Health and body condition of lactating females on rabbit farms

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ABSTRACT: The aim was to study relationships between morbidity, defined through prevalence of diseases of rabbit females, and BCS, and to assess the effect of several risk factors on both morbidity and BCS. Our study was based on individual examinations of 18,510 does in lactation on 103 farms. We evaluated BCS on a linear scale from 1 to 9, with 5 being the optimum. Prevalence of major diseases were 22.7%, 4.0%, and 6.4% for coryza, mastitis, and ulcerative pododermatitis, respectively. In addition, prevalence was 3.0% for diseases of minor presentation, including mange, which had a prevalence of 1.9%. The BCS of the R line (selected for growth) was 5.55 ± 0.14, whereas for the A line (selected for litter size) it was 4.40 ± 0.11. Females with more than 20 kindlings had on average a BCS 0.25 ± 0.07 units less than those in the 12th lactation (P = 0.0002). Optimal BCS 4.60 ± 0.11 was reached during the third lactation week. Sick females had a BCS 0.6 ± 0.11 units less than healthy females. Females with a footrest had on average a BCS 0.19 ± 0.05 units greater than those without. The absence of footrests was an enabling risk factor for ulcerative pododermatitis, the prevalence of which increased by 53%. Ulcerative pododermatitis was associated (P = 0.045) with diet; females consuming a rich energy diet were prone to having this disorder; 1 SD increase in DE (0.32 MJ) determined an increase in ulcerative pododermatitis prevalence of 0.8 percentage points. Diet was not an enabling risk factor for the other diseases. The genetic type to which a female belongs is a predisposing risk factor of disease; P, V and H were also maternal lines, while S group was exclusively formed by maternal lines. With regard to coryza, the S group had the greatest prevalence (44.0%), followed by A, P, R (19.0 to 21.0%); the V line, selected for prolificacy, showed the least prevalence (12.0%). For the case of mastitis although significant (P < 0.05), the magnitude of the differences between disease prevalence was less; R line had a mastitis prevalence of 11.0% while the least prevalence was observed for V does (4.0%). Simultaneous evaluation of both BCS and morbidity on the rabbit farm is recommended for the right assessment of welfare conditions. In this study, the relationships between both variables have been shown, as well as how other intrinsic and extrinsic risk factors modulate these variables; and thus, these factors should be considered during a welfare assessment.

Key words: animal welfare, body condition, diet, genetic types, health, rabbit

INTRODUCTION

Rabbit production efficiency (i.e., the profit of rabbit farming), depends, among many other factors,
visits to 103 farms in Spain and Portugal. All the farms were closed-cycle and specialized in meat production. Fuente (2008) have proposed a linear scale for measuring body condition in female rabbits, defining a BCS.

Morbidity has also been shown to influence both survival and reproductive performances of adult females (Rosell and de la Fuente, 2009a). The joint consideration of morbidity for some diseases and the mean BCS of the females in the farm, as well as the performance of the farm, are useful sources of information to evaluate conditions and welfare on farms (Broom and Kirkden, 2004; Grandin, 2010), which could result in the prescription of a treatment or change in management (Rosell et al., 2009). Given the importance of BCS and morbidity as indicators of conditions on the farm, they were used as the dependent variables in this study, with the aim of assessing the effect of a number of both endogenous (e.g., genetic type, age, physiological status) and exogenous (e.g., diet, season, features of the housing) factors on these variables for lactating does.

MATERIAL AND METHODS

Animal Care and Use Committee approval was not obtained for this study because data were obtained from an existing database, gathered from animals performing under commercial conditions, fulfilling Spanish and Portuguese law on animal welfare.

