 1.78 | 1.27 | 0.44 | 0.016 |

³SEM: Standard error of means (n=10 cages/treatment).
²Linear effect of density. Quadratic effect of density was always P>0.30.
¹Effect of average weaning weight per cage.
⁴Significant effect of contrast 24 vs (18, 12, 6) rabbits/m² (P<0.050).
⁵Tendency effect for contrast 24 vs (18, 12, 6) rabbits/m² (0.050 < P<0.15).
the results of Matics et al. (2004) that observed a natural preference by rabbits to increase density around weaning. These negative results just after weaning might be explained by the long journey between farms just after weaning and the time required to settle into new housing conditions, which might have favoured the outbreak of diarrhoea in this period. In the final fattening period (from 85 d of age to 2.2 kg BW) the negative effect of density was again seen (−0.20±0.069 g/unit of density increment; P=0.004), which is related to the reduction of available surface as observed in both optimal climatic conditions (Maertens and de Groote, 1984; Aubret and Duperray, 1992; Morisse and Maurice, 1997) and in hotter conditions (Nieves et al., 1996; Andréa et al., 2004).

The incidence of ringworm and injuries was unaffected linearly or quadratically by cage density (Table 1). However, rabbits caged at the highest density, compared to the average of the three lower densities, although no significant differences were detected, tended to be more sensitive to ringworm (68.9 vs 39.4%; P=0.075), and to show a greater aggressiveness (reflected in the higher percentage of injured animals, especially on the ears and tail; 16.8 vs 3.03%; P=0.12). The aggressions begun on average at 68.8±4.8 d after weaning (the first aggression was recorded 48 d after weaning, but the two-thirds point was detected from 72 d after weaning onwards). This result indicates the negative impact of high densities on rabbit behaviour due to lack of comfort, and it is in agreement with the impairment of growth performance in the final fattening period. The highest density also increased mortality in the whole fattening period compared to the average of the three lower densities (20.5 vs 9.63; P=0.043). This result differs from previous studies which did not find any relation between cage density and mortality (Maertens and de Groote, 1984; Aubret and Duperray, 1992), but it is in agreement with the trend observed in tropical conditions (Nieves et al., 1996; Mbanya et al., 2004). In this study, animals with lower weaning weights were more

Table 2: Effect of cage density on individual growth performance of rabbits that reached 2.2 kg

| Initial density, rabbits/m² | 6   | 12  | 18  | 24  | RSD¹ | L²  | P⁴  |
|-----------------------------|-----|-----|-----|-----|------|-----|-----|
| Initial density, cm²/rabbit |     |     |     |     |      |     |     |
| No. of rabbits              | 28  | 54  | 80  | 91  |      |     |     |
| 30 (weaning)-44 d           |     |     |     |     |      |     |     |
| Body weight at 44 d, g/rabbit | 914 | 892 | 873 | 842 | 102  | 0.001 | 0.001 |
| Daily gain, g/rabbit×d     | 26.3| 24.7| 23.1| 20.9| 7.6  | 0.001 | 0.12  |
| 44-58 d                     |     |     |     |     |      |     |     |
| Body weight at 58 d, g/rabbit | 1248| 1199| 1176| 1137| 143  | 0.001 | 0.001 |
| Daily gain, g/rabbit×d     | 24.4| 22.4| 22.1| 21.5| 5.4  | 0.024 | 0.001 |
| 58-85 d                     |     |     |     |     |      |     |     |
| Body weight at 85 d, g/rabbit | 1831| 1742| 1701| 1652| 207  | 0.001 | 0.001 |
| Daily gain, g/rabbit×d     | 20.8| 19.4| 18.7| 18.4| 4.5  | 0.014 | 0.39  |
| 85 d-2.2 kg                 |     |     |     |     |      |     |     |
| Body weight d, g/rabbit    | 2151| 2241| 2127| 2206| 258  | 0.81  | 0.001 |
| Daily gain, g/rabbit×d     | 17.3| 20.1| 14.9| 15.7| 6.6  | 0.004 | 0.011 |
| 30 d (weaning)-2.2 kg       |     |     |     |     |      |     |     |
| Daily gain, g/rabbit×d     | 22.2| 21.3| 18.9| 18.1| 3.3  | 0.001 | 0.31  |

¹RSD: residual standard deviation.
²Linear effect of density. Quadratic effect of density showed always P>0.30.
³Effect of weaning weight.
likely to die (Figure 1 and 2), as they probably had a lower milk intake during lactation and were more sensitive to diarrhoea. This result might suggest an advantage in delaying the weaning age.

