Animal Reproduction Science

Volume 150 , *Issues 1-2*, Pages 30-34, November 2014

Influence of coat colour, season and physiological status on reproduction of rabbit does in an Algerian local population

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DOI: http://dx.doi.org/10.1016/j.anireprosci.2014.07.023

Highlights

- •Genetic association between reproduction and Albino or Himalayan alleles of C gene.
- •Effect of season on receptivity, fertility and prolificacy of rabbits.
- •Unfavourable effect of lactation on receptivity and fertility of rabbit does.

Abstract

In Algeria, rabbit meat production is small-scale, mainly on small farms with rabbits from local populations whose productivity and growth are rather low, but which are well adapted to the local environment. Of these, farmers prefer white rabbits, with the Albino or Himalayan alleles of gene C. Our objective was to verify the appropriateness of this preference for white rabbit does over a period long enough to also assess the effect of season. From September 2006 to June 2010, reproduction data from 209 females (138 white and 71 coloured) mated by 51 males from the same population were recorded. There was neither effect of sire coat colour nor any interactions between coat colour, season and physiological status of does. There was a significant relationship between coat colour (white *vs.* coloured) and most reproductive traits, except receptivity and fertility, in favour of coloured females. Litter size was higher by 0.67 kits born ($P = 0.041$), 1.27 born alive ($P < 0.0001$) and 1.04 weaned ($P = 0.0011$). There was a highly significant effect of season on all the measured traits. Receptivity, fertility and prolificacy were significantly higher before the hot period; in summer, reproductive performance was depressed, but no more than during the following period, confirming the good adaptation of this local population to hot conditions. We can conclude that the preference of farmers for white animals is not justified because there is in this population an unfavourable genetic association between reproduction and Albino or Himalayan alleles of C gene, which needs to be explored in more detail.

Keywords:
Rabbit, Reproduction, Coat colour, Gene, Season

Contents lists available at ScienceDirect

Animal Reproduction Science

Volume 150, Issues 1-2, Pages 30-34, 2014

journal homepage: www.elsevier.com/locate/anireprosci

Influence of coat colour, season and physiological status on reproduction of rabbit does in an Algerian local population

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ARTICLE INFO

Article history:
Received 1 April 2014
Received in revised form 24 July 2014
Accepted 26 July 2014
Available online xxx

Keywords:
Rabbit
Reproduction
Coat colour
Gene
Season

ABSTRACT

In Algeria, rabbit meat production is small-scale, mainly on small farms with rabbits from local populations whose productivity and growth are rather low, but which are well adapted to the local environment. Of these, farmers prefer white rabbits, with the Albino or Himalayan alleles of gene C. Our objective was to verify the appropriateness of this preference for white rabbit does over a period long enough to also assess the effect of season. From September 2006 to June 2010, reproduction data from 209 females (138 white and 71 coloured) mated by 51 males from the same population were recorded. There was neither effect of sire coat colour nor any interactions between coat colour, season and physiological status of does. There was a significant relationship between coat colour (white *vs.* coloured) and most reproductive traits, except receptivity and fertility, in favour of coloured females. Litter size was higher by 0.67 kits born ($P=0.041$), 1.27 born alive ($P<0.0001$) and 1.04 weaned ($P=0.0011$). There was a highly significant effect of season on all the measured traits. Receptivity, fertility and prolificacy were significantly higher before the hot period; in summer, reproductive performance was depressed, but no more than during the following period, confirming the good adaptation of this local population to hot conditions. We can conclude that the preference of farmers for white animals is not justified because there is in this population an unfavourable genetic association between reproduction and Albino or Himalayan alleles of C gene, which needs to be explored in more detail.

