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Review

Genetics of growth, carcass and meat quality in rabbits

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ABSTRACT

This paper reviews the current knowledge on the genetics of growth, carcass and meat traits in rabbits. There is a great variety in size of rabbit breeds, from which commercial production uses medium size breeds for does and large breeds as terminal sires. Selection experiments for growth and feed efficiency have been successful. Selection for residual feed intake did not modify growth rate, acting on reducing the appetite. Selection for growth rate increased adult weight and led to poorer carcass yield when comparing selected and unselected animals at the same commercial weight, but not at the same age, near the same maturity stage. The results on meat/bone ratio do not show a clear pattern. Negative effects on intramuscular fat and some sensorial traits have been found in lines selected for growth rate, but meat quality in general does not seem to be affected.

1. Introduction

Growth is decisively important in rabbit meat production. Profit functions and economic weights of rabbit meat production have been estimated by Armero and Blasco (1992), Prayaga and Eady (2000) and Cartuche, Pascual, Gómez, and Blasco (2014). Table 1 shows the costs of a typical industrial rabbitry that can be managed by one person. The main economically important traits in rabbit meat production are feed conversion rate (FCR) and litter size. This means that feed efficiency (measured as FCR, feed intake or residual feed intake) can have a decisive influence on profits. Feed conversion rate is difficult and expensive to measure, so correlated traits, such as growth rate, are often used in selection programmes with the aim of improving FCR indirectly, although genetic correlations are not as favourable as in other species. Selection programmes in rabbit commercial schemes are based on three way crosses, in which two lines are selected for litter size and crossed to produce a crossbred commercial doe, and one line is selected for average daily gain (ADG) in order to produce terminal sires (Baselga & Blasco, 1989; Lebas, Coudert, Rochambeau, & Thébault, 1997). This scheme is similar to what is currently used in swine. However, there are important differences, as some aspects of meat quality (e.g., PSE: Pale, Soft, Exudative meat) play an important role in swine schemes and not in rabbits, which do not present PSE meat. Moreover, selection for reducing fat content is important in pigs, but as rabbits have very lean carcasses when sold (Dalle Zotte, 2002; Hernández & Gondret, 2006), fat content is not an important trait.

An important issue when comparing rabbit breeds or lines is to do the comparison at the same stage of maturity. Comparisons at the same commercial weight but a different stage of maturity can be interesting for commercial reasons, but not for finding genetic differences between groups related to carcass or meat quality. As some lines grow quicker than others do, when comparing animals at the same LW or carcass weight, rabbits of some lines are slaughtered at earlier ages, they are younger and the characteristics of the meat are different for two reasons: one is the genetic difference between lines and the other is the differences due to the age. Both effects are confounded, thus if the interest is in genetic differences between lines, they should be compared at the same stage of maturity; i.e., at the same proportion of adult body weight (BW) (Taylor, 1985). Many differences found between breeds or groups of animals under different treatments disappear or are substantially reduced when compared at the same stage of maturity. In commercial rabbit lines, if adult weight is not available, Pascual, Calle, and Blasco (2015) showed that comparisons at the same age can be used as a good approximation, but caution should be taken when comparing lines of very different size at the same age, because even at the same age, the stage of maturity can also be different (Ouhayoun & Rouvier, 1973).

2. Genetics of growth traits

2.1. Between-breed genetic variability

Rabbits show a great variation in breed size, from dwarf (about 1 kg of adult weight) to giant lines (about 7 kg of adult weight). From the large variety of existing breeds of rabbits, commercial production uses medium size breeds for reproduction due to their high prolificacy, and

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Table 1
Distribution of the costs of an industrial rabbitry with 750 reproductive does. Management in batches with A.I. Weaning at 35 days and slaughter at 2.2 kg of live weight (63 days). Elaborated from Cartuche et al. (2014).

	€/doe year	€/kg live weight	% total
Feeding rabbits for slaughter	60.5	0.53	29.4
Feeding does	32.7	0.28	15.9
Artificial insemination	8.69	0.08	4.2
Replacement reproductive stock	11.8	0.10	5.7
Health	14.3	0.12	6.9
Labour	37.3	0.32	18.1
Amortisation	20.2	0.18	9.8
Others	20.7	0.19	10.1

large breeds as terminal sires due to their high growth rate. This also facilitates doe management and lowers the maintenance cost, allowing the production of commercial rabbits with a high growth rate.

Comparisons between breeds of very different size have not been published in standard refereed journals but are available in proceedings of congresses by Ouhayoun and Poujardieu (1978) and by Bolet et al. (2000). Large differences in ADG (more than 15 g/day between 4 weeks. and 11 weeks. of age were found between breeds, as expected). An interesting result is the between-breeds negative (favourable) relationship between FCR and growth rate found by Ouhayoun and Poujardieu (1978). FCR between 4 weeks. and 11 weeks. varied from 3.61 of Flemish Giant to 4.52 of Small Russian. This type of results has been explained by McCarthy (1980) as due to a better thermoregulation per kg of live weight (LW) of heavy breeds; maintenance energy is lower per kg of BW in giant lines because it is proportional to metabolic weight, which is a power of BW lower than one ($BW^{0.75}$ in the case of adult BW). Therefore, more energy is available for growth in giant lines.