Sample and Population Description

Records for this study were collected between November 2007 and May 2010, in the course of 262 visits to 103 farms in Spain and Portugal. All the farms were closed-cycle and specialized in meat production. A total of 18,510 records were considered; they came from lactating females but some of them could also be simultaneously pregnant, when the reproductive rhythm of the farm was either intensive or semi-intensive. In general, females were not individually identified thus some animals could be inspected more than once in the successive visits. Given that data were recorded by a veterinary practitioner during routine visits to different farms, they do not follow an optimally balanced design: 39 farms were sampled only once, 19 twice, 22 three times, 10 four times, 5 five times, 4 six times, 2 seven times and 2 eight times. In view of the dispersion in the size of the farms, the number of sampled animals per visit also varied considerably, ranging from 12 to 144, with a median of 63 does.

The population from which the sample was taken was very large, easily covering most of the production scenarios currently used in the Iberian Peninsula (MARM, 2009). Regarding housing, both open-air and indoor units were present, the size of the farms on each visit ranged from 103 to 5,826 rabbit does, with a median size of 770. Size of population at risk within visit (i.e., lactating does), ranged from 50 to 1,300 with a median of 480 females. In most cases, does were bred by AI and were naturally mated on only 11% of the farms. The major genetic types used in Spain and Portugal were present in the sample; the most common types were those from Spanish breeding programs [Universidad Politécnica de Valencia (UPV), Institut de Recerca i Tecnologia Agroalimentàries (IRTA), and HYCAT] followed by types from French companies (EUROLAP, HYPHARM, HYCOLE) and finally animals belonging to breeds (New Zealand white, Californian, Fauve de Bourgogne, Spanish Giant, and so on), without any selection programs. Concerning reproduction rhythm, 83% of examined females were semi-intensively managed [i.e., naturally mated or artificially inseminated between 11 (88 farms) and 18 (9 farms) d after parturition, and kits weaned at 31- to 35-d of age]. Some females were intensively managed, being rebred within the first 10 d postpartum (2%). Others were extensively managed (15%; i.e., bred beyond 18 d after parturition, kits being weaned at 42-to 48-d of age). In the most extensive reproductive management, observed females were bred 45 d after parturition, with weaning age at 63 d, coinciding with the sale of growing rabbits. Figure 1 shows the age distribution of the examined females in our sample. In this figure 2,782 records were discarded from the complete data set because it was not possible to record their age, measured as number of accumulated parturitions, when they were inspected. This plot is quite similar to those previously reported in other studies characterizing Iberian rabbitries (Rosell and de la Fuente, 2009a).

Feeding is probably the factor that might induce a stronger bias, as records were obtained from farms supplied by a single feeding company (Nanta SA, Tres Cantos, Madrid), with information on DE and the digestible protein (DP)/DE ratio in diets. Even so, on the farms supplied by this company, a large variation in diet characteristics was also observed. From the feeding company records it was possible to obtain information on the diet characteristics that females were taking at the time of each visit. Regarding DE, diets ranged from 8.0 MJ/kg to 10.7 MJ/kg, as-fed; for DP it ranged from 106 g/kg to 130 g/kg, as-fed, the DP/DE ratio varied between 10.8 g/MJ and 13.7 g/MJ. These figures resemble the actual feed variation in the whole commercial rabbit population (Maertens, 2010; Pascaul, 2010; Xiccato and Trocino, 2010). All the females were fed for ad libitum
intake, but the conditions of feeding and water supply were widely variable; they reflected the current variation on these regards in commercial Iberian rabbit farming.

**Sampling Protocol**

Producers were asked for the total number of females present in the batch of lactating does (population at risk in this study). A random sample of approximately 10% was taken from these females for inspection. As on most farms, primiparous females were kept separately from the rest of lactating does and the same procedure was applied to them. To properly represent young females in the sample, the minimum number of primiparous females was determined by the proportion of primiparous females on the farm, frequently 10% of the batch; it was previously shown in Rosell and de la Fuente (2008, 2009a) that, given the conditions on Iberian farms, this procedure and proportion of sampled animals guarantees representativeness of all the females on the farm.

