World Rabbit Science

World Rabbit Sci. 2015, 23: 27-37
doi:10.4995/wrs.2015.3076

HUSBANDRY FACTORS AND HEALTH CONDITIONS INFLUENCING THE PRODUCTIVITY OF FRENCH RABBIT FARMS

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Abstract: In 2009, productivity data from 95 kindling to finishing rabbit farms in France were analysed to identify rearing factors and health conditions that influenced their productivity. Farm productivity, expressed on a yearly basis, was described with 4 productivity indexes: doe fertility and prolificacy, viability of young rabbits in the nest and mortality during the fattening period. The productivity data were obtained with the technical support of the farm and expressed in a standardised way. The average numerical productivity observed in the sample of farms was 50.9 rabbits produced per doe and per year (confidence interval at 95% [$CI_{95\%}$; 49.6-52.2]). The husbandry management and health conditions were described based on a questionnaire filled out during an interview with the farmer and a farm visit. Explanatory data were organised into meaningful blocks relative to biosecurity measures, maternity management, sanitary context and farm structure. The relationship among the 4 thematic blocks and the productivity indexes was studied in a single model using a partial least squares (PLS) regression model. Fertility (81.0%, $CI_{95\%}$ [80.0-82.0]), viability of young at nest (85%, $CI_{95\%}$ [85.0-85.3]) and mortality rate during fattening (7.2%, $CI_{95\%}$ [6.4-7.9]) were significantly associated with common factors related with maternity management and the health context, whereas prolificacy (9.7 live kits per parturition, $CI_{95\%}$ [9.5-9.9]) was mostly influenced by a specific set of variables pertaining to those 2 blocks. Farm structure and biosecurity measures had a limited impact on fertility and on kit viability before weaning. The health conditions of the doe herd and the fattening rabbits were found to be significantly associated with several productivity indexes, but their impacts on productivity were as high as the impact of the other blocks. Genetic strain of the females, doe replacement strategy and nursing and weaning practices appeared to significantly influence reproductive performance, viability of kits before weaning and mortality rate during the fattening period. Maternity management therefore seemed to be the key point in rabbit unit management that governed the numerical productivity of the farm.

Key Words: rabbit, productivity, health, husbandry, reproduction.

INTRODUCTION

In the last 2 decades the productivity of rabbit farms has increased though the generalisation of artificial insemination, cycled production and genetic selection for increased prolificacy (Castellini *et al.*, 2010). More specifically, the results from the French RENACEB network, which collects annual technical data on about 1000 rabbit farms, show that the number of rabbits produced per doe in a year increased from 42.7 in 2006 to 50.5 in 2010 (Coutelet, 2011). This intensification contributes to the economic sustainability of rabbit production (Fortun-Lamothe *et al.*, 2009), but zootechnical and economic results remain highly variable among farms (Jentzer, 2009; Serrano *et al.*, 2012). In addition, experts from the EFSA-AHWA panel emphasised that the mortality rates of young rabbits reported in the literature did not decrease over a 25-year period (1980-2005) despite the modernisation of rabbit husbandry techniques (EFSA, 2005); emergence of the Epizootic Rabbit Enteropathy syndrome (Licois *et al.*, 2006) certainly contributed to preventing improvement in rabbit viability during this period. Identifying rearing practices that directly

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http://dx.doi.org/10.4995/wrs.2015.3076

influence productivity would make it possible to propose measures to improve breeding performance and control the mortality rate in farm rabbits (Scholaut *et al.*, 2013; Pascual *et al.*, 2013).

Numerical productivity, defined as the number of rabbits produced (i.e. processed for meat production) per doe and per year, could be split into 5 main components: reproductive rhythm, fertility, prolificacy and viability of kits during nursing and fattening periods. The influence of various rearing practices on these indexes has been widely studied under experimental conditions, but rarely under field conditions and on a large sample of farms. In addition, the usual statistical procedures used in these studies do not allow the explanation of a composite outcome, such as productivity described by several productivity indexes. Furthermore, the main components of productivity corresponding to the phases of the production cycle (gestation, nursing, fattening) are likely to be influenced by different practices. Our objective was therefore to explore the relationships between the numerical productivity as a composite outcome (i.e. composed of 5 main productivity indexes) and rearing practices organised into blocks describing husbandry management.