The negative effect of density on growth performance did not prevent the final rabbit production (kg/m$^2$) increasing linearly with density ($P=0.001$) (Table 3). In this case, a quadratic effect was also observed ($P=0.008$), as rabbit production did not increase in direct proportion to the number of rabbits – due to their lower growth rate and higher mortality at the highest cage density. Accordingly, to reduce mortality, ringworm, and injured animals, density must be below 41 kg/m$^2$ – which is the highest value recommended in Europe (Trocino and Xiccato, 2006). In our conditions of heat stress, a cage density of around 16-18 rabbits/m$^2$ produced around 34 kg/m$^2$, and a one week reduction in the length of the fattening period (compared to animals caged at the highest density) could be recommended. A lower density (12 kg/m$^2$) improves growth rate and fattening duration (by 16% and 4%, respectively), but also reduces final production per m$^2$ by around 29%. Under our conditions, the only way to introduce a high cage density would be to shorten the length of fattening – and accordingly significantly reduce the slaughter weight.

Table 3: Effect of cage density on final rabbit production (kg live body weight/m$^2$).

| Initial density, rabbits/m$^2$ | 6   | 12  | 18  | 24  | SEM$^1$ | L$^2$ | Q$^3$ | $P_{cov}^4$ |
|-------------------------------|-----|-----|-----|-----|---------|-------|-------|------------|
| Initial density, cm$^2$/rabbit |     |     |     |     |         |       |       |            |
| 1667                          | 833 | 555 | 417 |     |         |       |       |            |
| 44 d                           |     |     |     |     |         |       |       |            |
| Live body weight, kg/m$^2$     | 4.74| 9.76| 14.4| 17.0| 0.52    | 0.001 | 0.018 | 0.11      |
| No rabbits/m$^2$               | 5.31| 11.0| 16.7| 21.0| 0.26    | 0.001 | 0.20  | 0.001     |
| 58 d                           |     |     |     |     |         |       |       |            |
| Live body weight, kg/m$^2$     | 6.51| 12.9| 19.4| 22.1| 0.75    | 0.001 | 0.066 | 0.15      |
| No rabbits/m$^2$               | 5.29| 10.8| 16.5| 19.8| 0.53    | 0.001 | 0.066 | 0.001     |
| 85 d                           |     |     |     |     |         |       |       |            |
| Live body weight, kg/m$^2$     | 9.59| 18.7| 27.8| 31.6| 1.04    | 0.001 | 0.014 | 0.062     |
| No rabbits/m$^2$               | 5.27| 10.8| 16.5| 19.4| 0.59    | 0.001 | 0.021 | 0.001     |
| 2.2 kg                         |     |     |     |     |         |       |       |            |
| Live body weight, kg/m$^2$     | 11.3| 24.2| 34.3| 41.1| 1.54    | 0.001 | 0.008 | 0.008     |
| No rabbits/m$^2$               | 5.19| 10.8| 16.4| 18.9| 0.56    | 0.001 | 0.024 | 0.001     |

$^1$SEM: standard error of the means (n=10 cages/treatment). $^2$Linear effect of density. $^3$Quadratic effect of density. $^4$Effect of average weaning weight per cage.
Table 4: Effect of cage density and sex on carcass performance.