**BCS and Morbidity Assessment**

Body condition score evaluation was conducted following the scale described by Rosell and de la Fuente (2008). The key issue when applying this scale was the joint evaluation of the BW (that was estimated at handling), and the tactile appraisal of body cell mass (Roubenoff et al., 1997), covering lumbar and sacrum regions, as well as posterior limbs. After the evaluation of BCS, morbidity assessment was conducted by checking for the presence of clinical signs of any disease. The most common disorders in rabbit does on Iberian farms were: 1) diseases of the respiratory system, particularly coryza; 2) mastitis, either chronic or acute; and 3) ulcerative pododermatitis (Rosell et al., 2009). In addition to these 3 major diseases, any other clinical sign or disease of minor presentation were recorded: Mange (mainly psoroptic but occasionally sarcoptic), digestive signs (i.e., compatible with enteritis-diarrhea or with mucoid enteropathy), myxomatosis, cutaneous pseudomonosis, purulent eye, and abscesses. Morbidity was individually defined for each one of the major diseases as well as for any other disease. To this end, 4 binary variables indicating whether the animal had or not clinical signs for each particular disease (coryza, mastitis, pododermatitis, or any other disease) were defined. In addition, an overall morbidity index variable was defined by assigning the animals to the healthy category when they were free from any clinical sign, or to the sick category in any other case. Disease occurrence was recorded through prevalence (Thrusfield, 2005). Both BCS and morbidity assessments were always conducted by the same trained veterinarian.

**Statistical Analysis**

Linear mixed models were employed to assess the association between the different factors and BCS; the initial used model was the following:

$$BCS_{ijklmnopqrs} = Y_i + M_j + f_k + YM_{ijk} + G_l + Ml_{im} + P_n + LW_{0} + FR_p + MED_{q} +INY_r + DE \times \beta_1 + (DP/DE) \times \beta_2 + e_{ijklmnopqrs}$$

where BCS measurements were explained by the effect of the $i$th year ($Y$; 4 levels: 2007, 2008, 2009, and 2010), the effect of the $j$th calendar month ($M$; 12 levels), the effect of the $k$th farm ($f$), this factor was treated as random, the effect of the $ijk$th interaction of year, month, and farm, which represents the effect of the visit, this factor was treated as random as well, the effect of the $l$th genetic type ($G$) to which the female belongs; this factor was defined by 8 levels, the effect of the $m$th overall morbidity index ($MI$; 2 levels: healthy or sick), the effect of the $n$th kindling order ($P$; 16 levels: parturition from the first to the 12th were individually considered, the 13th included females with 13, 14 and 15 kindlings, the 14th females with 16, 17, 18, 19 and 20 kindlings, the 15th females with more than 20 kindlings, and the 16th level included females with an unknown number
of accumulated kindlings), the effect of the \( o \)th lactation week (LW; 6 levels: the last 1 included females in the 6th or later), the effect of the \( p \)th level of having a foot-rest (FR; 2 levels: with or without footrest), the effect of the \( q \)th level of medication in the feed (MED; 4 levels: the first included females for which no information on this regard was available, other included animals being given white feed (without drugs), the third included records from females fed on a diet with non-absorbable drugs (e.g., zinc bacitracin), and the last one included records from females taking bio-available drugs (e.g., tilmicosin), the effect of the \( r \)th level of parenteral drug that females were injected with occasion of kindling (INY; 3 levels: the first included records from females with no available information, the second included does that were not subjected to any parenteral treatment, and the third included records from does subjected to parenteral antimicrobial treatment), and finally \( \beta_1 \) and \( \beta_2 \) were linear regression coefficients on DE and on the DP/DE ratio in the diet that does were fed.