MATERIALS AND METHODS

Study sample

The study population consisted of a sample of rabbit farms which provided animals to French rabbit slaughterhouses in 2009. A 2-level sampling scheme was adopted: firstly, slaughterhouses were randomly selected from the list of rabbit slaughterhouses in France, stratified according to their share in national rabbit meat production. Secondly, farms were randomly selected from the list of the slaughterhouse suppliers; the number of farms selected per slaughterhouse was proportional to its share in French rabbit meat production. A target of 100 farms was set to fulfil logistic constraints (data collection over 1 yr by 3 trained investigators) and to allow statistical analysis. Taking into account a possible refusal rate of about 40%, 145 farms were selected and contacted.

Data collection

Data were retrospectively collected during a visit to the farm by one of the 3 trained researchers from ANSES (French Agency for Food, Environmental and Occupational health) in 2010. A questionnaire (Table 1, questionnaire in French available as supplementary material) was filled in by means of an interview with the farmer, a consultation of log-books or official documents and a visit to the rabbit buildings. The questionnaire involved husbandry practices, the health context as reported by the farmer and building characteristics. The list of veterinary products bought in 2009 (obtained from the suppliers of veterinary products and from the feed suppliers) was added to the data from the questionnaire.

Definition of explanatory variables (X-blocks)

Explanatory variables, extracted from the questionnaire and from the list of veterinary products, were organised into 4 thematic blocks: X_1: Biosecurity measures, X_2: Maternity management, X_3: Sanitary context and management, X_4: Farm structure. These thematic blocks were relevant from an operational point of view: biosecurity measures described in block X_1 and, to a lesser extent, husbandry practices from block X_2, could be easily corrected by the farmer in the short term. In contrast, the farmer only had partial control of the sanitary context (block X_3). Lastly, variables pertaining to block X_4 described structural and fixed characteristics of the rabbit unit. Only variables with less than 5% of values missing and with a minimal frequency of 10% per category were considered for statistical analysis. All variables under study were first described in terms of frequency or as mean and standard deviation using SAS® 9.1. The categorical variables were coded as dummy variables for statistical processing.

Definition of the outcome variables (Y-block)

Zootechnical performance for 2009 was provided by the farm's technical support (feed suppliers, production organisations), if not available at the farm. As calculation of productivity indexes differed among farms affiliated with different production organisations, crude data were collected for 2009: number of insemination or mating bouts,

Table 1: Summary of items included in the questionnaire. The number of questions per subset is indicated in brackets.

X_1: Hygiene and Biosecurity (42)
Cleaning and disinfection practices
All in / all out practices
Hygiene procedures (dead rabbit disposal, staff clothes and footwear, wildlife control)
X_2: Husbandry management (49)
Maternity management (28)
Doe management (reproduction method, genetics, replacement, culling)
Nursing and weaning practices (nursing control, fostering)
Feeding and watering (21)
Feeding programmes and feed restriction strategy
Watering (supply, treatments)
X_3: Health context (52)
Diseases (does and rabbits) as reported by the farmer
Veterinary supervision (visits, analyses)
X_4: Farm structure (66)
Items related to rabbit houses (47)
Size
Building characteristics (ventilation, heating system, lighting)
Feeding, watering, and manure disposal systems
Description of cages (size, partitions, nests)
General items related to the farm (19)
Farm staff characteristics
Animals and crops produced on the farm
Rabbits on the farm (type, number of houses)

number of parturitions, number of live born kits, number of weaned rabbits and number of rabbits sold. These data were used for the calculation of standard productivity indexes. Numerical productivity, defined as the number of rabbits produced per doe and per year, was divided into 5 productivity indexes following the given formula:

$$\textit{Productivity} = \textit{Fertility} \times \textit{Prolificacy} \times \textit{Viability at nest} \times (1 - \textit{Fattening mortality}) \times \textit{Reproduction rhythm}$$