| Initial density, rabbits/m² | 6    | 12   | 18   | 24   | Sex  | RSD\(^1\) | L\(^2\) | P\(_{sex}\)\(^3\) | P\(_{cov}\)\(^4\) |
|-----------------------------|------|------|------|------|------|-----------|--------|-----------------|-----------------|
| Initial density, cm\(^2\)/rabbit | 1667 | 833  | 555  | 417  | Males| Females  |        |                 |                 |
| \(N_\text{g}\)            | 4    | 10   | 14   | 14   |      |          |        |                 |                 |
| \(N_\text{b}\)            | 6    | 10   | 15   | 16   |      |          |        |                 |                 |
| Live body weight at slaughter (BW), g | 2261 | 2265 | 2159 | 2198 | 2188 | 2253     | 130    | 0.041           | 0.022           |
| Skin weight, %BW          | 16.1 | 16.8 | 16.9 | 16.8 | 17.3 | 16.0     | 1.19   | 0.27            | 0.001           | 0.48            |
| Digestive tract weight, %BW | 16.5 | 15.9 | 15.5 | 15.9 | 15.5 | 16.3     | 1.75   | 0.47            | 0.078           | 0.14            |
| Hot carcass weight, %BW   | 62.9 | 62.9 | 62.5 | 62.5 | 62.7 | 62.7     | 2.05   | 0.52            | 0.92            | 0.20            |
| Hot carcass weight (HCW), g | 1386 | 1388 | 1380 | 1379 | 1384 | 1383     | 45     | 0.52            | 0.83            | 0.001           |
| Chilled carcass weight (CCW), g | 1230 | 1256 | 1262 | 1250 | 1252 | 1248     | 53     | 0.61            | 0.83            | 0.001           |
| Dressing out percentage\(^5\), % BW | 55.7 | 56.9 | 57.2 | 56.6 | 56.7 | 56.5     | 2.48   | 0.56            | 0.88            | 0.014           |
| Drip loss percentage\(^6\), % HCW | 11.3 | 9.62 | 8.52 | 9.41 | 9.54 | 9.85     | 2.50   | 0.097           | 0.88            | 0.016           |
| Head weight, % CCW        | 10.0 | 9.96 | 10.2 | 10.3 | 10.3 | 9.97     | 0.83   | 0.22            | 0.14            | 0.001           |
| Liver weight, % CCW       | 4.79 | 4.89 | 5.19 | 5.01 | 5.00 | 4.93     | 0.97   | 0.50            | 0.84            | 0.72            |
| Kidney weight, % CCW      | 0.95 | 0.92 | 0.92 | 0.90 | 0.93 | 0.91     | 0.15   | 0.34            | 0.56            | 0.12            |
| Other viscera weight\(^1\), % CCW | 1.97 | 2.08 | 2.07 | 2.03 | 2.07 | 2.01     | 0.32   | 0.98            | 0.44            | 0.17            |
| All viscera weight, % CCW | 7.71 | 7.90 | 8.18 | 7.94 | 8.00 | 7.86     | 1.17   | 0.65            | 0.66            | 0.38            |
| Perirenal fat weight, % CCW | 1.63 | 1.81 | 1.54 | 1.54 | 1.63 | 1.63     | 0.53   | 0.22            | 0.97            | 0.001           |
| Scapular fat weight, % CCW | 0.67 | 0.88 | 0.89 | 0.99 | 0.86 | 0.86     | 0.45   | 0.042           | 0.88            | 0.13            |
| Whole fat weight, % CCW   | 2.29 | 2.73 | 2.44 | 2.54 | 2.51 | 2.50     | 0.87   | 0.75            | 0.95            | 0.003           |
| Reference carcass weight, g | 1014 | 1033 | 1031 | 1022 | 1024 | 1026     | 55     | 0.97            | 0.83            | 0.001           |
| Reference carcass weight, % BW | 45.9 | 46.8 | 46.6 | 46.4 | 46.4 | 46.5     | 2.56   | 0.96            | 0.77            | 0.002           |
| Dorsal length, cm         | 26.9 | 27.3 | 26.1 | 25.4 | 26.2 | 26.6     | 1.61   | 0.001           | 0.37            | 0.039           |
| Thigh length, cm          | 7.21 | 7.13 | 7.52 | 7.20 | 7.25 | 7.28     | 0.76   | 0.86            | 0.76            | 0.17            |
| Lumbar circumference\(^6\), cm | 16.3 | 16.7 | 16.5 | 16.1 | 16.2 | 16.5     | 0.86   | 0.13            | 0.11            | 0.001           |