Some animals in the data set were crossbred, and this was considered in the design of the genetic effect definition (i.e., a F1 female would contribute 0.5 to each one of the 2 genetic types that were present in its genetic composition). Heterotic effects were not considered in the model; it was not possible to estimate them because within contemporary groups crossbred and the appropriate purebred are very scarce. The genetic types considered could be clustered within 3 categories for the purpose of description. The first one included animals of completely unknown origin and represented a particular level in the data set (N). Another category included animals assigned to a certain breeding program, without there being full knowledge about which particular genetic line they belonged to, in this category 2 levels of genetic groups were considered (U and S), the S group exclusively included maternal lines. Finally, the third category included individual lines, 4 of them being maternal, selected for litter size (V, H, P and A), and another being selected for growth (R).

A generalized linear model assuming a binomial distribution for the traits of interest and a logit link function were employed for the study of morbidity. In this model, the same risk factors as in that used for studying BCS were used, with the exception that now morbidity was replaced by the BCS effect, which was fitted as a linear covariate.

Once the models were solved, a set of linear contrasts were conducted to obtain least squared means for the levels of interest, and Wald hypothesis tests were conducted to check their statistical significance. All the analyses were conducted using the lme4 package (Bates, 2007) of the R statistical program (R Development Core Team, 2007).

### RESULTS AND DISCUSSION

#### Data Description

Data to conduct this study were obtained after individual evaluation of lactation does. Two set of traits were assessed in these examinations, BCS and morbidity. Body condition score was measured using the subjective linear scale previously described by Rosell and de la Fuente (2008). After the evaluation of body condition any clinical signs were recorded. A total of 18,510 records for BCS were used, this trait showed an average of 4.64, with a SD of 1.03; Figure 2 shows its frequency distribution. Prevalences of major diseases were 22.7%, 4.0%, and 6.4%, for coryza, mastitis, and ulcerative pododermatitis, respectively. In addition, prevalence for minor presentation diseases was 3.0%, and this group included mange, which had a prevalence of 1.9%. In clinical practice, mange is considered a condition in itself, but given its low prevalence in our study, it was treated as part of the minor disease group. When all the diseases were jointly considered, a sick animal percentage of 32.1% was observed, with similar figures previously being shown by Rosell and de la Fuente (2004, 2009a).

Regarding the distribution of major diseases, 3.3% of females had clinical signs of co-morbidity: coryza and mastitis (0.9%) and coryza and ulcerative pododermatitis (1.5%) combinations being the most frequent. The percentage of females having signs of all the major disease at the time was 0.3%. In spite of these low proportions, given the large number of records they account for a total of approximately 310 females for the case of co-morbidity of coryza and ulcerative pododermatitis.

![Figure 2. Body condition score distribution of examined female rabbits (n = 18,510) from 103 farms in Spain and Portugal.](image-url)
Factors Affecting Body Condition

Despite the subjective nature of this appraisal procedure, there is evidence of its usefulness in practical BCS evaluation. On the one hand, measurement repeatability (i.e., the ratio between the estimated variance associated to the animal and the total phenotypic variance), where the same animal was assessed on repeated occasions within a short time, was 0.7 (results not provided). On the other hand, a comparison between the method used here and the perirenal fat thickness method (Pascual et al., 2004) is being conducted and although this experiment is still in progress, some indications on the coincidences of both procedures have already been observed.

No significant differences ($P > 0.05$) were observed throughout year of visit, even though in 2007 and 2010 no records were taken during the whole calendar year. Throughout month within year BCS evolved as shown in Figure 3, with an almost flat pattern, and only observing a non-significant ($P > 0.1$) increase in the average BCS for cold months (December and January). Concerning the diet, nonsignificant regression coefficients ($P > 0.05$) were observed both for DE and the DP/DE ratio, although in general greater DE led to greater BCS, $0.04 ± 0.02$ units of BCS per SD of DE (0.3 MJ); this was previously shown in rearing young females (Nizza et al., 1997), and both primiparous (Quevedo et al., 2006) and multiparous does (Xiccato et al., 2005). Body condition score was significantly ($P = 0.0005$) affected by providing cages with a footrest. Females with a footrest had on average ± SE a BCS $0.19 ± 0.05$ units greater ($P < 0.001$) than those without. The type of drugs in the feed did not have a significant effect; on the contrary, those females subjected to parenteral administration had a BCS $0.19 ± 0.06$ units less ($P = 0.003$) than those not subjected to this administration.