2.2. Genetic parameters of growth traits

There are many estimates of heritabilities of weight at a given age, typically at slaughter time (SW), which varies between countries from 9 weeks. (Spain) to 13 weeks. of age (North of Italy). There are also many heritability estimates of weaning weight (WW), daily gain (SW-WW) and ADG. Hernández and Gondret (2006) give an average heritability for SW of 0.27 from 17 publications, ranging from 0.12 to 0.67. Although they are widely used, average estimates of many papers are not very useful for several reasons. First, estimates may differ in quality, as some have large standard errors or are biased due to the model used or the method of estimation. Second, environmental variability can differ among farms. Third, negative estimates are not normally published or methods of estimation force estimates to be positive, producing bias in the average of estimates. Fourth, some relationships used may lead to estimates that contain non-additive variability (for example, dominance, epistasis, maternal effects, etc.). Generally speaking, estimates of heritabilities tend to be optimistic, so it is usually better to examine the estimates from selection experiments in which control populations or divergent selected populations can offer additional evidence provided by realised heritability estimates. Recently, Piles et al. (2017) have shown that selecting rabbits for daily gain under ad libitum conditions can be inefficient under restricted feeding, due to competition between rabbits for feed under restricted conditions. This should be taken into account when selecting for commercial rabbit farms, if they keep their rabbits under a restricted feeding regime.

Estimates of genetic correlation between growth rate and FCR are lower than those found in other species. Although they have a wide confidence interval, the three values available in the literature are quite similar; Piles, Gomez, Rafel, Ramon, and Blasco (2004) give −0.49 (confidence interval at 95% probability [−0.94. -0.10]) and −0.47 (confidence interval at 95% probability [−0.99, 0.13]) for two different populations, and Drouilhet et al. (2013) give −0.38 (s.e. 0.18, which leads to an approximate confidence interval of [−0.74, −0.02]). As the heritability of FCR is not different from the heritability of ADG (between 0.22 and 0.31; Piles et al. (2004), Drouilhet et al. (2013)), if the true genetic correlation is around −0.4 or −0.5, selection for growth rate would be considerably less efficient for improving FCR than direct selection for FCR.

Measures of feed efficiency other than FCR have been proposed and we discuss them in Section 5.2. Proposed by Koch, Swiger, Chambers, and Gregory (1963), residual feed intake (RFI) is the difference between actual feed intake and expected feed intake, according to the requirements for maintenance and growth of the animal. Residual feed intake is often estimated as the residual of a regression equation of feed intake (FI) on ADG and average metabolic weight (average LW between 30 and 63 days to the power 0.75). Residual feed intake has a low heritability (0.10 to 0.16) according to results of Drouilhet et al. (2013). The high value (0.45) from Larzul and de Rochambeau (2005) comes from a short divergent selection experiment (one generation) in which growth estimates of BW, ADG and RFI were all unusually high, thus their results should be taken with caution. Genetic correlation between RFI and FCR is very high (0.96, s.e. 0.03, Drouilhet et al., 2013) which means that both traits probably have a similar genetic basis. If this is the case, as the heritability of FCR is much higher, the advantage of using RFI instead of FCR in selection is unclear. Piles et al. (2007) have estimated heritabilities of the partial regression coefficients used to define RFI using Bayesian techniques (Blasco, 2017). Estimates of the heritability of these coefficients are similar to the estimates for ADG. In Section 3.2, we shall discuss advantages and drawbacks of the different forms of measuring feed efficiency.

3. Genetics of carcass traits

3.1. Between-breed genetic variability

Comparisons of different breeds and crosses show different tendencies when performed at the same age (Brun & Ouhayoun, 1989, 1994; Lukefahr, Hohenboken, Patton, & Kennick, 1982; Metzger et al., 2006a; Metzger et al., 2006b; Ouyed, Rivest, & Brun, 2011; Ozimba & Lukefahr, 1991; Rouvier, 1970; Szendrő et al., 2009; Szendrő et al., 2010) or at the same BW (Gómez, Baselga, Rafel, & Ramon, 1998; Hernández, Ariño, Grimal, & Blasco, 2006; Pla, Guerrero, Guardia, Olivier, & Blasco, 1998; Pla, Hernández, & Blasco, 1996).

Breeds with a lower adult BW consequently have a higher maturity at slaughter, as observed by Gómez et al. (1998), Hernández et al. (2006) and Pla et al. (1996, 1998). They had better dress out percentage, lower ratio of the fore part, higher ratio of the hind part and greater fat depots (e.g. perirenal fat weight).

The number of studies evaluating the effects of heterosis based on the different crosses is scarce (Brun & Ouhayoun, 1989, 1994; Ouyed et al., 2011). Although in some cases favourable results were obtained for carcass yield and carcass fatness, carcass composition traits were generally unaffected by individual or by maternal heterosis.

3.2. Genetic parameters of carcass traits

Due to the large samples needed to estimate genetic parameters with enough precision, the number of studies estimating the genetic parameters for carcass traits of rabbits is scarce. Heritability estimates of the weight of different carcass parts are in general moderate, and common litter effects are also moderate (Al-Saef et al., 2008; Ferraz, Johnson, & Eler, 1991; Ferraz, Johnson, & Van Vleck, 1992), (ranging between 0.29 and 0.39), but they are equal or higher than the respective heritabilities of the body parts showing maternal influence for these traits. The heritability estimates of carcass ratio traits have been generally higher than those for carcass parts and carcass composition traits, and varied from moderate to high. The highest heritability estimate was observed for fat (perirenal fat percentage), whereas muscle