\(^1\)RSD: residual standard deviation. \(^2\)Linear effect of cage density. \(^3\)Effect of sex. \(^4\)Effect of live body weight at slaughter. \(^5\)Thymus, trachea, oesophagus, lungs and heart. \(^6\)Quadratic effect of cage density (\(P<0.05\)). \(^7\)Quadratic trend of cage density (0.05 < \(P<0.15\)).
Although rabbits were slaughtered when the average weight of the cage was 2.2 kg/rabbit, a negative effect of cage density is observed on slaughter weight ($P=0.041$), and this has been used as a covariate when carcass traits were analysed (Table 4). Cage density had a minor influence on the carcass compared to growth traits, and this is in agreement with previous works (Aubret and Duperray, 1992; Xiccato et al., 1999; Combes and Lebas, 2003). The proportion of scapular fat increased with cage density ($P=0.042$). An older age at slaughter when cage density is increased might explain this observation (Dalle Zotte et al., 2002). However, this result should be confirmed as no effect was detected on the proportion of perirenal fat ($P=0.22$), and scapular fat might have been removed with the skin. Cage density linearly reduced dorsal length ($P<0.001$) which is another signal of the lack of comfort in animals caged at high densities.

Drip loss percentage increased linearly and quadratically ($P=0.097$ and 0.018, respectively) with decreasing densities, showing a minimum value for a density of 18 rabbits/m$^2$. The slaughter of younger animals (with almost the same weight: 2.2 kg) when cage density decreased might account for this result – as other authors have detected an increase in drip loss percentage when age at slaughter decreases (Xiccato et al., 1993; Bernardini et al., 1995). This result is related to the quadratic trend ($P=0.12$) of cage density on the dressing out percentage – which showed a maximum at 17.1 rabbits/m$^2$. Cage density also quadratically affected the lumbar circumference and obtained a maximum value at 14.3 rabbits/m$^2$. The sex had little influence on carcass traits. Females were heavier at slaughter compared to males ($P=0.022$) and had a lower skin weight proportion ($P<0.001$). They also tended to have a higher digestive tract weight ($P=0.078$) and a longer lumbar circumference ($P=0.11$). Neither cage density nor sex had effect on hot, chilled, and reference carcass weight, viscera weight, nor on the proportion of dissectible fat weight (scapular and perirenal) and thigh length.

**CONCLUSIONS**

A cage density above 6 rabbits/m$^2$ impaired growth performance during fattening, with minor effects on carcass traits, but improved rabbit production (expressed in kg/m$^2$). A high density (24 rabbits/m$^2$) increased mortality, ringworm, and the number of injured animals with respect to animals caged at lower densities. Accordingly, under our heat stress conditions, it is recommended to use a maximum density of 18 rabbits/m$^2$ (or 34 kg/m$^2$ at the end of fattening) to avoid difficulties and maximise rabbit production (kg/m$^2$).

**Acknowledgements:** Authors are grateful to CONDES (Consejo de Desarrollo Científico y Humanístico) from Zulia University for the financial support to maintain the experimental rabbit farm. Ana María Campos (Agronomy Faculty at Zulia University), also the Microbiology Department of the Veterinary Faculty at Zulia University, and to Javier González (Nanta SA) for their technical help.

**REFERENCES**

Andréa M.V., de Carvalho G.J.L., Nunes S.C., Costa C.N., Barbosa R.P. 2004. Densidade populacional no desempenho produtivo de coeleos. *Arch. Zootec.*, 53: 391-394.