Body condition score was clearly influenced by the genetic type the females belonged to (as defined in this study); Table 1 shows averages for the different genetic types. The genetic type with the greatest average BCS was R ($5.55 ± 0.14$), which makes sense since this is a line selected for growth rate. This group was followed by A ($4.40 ± 0.11$), which has been successfully selected for litter size for more than 35 generations (Ragab and Baselga, 2011). The BCS averages for the other lines are significantly different from A, except P line, but not between them, with values ranging from 4.08 to 4.30.

Figure 3 shows average BCS for the different kindlings. From first to fifth kindling, a clear and fairly linear rise of $0.2 ± 0.03$ BCS units was observed. From here on, up to the 12th kindling, erratic and nonsignificant (as an overall pattern) behavior was observed. Finally, in later parities a decline in BCS was observed, females with more than 20 kindlings had on average a BCS $0.21 ± 0.07$ units less than those in the 12th lactation ($P = 0.001$). Quevedo et al. (2006) and Theilgaard et al. (2007) found a similar pattern in the evolution of BCS with the age of the animals.

For lactation status (Figure 5) a fairly quadratic pattern with the day in lactation was observed. Females in early lactation (first week) had the least BCS average $4.15 ± 0.11$, which increased to $4.56 ± 0.11$ during the third lactation week, and from here on it started to decline to $4.38 ± 0.11$ during the fourth week of lactation, where BCS remained constant for longer lactations. In our study, BCS as a function of lactational status followed a pattern different to that observed by Quevedo et al. (2006) and Theilgaard et al., (2009); under experimental conditions, they observed the maximum BCS average during wk 2 of

![Figure 3](image-url)

**Figure 3.** Month effect on BCS and disease prevalence in female rabbits ($n = 18,510$) from 103 farms in Spain and Portugal.
lactation. Morbidity of the does clearly influenced their BCS; sick females had a BCS of 0.6 ± 0.01 units less ($P < 0.001$) than healthy females.

### Table 1. Body condition score averages and disease prevalence (in percentage) by genetic groups of female rabbits (n = 18,510) from 103 farms in Spain and Portugal