The definitions of indexes were these used by the RENACEB network. Fertility is the number of parturitions divided by the number of artificial inseminations or mating bouts. Prolificacy is the number of live kits born per parturition. Viability at nest is the percentage of weaned kits over live-born kits and the mortality rate during the fattening period is calculated by dividing the number of dead rabbits by the number of weaned rabbits. As 96% of the studied farms used a 42-d cycle for reproduction, the reproduction rhythm parameter was omitted due to its lack of variability.

Selection of explanatory variables for the PLS-regression

A screening step (using SAS® 9.1) was carried out using a linear regression analysis to select the explanatory variables associated with the 4 productivity indexes (fertility, prolificacy, viability at nest and mortality during the fattening period). The variable for fertility was raised to the fourth power and the variable for the mortality rate during fattening was transformed with an arcsine transformation to ensure normality (Kolmogorov-Smirnov test). An explanatory variable was selected for further analysis if it was significantly associated with at least one of the 4 outcome variables at $P<0.15$. All bilateral relationships between the 43 selected explanatory variables were then checked using the likelihood ratio χ^2- test or the Kruskal Wallis test on the ranks. For relationships between variables evidencing a strong structural collinearity, one of the variables of interest (the one most closely related to the considered outcome variable or related to several outcome variables) was chosen.

Multiblock PLS regression analysis

The aim was to identify factors within the 4 explanatory blocks (X_1 to X_4) which simultaneously explain each outcome Y (productivity indexes). The multiblock Partial Least Squares (PLS) regression method was applied because of its stability in case of multicollinearity within explanatory blocks (Wold, 1984; Wangen and Kowalski, 1988). As in standard factorial analysis such as Principal Component Analysis, the concept is to summarise each block which contains several variables by a new variable called component. This component is the best summary of the variables in the block. In multiblock analysis, each explanatory block (X_n) and the dependent block Y are summarised using one or several components. The explanatory components associated to X_n blocks are built to maximise their relationship with the dependent components associated to Y block (Bougeard *et al.*, 2011a). The multiblock PLS and the associated interpretation tools were performed using code programs developed in R (http://www.r-project.org/). They are available upon request to the author and will be soon ready for use in the ade4 package (http://pbil.univ-lyon1.fr/ade4/home.php?lang=eng).

Interpretation indexes for multiblock PLS regression results

The outcomes of the multiblock PLS regression are summed up into 3 interpretation indexes (Bougeard *et al.*, 2011b). The first index provides the link between each explanatory variable and each dependent one by means of the regression coefficient and its bootstrapped confidence interval (Freedman, 1981; Gosselin *et al.*, 2010). The second index is the "Variable Importance" index (VarImp, shown as % with bootstrapped confidence intervals), quantifying the contribution of each explanatory variable in the prediction of the Y-block. The third index is the "Block Importance" index (BlockImp, expressed as % with bootstrapped confidence intervals), quantifying the contribution of each X-block in the prediction of the Y-block.

RESULTS AND DISCUSSION

Description of the farm sample

Over 145 contacted farms, 118 farmers agreed to take part, representing a participation rate of 81% and 27 refused a visit, mainly claiming of lack of time or the imminent closure of their farm. Five farms were excluded *a posteriori* because 3 were too small (less than 50 does) and too atypical to be described using the questionnaire and 2 were specialised in rabbit fattening only. Complete data on farm characteristics, zootechnical results and veterinary product purchases were finally obtained from 95 out of the 113 farms included in the study. As there is no exhaustive list of rabbit farms in France, the sampling frame was based on the list of slaughterhouse suppliers. Therefore farms specialised in farrowing (selling kits at weaning) and farms with their own slaughtering unit for the local market were excluded from the target population. However, the slaughterhouses involved in the study (producing 47,019,329 tons of rabbits) accounted for 92% of rabbit processing in France in 2008 (Agreste, 2012).