Association of Official Analytical Chemists. 2000. *Official methods of analysis.* 17th Ed. AOAC, Washington, DC, USA.

Aubret J., Duperray J. 1992. Effect of cage density on the performance and health of the growing rabbit. *J. Appl. Rabbit Res.*, 15: 656-660.

Bernardini M., Castellini C., Dal Bosco A. 1995. Qualità della carcassa di coniglio in funzione del tipo genetico e dell’eta di macellazione. In *Proc.: XI ASPA Congress, Grado (GO), Italy*, pp. 127-128.

Blasco A., Ouhayoun J., Masoero G. 1993. Harmonization of criteria and terminology in rabbit meat research. *World Rabbit Sci.*, 1: 3-10.

Cervera C., Fernández-Carmona J. 1998. Climatic environment. In: *The nutrition of the rabbit*. Ed. De Blas C., Wiseman J.. CABI Publishing. Wallingford. UK. pp. 273-296.

Combes S., Lebas F. 2003. Les modes de logement du lapin en engraissement: influence sur les qualités des carcasses et des viandes. In *Proc.: 10èmes Journées de la Recherche Cunicole, Paris, France*, pp. 185-200.

Dalle Zotte A. 2002. Perception of rabbit meat quality and major factors influencing the rabbit carcass and meat quality. *Livest. Prod. Sci.*, 83: 263-267.
CAGE DENSITY UNDER HEAT STRESS

De Blas C., Wiseman J., Fraga M.J., Villamide M.J. 1992. Prediction of the digestible energy and digestibility of gross energy of feeds for rabbits. 2 mixed diets. Anim. Feed Sci. Technol., 39: 39-59.

European Food and Safety Authority. 2005. Scientific Opinion of the Scientific Panel on Animal Health and Welfare on “The impact of the current housing and husbandry systems on the health and welfare of farmed domestic rabbit”, EFSA-Q-2004-023. EFSA Journal, 267: 1-31.

Holdrige L.E. 1978. Ecología basada en zonas de vida. Trad. de 1° ed. Revista Inglesa por Humberto Jiménez Saa. Instituto Interamericano de Ciencias Agrícolas (IICA), San José, Costa Rica. 276 pp.

Maertens L., De Groote G. 1984. Influence of the number of fryer rabbits per cage on their performance. J. Appl. Rabbit Res., 7: 151-153.

Marai I.F.M., Ayat M.S., Abd 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 alleviation under Egyptian conditions. Trop. Anim. Health Prod., 33: 451-462.

Marret’s L., De Blas C., Wiseman J., Fraga M.J., Villamide M.J. 1992. Prediction of the digestible energy and digestibility of gross energy of feeds for rabbits. Anim. Feed Sci. Technol., 39: 39-59.

Morisse J.P., Maurice R. 1997. Influence of stocking density or group size on behaviour of fattening rabbits kept under intensive conditions. Appl. Anim. Behav. Sci., 54, 351-357.

Nieves D., Alexis L., Daniel F. 1996. Efecto de la densidad de alojamiento en conejos de engorde. Revista Unelze de Ciencia y Tecnología, 14: 21-32.

Peters W., Noguera N., Materano G., Romero G. 1983. Estudio detallado de suelos de la Granja Experimental Ana María Campos de la Facultad de Agronomía. Facultad de Agronomía, La Universidad del Zulia, Maracaibo. Mimeo. Venezuela. 14 pp.

Trocino A., Xiccato G. 2006. Animal welfare in reared rabbits: a review with emphasis on housing systems. World Rabbit Sci., 14: 77-93.

Van Soest J.P., Robertson J.B., Lewis B.A. 1991. Methods for dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74: 3583-3597.

Xiccato G., Verga M., Trocino A., Ferrante V., Queaque P.I., Sartori A. 1999. Influence de l’effectif et de la densité par cage sur les performances productives, la qualité bouchère et le comportement chez le lapin. In Proc.: 8èmes Journées de la Recherche Cunicole, Paris, France, pp. 59-62.