<table>
<thead>
<tr>
<th>Genetic group</th>
<th>BCS</th>
<th>Coryza</th>
<th>Mastitis</th>
<th>Ulcerative pododermatitis</th>
<th>Minor frequency diseases</th>
<th>Overall disease index</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>4.20 ± 0.13&lt;sup&gt;AB&lt;/sup&gt;</td>
<td>22&lt;sup&gt;C&lt;/sup&gt;</td>
<td>6&lt;sup&gt;ABC&lt;/sup&gt;</td>
<td>11&lt;sup&gt;C&lt;/sup&gt;</td>
<td>4&lt;sup&gt;AB&lt;/sup&gt;</td>
<td>30&lt;sup&gt;E&lt;/sup&gt;</td>
</tr>
<tr>
<td>U</td>
<td>4.08 ± 0.16&lt;sup&gt;AB&lt;/sup&gt;</td>
<td>16&lt;sup&gt;AC&lt;/sup&gt;</td>
<td>4&lt;sup&gt;A&lt;/sup&gt;</td>
<td>4&lt;sup&gt;A&lt;/sup&gt;</td>
<td>8&lt;sup&gt;AB&lt;/sup&gt;</td>
<td>24&lt;sup&gt;AE&lt;/sup&gt;</td>
</tr>
<tr>
<td>S</td>
<td>4.20 ± 0.11&lt;sup&gt;AB&lt;/sup&gt;</td>
<td>44&lt;sup&gt;B&lt;/sup&gt;</td>
<td>6&lt;sup&gt;AC&lt;/sup&gt;</td>
<td>12&lt;sup&gt;C&lt;/sup&gt;</td>
<td>4&lt;sup&gt;A&lt;/sup&gt;</td>
<td>50&lt;sup&gt;B&lt;/sup&gt;</td>
</tr>
<tr>
<td>V</td>
<td>4.24 ± 0.12&lt;sup&gt;A&lt;/sup&gt;</td>
<td>12&lt;sup&gt;A&lt;/sup&gt;</td>
<td>4&lt;sup&gt;A&lt;/sup&gt;</td>
<td>9&lt;sup&gt;B&lt;/sup&gt;</td>
<td>5&lt;sup&gt;AB&lt;/sup&gt;</td>
<td>20&lt;sup&gt;CA&lt;/sup&gt;</td>
</tr>
<tr>
<td>H</td>
<td>4.12 ± 0.14&lt;sup&gt;B&lt;/sup&gt;</td>
<td>18&lt;sup&gt;C&lt;/sup&gt;</td>
<td>8&lt;sup&gt;BC&lt;/sup&gt;</td>
<td>9&lt;sup&gt;CB&lt;/sup&gt;</td>
<td>8&lt;sup&gt;B&lt;/sup&gt;</td>
<td>31&lt;sup&gt;E&lt;/sup&gt;</td>
</tr>
<tr>
<td>A</td>
<td>4.40 ± 0.11&lt;sup&gt;D&lt;/sup&gt;</td>
<td>21&lt;sup&gt;C&lt;/sup&gt;</td>
<td>7&lt;sup&gt;ABC&lt;/sup&gt;</td>
<td>11&lt;sup&gt;C&lt;/sup&gt;</td>
<td>5&lt;sup&gt;B&lt;/sup&gt;</td>
<td>32&lt;sup&gt;E&lt;/sup&gt;</td>
</tr>
<tr>
<td>P</td>
<td>4.30 ± 0.15&lt;sup&gt;ABD&lt;/sup&gt;</td>
<td>22&lt;sup&gt;C&lt;/sup&gt;</td>
<td>7&lt;sup&gt;ABC&lt;/sup&gt;</td>
<td>9&lt;sup&gt;CB&lt;/sup&gt;</td>
<td>6&lt;sup&gt;AB&lt;/sup&gt;</td>
<td>31&lt;sup&gt;E&lt;/sup&gt;</td>
</tr>
<tr>
<td>R</td>
<td>5.55 ± 0.14&lt;sup&gt;C&lt;/sup&gt;</td>
<td>19&lt;sup&gt;C&lt;/sup&gt;</td>
<td>10&lt;sup&gt;B&lt;/sup&gt;</td>
<td>23&lt;sup&gt;D&lt;/sup&gt;</td>
<td>4&lt;sup&gt;AB&lt;/sup&gt;</td>
<td>42&lt;sup&gt;D&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

1 N = included animals of completely unknown origin; U and S = included animals assigned to a certain breeding program, without there being full knowledge about which particular genetic type they belonged to; V, H, P, A, and R = included individual lines, 4 of them being maternal, selected for litter size (V, H, P and A), and another being selected for growth (R).

A-E Within a column groups not sharing a letter are significantly ($P < 0.05$) different in a Wald test.

### Figure 4. Kindling effect on BCS and disease prevalence in female rabbits (n = 18,510) from 103 farms in Spain and Portugal.

### Figure 5. Week in lactation effect on BCS and disease prevalence in female rabbits (n = 18,510) from 103 farms in Spain and Portugal.

**Factors Affecting Morbidity**

Concerning the effect of the year, in spite of all the drops and rises in disease prevalence (results not shown),
a clear pattern was not observed. The month of the year (Figure 3) did not show any significant association ($P > 0.05$) with mastitis or ulcerative pododermatitis. On the contrary, coryza prevalence was significantly increased ($P < 0.05$) during hot weather. During cold month, erratic behavior was observed; thus when evaluating this disease practitioners might accept a greater prevalence (about 4 to 5 percentage points more) during high temperature month and the month after (i.e., fall). Similar results were observed by Rosell et al. (2009). For the case of the overall morbidity index a similar pattern was observed (i.e., the least disease prevalence was detected during March, April and May and also during cold months, the greatest prevalence being observed during summer and fall months).