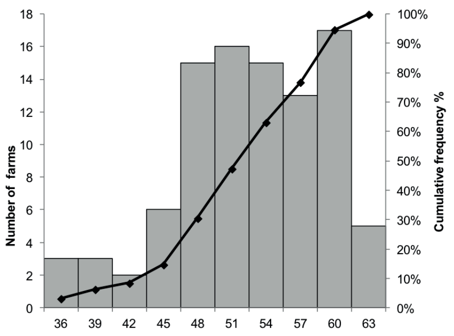

Figure 1: Distribution of productivity expressed as the number of rabbits produced per doe and per year (95 farms, France, 2009).

Descriptive analysis of numerical productivity and productivity indexes

The average numerical productivity observed was 50.9 rabbits produced per doe and per year (confidence interval at 95% [$CI_{95\%}$; 49.6-52.2]). (Figure 1). This is very similar to that reported by the French network RENACEB in 2009: 50.9 ([50.4-51.2]) for 915 farms (Lebas, 2010). Therefore, the results of this study may reasonably be extrapolated to all kindling to finishing rabbit farms in France. Productivity of rabbit farms could be described using various indexes; numerical (i.e. number of rabbits

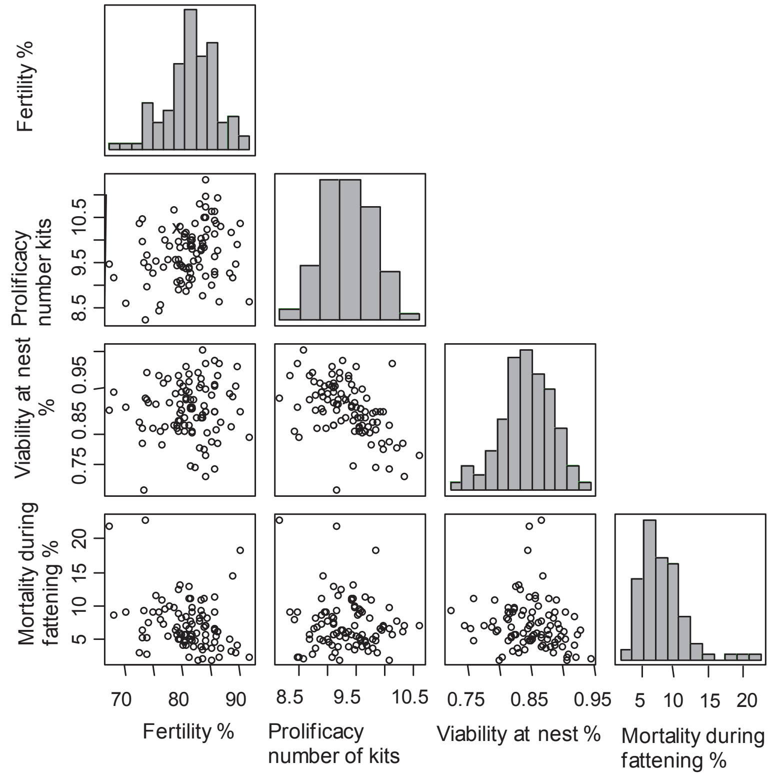

Figure 2: Scatter plot and distribution of the 4 productivity indexes (fertility, prolificacy, viability at nest and mortality during the fattening period), 95 rabbit farms, France, 2009.

produced) or weight-based (i.e. mass of rabbits produced), related to different denominators (per productive doe or per doe cage) and time references (production per batch or per year). In our study, productivity was expressed as the number of rabbits produced per doe and per year to sidestep the seasonal effect which influences rabbit production when it is measured at batch level (Marongiu *et al.*, 2007; Garrido *et al.*, 2009). As we worked on numerical productivity, factors affecting the growth rate of fattening rabbits and the food conversion ratio were not addressed in this study.

Fertility (81.3%±4.8, range: 67-92%) and prolificacy (9.7±0.6 live kits per parturition, range: 8.2-11.3 l) positively correlated (Pearson correlation coefficient r=0.25, P=0.01) as shown in Figure 2. In contrast, prolificacy negatively correlated to viability at nest (85.1±4.3, range: 72-95%, r=–0.51, P<0.01). Mortality during fattening, which was the most variable index (7.1%±3.1, range: 1.9-11.3%), negatively correlated to fertility (r=–0.28, P=0.01). The productivity indexes correlated strongly with numerical productivity (fertility, r=0.60, P<0.001; prolificacy, r=0.51, P<0.001; mortality during fattening, r=–0.45, P<0.001), except for viability at nest (r=0.08, P=0.79).

Factors affecting doe fertility and viability of the rabbits.

The 22 explanatory variables selected to be included in the multiblock PLS analysis are described in Table 2. The female genetic type (3 types A, B and C) was coded as dummy variables (Hybrid B, Hybrid C; Hybrid A was the reference category) and the frequencies of hybrids A, B and C are not shown to ensure confidentiality.

Table 2: Definition and distribution of explanatory variables selected to identify factors related to productivity in rabbit farms (frequencies or mean [standard deviation], 95 farms, France, 2009).

X_1: Biosecurity	
Hand washing before entering	
Yes	45
No	50
Changing clothes before entering	
Yes	73
No	22
Wet cleaning of cages	
Yes	85
No	10
Rabbit crating for transport to slaughterhouse	
Mobile crates introduced in the building	76
Crates fixed on the transport truck	19
X_2: Maternity management	
Age at first insemination	
≤17 wk	9
≥18 wk	86
Grand-parental does for replacement	
Yes	59
No	41
Controlled nursing	
Yes	46
No	49
Age at weaning (2 dummy variables)	
≤33 d	23
34-36 d (Reference)	61
≥37 d	11
X_3: Sanitary context and management	
Symptoms of ERE during fattening period	
Yes	41
No	54
Doe replacement for health reasons	
Yes	47
No	48
Water acidification during the fattening period	11
Yes	84
No	
Hepatoprotectant used	69
Yes	26
No	
Amount of antibiotics per fattening rabbit (mg/produced kg)	11.73 (4.91)
Use of antibiotics by injectable route	
Yes	20
No	75
X_4: Farm structure	
Age of rabbit buildings (years)	19.1 (8.5)
Deep pit for manure collection in doe room/building	
Yes	41
No	54
Heating system in doe room/building	
Yes	72
No	23
All in – all out management	
Yes	33
No	62
Rabbit production under quality certification	
Yes	27
No	78

The first 2 components of the PLS model were retained, accounting for 68% of the variance of block Y. The regression coefficients and their confidence intervals of the explanatory variables were computed for each dependent variable; only significant results are shown in Table 3. Fertility appeared to be the productivity index linked to the highest number of variables, pertaining to the 4 thematic blocks. In particular, biosecurity measures and all-in/all-out management seemed to play a significant role in the does' fertility. Poor hygiene conditions may have an impact on reproductive performance. As an example, strong reinforcement of hygiene and biosecurity measures (transition to a Specific Pathogens Free status) in a genetic selection unit for rabbits led to improvement in the does' fertility (Hendrickx *et al.*, 1994). Indeed, a clear relationship between doe health and fertility has been established under intensive rearing conditions, since sub-clinical infection and inflammation of the genital tract cause hypo-fertility in does (Dal Bosco *et al.*, 2005).

As observed in the description of productivity indexes, doe fertility and mortality rate during the fattening period were negatively correlated and this opposition was clearly seen in the PLS regression (coefficients with opposite signs for the significant factors). As a consequence, all the variables significantly associated with mortality during the fattening period were also linked to fertility, even though some of the associations appeared to be irrelevant or difficult to

Table 3: Contribution of the explanatory variables to the explanation of the four variables of productivity by means of significant regression coefficients β associated with their 95% confidence interval (PLS regression, 95 rabbit farms, France, 2009).