The only disease positively affected by providing cages with footrests was, as would be expected, ulcerative pododermatitis; under normal conditions it is expected to observe 53% less ulcerative pododermatitis prevalence when cages are provided with a footrest; prevalence drops from 15% to 7% ($P < 0.0001$). Rosell and de la Fuente (2009b) observed similar results. Ulcerative pododermatitis was associated with diet ($P = 0.045$). Animals taking diets with great energy content have the greatest prevalence. One SD increase in DE (0.3 MJ) determined an increase in ulcerative pododermatitis prevalence of 0.8 percentage points. This could be explained by the fact that the heavier the animal, the greater the damage to its hock on contact with the cage floor. For the other diseases, diet was not an enabling risk factor.

Mastitis prevalence was negatively affected by providing drugs in the diet. Administering parenteral drugs or drugs in the feed did not seem to have any significant effect on disease prevalence. A priori this could be considered an unexpected result; however, our estimate refers to the differences between farms or visits with and without parenteral drug administration and not to the effect of drug administration within a farm. As the initial conditions regarding prevalence in the across farm or visit comparison can be different, our test does not only include the effect of drug administration, but also difference in the initial prevalence; which are expected to be much greater in farms under drug administration than in those without this administration.

The genetic type to which a female belongs is, in general, a predisposing risk factor of disease. Regarding coryza, animals from group S had the greatest prevalence (44.0%), followed by A, P, R and the group of animals for which the genetic origin was unknown. The V line, a maternal line greatly selected for prolificacy, showed the least prevalence (12.0%). For the case of mastitis, although significant ($P < 0.05$), the magnitude of the differences between disease prevalence was less. R-line animals had a mastitis prevalence of 10.0% while the lowest prevalence was observed for V line and animals from U origin (4.0%); note that within this origin V line has increased influence. Other maternal lines like P, H, A and animals from S had a middle prevalence for mastitis, approximately 6.0% to 8.0%. The R line, selected for growth rate, showed the greatest prevalence for ulcerative pododermatitis (23.0%), females of U origin being found at the other extreme (4.0%); the remaining lines and origins were found in a middle situation, with a prevalence ranging from 9.0% to 12.0%. Regarding minor diseases, animals from S origin had the least prevalence (4.0%), while H line showed the greatest prevalence (8.0%). For the index indicating overall sanitary status of the rabbit does, ranking of lines and origins was similar to that observed for coryza, given the considerable influence of the disease in this index.

It has been observed, even given the inaccurate way in which some genetic types were defined in this study, that remarkable changes in disease prevalence can be observed under normal conditions. Also, in most of the cases, genetic type is unique within farm or visit; this produces a hierarchical structure where farm effects are nested within the different genetic groups. Thus, reported results can be undertaken as averages of visit effects, indeed this design is much less powerful than a cross-classified one, but unbiased results are expected given the number of records and visits within each genetic group. In fact a simulation test was conducted to check for the capabilities of the data structure to recover certain assumed differences between the genetic groups and this test was successfully passed. In previous studies similar results for origin of animals were observed by Rosell and de la Fuente (2004); for example, S line always had the greatest prevalence of coryza and R line the greatest prevalence of ulcerative pododermatitis.