	Fertility	Prolificacy	Viability at nest	Mortality during fattening
X_1: Biosecurity				
Hand washing: yes (*vs.* no) [Hand]	0.34 (0.12-0.55)			
Change clothes: yes (*vs.* no) [Clothes]	0.30 (0.07-0.54)	0.27 (0.01-0.53)		
X_2: Maternity management				
Age at first AI: ≤17 wk (*vs.* ≥18 wk) [Firstai]		–0.22 (–0.41- –0.03)		
Grand-parental does: yes (*vs.* no) [GPRepl]	0.29 (0.07-0.51)		0.29 (0.05-0.54)	–0.27 (–0.50- –0.04)
Doe genetics hybrid B: yes (*vs.* no) [HybridB]	0.19 (0.01-0.37)			
Doe genetics hybrid C: yes (*vs.* no) [HybridC]	0.28 (0.07-0.50)	–0.52 (–0.76- –0.27)	0.50 (0.28-0.71)	–0.32 (–0.61- –0.03)
Controlled nursing: yes (*vs.* no) [Nurse]	0.34 (0.14-0.55)		0.26 (0.02-0.49)	–0.29 (–0.52- –0.06)
Late weaning: ≥37 d (*vs.* <37 d) [Wean37]	–0.22 (–0.43- –0.02)			
X_3: Sanitary context and management				
Symptoms of ERE: yes (*vs.* no) [ERE]	–0.24 (–0.46- –0.02)			
Replacement for health reasons: yes (*vs.* no) [Doerepl]		–0.26 (–0.49- –0.04)		
Water acidification: yes (*vs.* no) [Acid]	–0.33 (–0.57- –0.09)		–0.25 (–0.47- –0.03)	0.28 (0.06-0.50)
Hepatoprotectant used: yes (*vs.* no) [Liver]		0.32 (0.08-0.55)		
Amount of antibiotics per fattening rabbit [Atbrab]	–0.46 (–0.69- –0.23)			0.33 (0.09-0.57)
X_4: Farm characteristics				
Building age (+1 yr) [Age]	–0.26 (–0.46- –0.07)			
Deep pit: yes (*vs.* no) [Pit]		–0.27 (-0.53- –0.01)		
All in – All out: yes (*vs.* no) [Allin]	0.27 (0.07-0.48)			
Quality certification: yes (*vs.* no) [Label]	0.21 (0.02-0.39)			

ERE: Epizootic Rabbit Enteropathy.

explain (such as the impact of water acidification for fattening rabbits on fertility). This is one of the limitations of multiblock analysis, where all the selected X variables are used to explain all the Y variables (Bougeard *et al.*, 2012). Nevertheless, we noticed that husbandry practices relative to doe herd management and to nursing management (use of Hybrid C genetic type, controlled nursing, presence of a great-parental herd and weaning after 37 d) had an impact on fertility and also on viability during the nesting and fattening periods. A current trend in rabbit husbandry is to wean kits at around 25 d of age to both reduce doe' energy requirements by shortening the lactation period and to ensure better coverage of the kits' nutritional requirements thanks to a specific feeding programme (Xiccato *et al.*, 2004). One quarter of the studied farms were weaning kits before 32 d and this practice seemed to have no significant impact on productivity. On the contrary, the weaning of kits after 5 wk of age appeared to decrease kit viability during the fattening period (coefficient: –0.22, $CI_{95\%}$ [–0.43-–0.02]). In fact, this practice had been identified previously as a risk factor for acute ERE during the fattening period in French rabbit farms (Le Bouquin *et al.*, 2009). Later weaning also appeared to decrease doe fertility, as it extends the overlapping of lactation and pregnancy periods; the longer overlapping increases the does' energy deficiency (Castellini *et al.*, 2010). Controlled nursing was another practice identified as affecting the doe fertility (0.34, $CI_{95\%}$ [0.14-0.55]), the viability of rabbits at the nest (0.26, $CI_{95\%}$ [0.02-0.49]) and the mortality during the fattening period (–0.29, $CI_{95\%}$ [–0.52-–0.06]). Controlled nursing was proven to naturally enhance does' receptivity at AI and subsequently their fertility (Eiben *et al.*, 2007, 2008) but its impact on kit mortality was not so well established (Le Normand *et al.*, 1994; Coureaud *et al.*, 1998; Eiben *et al.*, 2007 and 2008). Our study tended to provide new evidence in favour of controlled nursing as a way to enhance the viability of young rabbits. Lastly, using a Grand-Parental herd for doe replacement has been known since the 1980s to improve fertility and viability (Roustan *et al.*, 1986) and it helps accelerate the spread of genetic improvement in highly selected rabbit breeds (Trouslard-Kerdiles and Poujardieu, 1998). This replacement strategy was associated with higher yearly productivity in farms from the RENACEB network (ITAVI, 2007), as in our study.