Figure 4 shows disease prevalence for the different kindlings. With respect to coryza, the most relevant result concerns the significant increase ($P = 0.003$) in prevalence from the first (15.0%) to third kindling (25.0%), followed by a drop to around 20.0% prevalence in the fifth to sixth kindling. Mastitis prevalence showed a flat pattern. Ulcerative pododermatitis showed a continuous increase in prevalence during the first part of the life of the female, during the first 3 to 4 kindlings prevalence rose from 4.0% to 10.0% to 11.0%. From third and fourth parturition onwards, a decline in prevalence is expected for coryza, whereas a constant pattern must be expected for ulcerative pododermatitis. Females older than 15 parturitions, both for ulcerative pododermatitis and coryza showed a worsening in prevalence, and for these females an important declien in BCS was observed as well. These animals could be considered old, and similar to aged humans they showed a reduction in body condition (Roubenoff et al., 1997; Morley, 2001). Based on
the age patterns both for BCS and disease prevalence, a systematic early culling age cannot be recommended, particularly if the average culling age per doe is considered to be 14.9 mo and 6 parturitions (Rosell and de la Fuente, 2009a).

Lactational status was a predisposing risk factor only for coryza (Figure 5); during the fourth and fifth week of lactation a significant \( P < 0.05 \) increase in prevalence was observed in comparison with the wk 1 and wk 2 of lactation. In particular, during wk 2 of lactation a prevalence of 3.0 percentage points less than that in the fourth lactation was observed. Given the great influence of coryza in the overall index a similar pattern was observed for this other trait. As for genetic type design, visit or farm effect could be said to be nested within lactational status of the females, normally within a farm or visit, a single reproductive rhythm was followed. Even so, our results indicate that coryza prevalence increased during late lactation.

**Relationship between Morbidity and Body Condition**

Body condition score greatly influenced the risk of getting any disease, thus for coryza, mastitis and ulcerative pododermatitis; an increase in BCS of 1 SD, 1.03 units, led to reductions in prevalence of 5.8, 2.4, and 3.8 percentage points, respectively. For minor diseases this reduction was 1.3 percentage points. On the overall disease index prevalence this reduction was 9.0 percentage points. Note that given the non-linearity of the models for studying prevalence of diseases, these relationships are not constant for the whole explanatory variable domain. Although in this study there is no information to assess why sick does show reduced BCS, a number of hypotheses, extracted from other species, could be posed. On the one hand, anorexia associated with the diseases and pain (Bareille et al., 2003); and on the other, the great nutrient requirements that the immune system has in sick animals (Johnson, 1998; Moberg, 2000).

The opposite relationship between disease prevalence and BCS (i.e., BCS on prevalence), was significant. By increasing BCS, a decline in all disease prevalence was observed. It has to be noted that this way of assessing the relationship between these 2 set of traits, BCS and disease prevalence, is not the most appropriate since the sense of the relationship has to be defined a priori. The most adequate statistical tools to properly investigate causality among traits are simultaneous models (Rosa et al., 2011), where the sense of the relationship can be left undefined. A great effort was made to fit these models to our data set, but given limitations in data design to properly identify model parameters this was not possible.

When a reduction in average BCS is observed in the course of a visit, it should initially be thought that either a clinical or subclinical disease is present on the farm; in the first case, clinical signs would confirm this hypothesis. Simultaneously, if great prevalence of clinical diseases is observed, a reduction in BCS would be expected, and this situation might predispose either to a worsening of the existing condition, or to the appearance of a new disease outbreak.

Given the influence of diet energy content on BCS and major diseases prevalence, even though digestive problems are not observed, the practitioner is recommended to ask producers about the type of diet given to the females. The joint consideration of the aforementioned relationships between ulcerative pododermatitis and mastitis prevalence, BCS, genetic type, diet, and cage equipment clearly shows the complexity and multifactorial determination of the traits of interest in this study.

**Implications**

The main objective was to assess the factors that could influence 2 of the major criteria when defining rabbit doe welfare on commercial farms: health and body condition. In this study, their interrelationships have been shown, and also how they are modulated by other intrinsic and extrinsic risk factors. For diagnosis and evaluation of the health in the farm, simultaneous consideration of both BCS and morbidity of rabbit does are recommended. For the right assessment of welfare conditions on rabbit farms, practitioners must weigh these concurring risk factors when evaluating the sanitary status and body condition of females.

**LITERATURE CITED**


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