An increase in antibiotics administered to rabbits and systematic water acidification during the fattening period were associated with a decrease in the doe fertility and in viability of rabbits. Chauvin *et al.* (2011) reported that antibiotics in growing rabbits were mainly administered in feed to prevent digestive disorders during the fattening period. Water acidification was an uncommon practice (13% of the farms) associated with a high reported occurrence of colibacillosis during the fattening period (54 *vs.* 27% in non-using farmers, P=0.04). High antibiotics consumption and water acidification should thus be considered as indicators of a declining health situation, mostly due to digestive disorders that remained the main health issue observed by farmers in our study, as in other countries (Rosell *et al.*, 2009).

Factors affecting prolificacy

In contrast with the 3 other productivity indexes which were associated with almost all the same husbandry factors, prolificacy was linked to a specific set of 6 variables. As expected, 4 of them dealt with the management (age at first AI, Hybrid C genetic type) and the health status of the doe herd (replacement of does for sanitary reasons and use of product to protect liver). As an example, it was demonstrated that the age at first artificial insemination (14 *vs.* 17.5 wk) was a factor influencing the entire reproductive career of does (Rommers *et al.*, 2006). Body composition and the does' energy balance throughout successive reproduction cycles are critical factors conditioning reproductive performance (Castellini *et al.*, 2010); practices aiming to improve doe body condition and energy metabolism, such as the use of products to prevent steatosis in our study, are also likely to contribute to enhancing doe prolificacy. According to a Spanish epidemiological study (Rosell and De La Fuente, 2009), culling is more frequent than mortality in rabbit does kept under commercial conditions and culling for technical reasons such as low productivity or infertility is more prevalent than culling for health reasons (i.e. infections or poor body condition). In our study, technical culling was practiced in 85% of the farms (results not shown), but culling for health reasons was reported by only half of the farmers; these farmers also more frequently observed problems such as sore hocks (38 *vs.* 21%; P=0.06), staphylococcosis (32 *vs.* 17%; P=0.02), mastitis (17 *vs.* 2%; P=0.04) and myxomatosis (17 *vs.* 2%; P=0.04) in their does than farmers who did not apply culling for health reasons. This practice therefore seems to be associated with a deterioration of the health of the reproductive herd that impairs the reproductive performance and productivity of the entire farm (Pascual *et al.*, 2013).

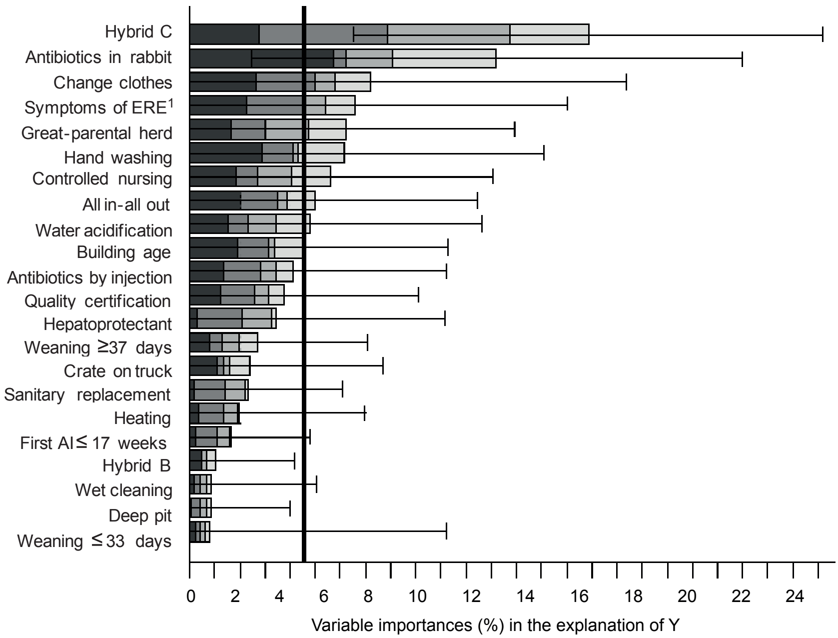

Figure 3: Variable Importance (VarImp) of the explanatory variables to explain global productivity (Y), associated with their 95% confidence interval (PLS regression, 95 rabbit farms, France, 2009). For each explanatory variable, the importance of each Y index is provided, obtained from the absolute value of the associated regression coefficients. ■ Fertility; ■ Prolificacy; ■ Viability; □ Mortality.

[1]ERE: Epizootic Rabbit Enteropathy.

Factors and blocks affecting the productivity block

The hybrid genetics C was associated with the 4 productivity indexes and was the single variable which made a significant contribution (VarImp=15.9%, $CI_{95\%}$ [6.5-25.2]) to explaining productivity block Y (Figure 3). However, the numerical productivity in Hybrid C farms (50.2±5.9) was similar to that of farms with Hybrid A (50.7±7.0) and Hybrid B (51.9±6.2). This paradoxical result showed that the 3 genetic strains under consideration differed in terms of reproductive and viability performance, but ultimately expressed a similar level of numerical productivity in our study.

Contributions of the 4 X-blocks in the explanation of productivity block Y were similar and non-significant: the BlockImp was equal to 20% for X_1 ($CI_{95\%}$ [9-32]), 28% for X_2 ($CI_{95\%}$ [16-41]), 31% for X_3 ($CI_{95\%}$ [18-44]) and 21% for X_4 ($CI_{95\%}$ [10-30]). Biosecurity, husbandry management, sanitary context and farm structure were factors found to affect farm productivity in a similar way. This result therefore highlighted that the zootechnical performance of rabbit units depended both on husbandry factors that were directly under the farmer's control and on more structural or external features that could not be changed in the short term or were hard to handle.

CONCLUSION

The specific aim of our study was to propose a global model to explain the main components of rabbit farm productivity with regard to both structural farming factors and rearing management factors. Among all the studied parameters, those relative to doe herd management and nursing practices seemed to be the most influential, due to their impacts on reproductive performance and also on viability of rabbits. This finding raises the need for a more in-depth study of the influence of doe herd management on the overall productivity of commercial rabbit unit. This study provides elements to enhance the zootechnical performance of rabbit farms and reduce mortality during rearing, but other parameters related with the economic, environmental and social impact of rabbit production must also be taken into consideration in order to improve its sustainability.

Acknowledgments: The authors wish to acknowledge the CLIPP-Lapin de France, the SNGTV (French Veterinary Society - rabbit branch) and the FFC (French Federation of Cuniculture) for their collaboration. We also wish to thank the farmers and the rabbit production organisations who participated in the study. The authors are grateful to Ms. Anaïs Croisier for her participation as an investigator and to Mr. Guillaume Coutelet from the French Institute for Avian Production for his technical expertise. Funding was provided by the French Agency for Veterinary Medicinal Products (ANSES-ANMV)

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