1. Introduction

In Algeria, rabbit meat is mainly produced on small farms with rabbits from local populations, whose productivity and growth are rather low, but which are well adapted to the local environment (Daoud-Zerrouki, 2006). During the 1980s, attempts were made to introduce rabbits from European selected strains. However, these strains were not carefully maintained as pure breeds, and gradually mixed with the local populations. As they were Albino or Himalayan (alleles c and ch of the C gene for coat colour, Aigner et al., 2000), these alleles are now in segregation in the local populations, and white rabbits (Albino or Himalayan) often appear in the progeny of white or coloured parents. Many farmers prefer white rabbits. The objective of this experiment was to verify the validity of

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http://dx.doi.org/10.1016/j.anireprosci.2014.07.023
0378-4320/

Table 1
Results of the analysis of variance of reproductive performance of rabbit does: statistics and *P* values for fixed effects.

	Number of data	Mean	RSE	Dam coat colour (1)	Dam coat colour (2)	Physiological status	Season	Year within season
Dam weight at presentation (g)	3270	3314	283	<0.001	0.056	<0.001	<0.001	<0.001
Receptivity (%)	3564	38.3	0.43	0.150	0.450	<0.001	<0.001	<0.001
Fertility (%) of receptive does	1364	62.3	0.45	0.500	0.570	<0.001	0.001	0.002
Weaning rate (%)	748	74.9	0.42	0.029	0.058	0.054	0.035	0.006
Total litter size at birth	850	6.98	2.20	0.004	0.028	0.002	0.112	0.020
Alive litter size at birth (all litters born)	850	5.81	2.80	<0.001	0.001	0.001	0.037	<0.001
Alive litter size at birth (with at least 1 born alive)	748	6.60	2.20	<0.001	0.004	0.033	0.025	0.014
Survival rate at birth % (all litters born)	850	80.54	31.48	0.001	0.006	0.117	0.245	<0.001
Survival rate at birth % (litters with at least 1 born alive)	748	91.52	15.54	0.007	0.016	0.962	0.010	0.340
Litter size at weaning (litters with at least 1 born alive)	748	4.02	2.84	0.001	0.003	0.009	0.006	<0.001
Survival rate at weaning % (litters with at least 1 born alive)	748	60.40	37.32	0.078	0.125	0.085	0.008	0.003
Litter size at weaning (litters with at least 1 weaned)	560	5.37	2.05	0.019	0.029	0.2046	0.003	0.077
Survival rate at weaning % (litters with at least 1 weaned)	560	80.68	20.97	0.720	0.728	0.896	0.034	0.131

RSE: residual standard error; (1): residual used as an error term; (2): female within phenotype random effect used as an error term.

this preference for white rabbit does during a period long enough to also assess the effect of season.

2. Materials and methods

2.1. Animals

At the ITMAS (Agricultural Technical Institute) of Tizi-Ouzou (Algeria), an experimental herd was set up from the local population, and managed from September 2006 to June 2010 as a closed herd, restocking with no introduction of new rabbits. Reproduction data from 209 females (138 white and 71 coloured) mated by 43 males (9 white, 20 coloured and 14 of unknown phenotype) were recorded.

The livestock building was open to daylight by windows. It included a maternity cell with a capacity of 80 cages, and a fattening cell with 100 cages. The animals were housed individually in wire cages on a flat deck. Environmental conditions, temperature, humidity and lighting were natural. The animals were fed *ad libitum* with a commercial pellet feed (16.6% crude protein and 12.3% crude fibre). Watering was automatic.

Females were mated first between 4 and 5 months of age according to their weight. At presentation to the male, weight was recorded. If the female was not receptive, i.e. if it did not accept the mating, it was mated again 3 or 4 days later. Gestation was checked by abdominal palpation 12 days after mating; if it was negative, the rabbit does were immediately mated again. The receptivity rate (i.e. the percentage of females which accepted the mating) and the fertility rate (percentage of mated females which gave birth) were calculated. At birth, live and stillborn kits were counted, together with their number at weaning, at about 30 days later, which allowed analysis of the survival rate at birth and at weaning. Weight and growth of kits were also recorded (Abdelli-Larbi et al., 2012).

2.2. Statistical analysis

Data were analysed with an analysis of variance procedure (GLM/SAS).

2.2.1. Selection of fixed effects

In a first step, the statistical model included the fixed effect of coat colour (two levels: Albino or Himalayan *vs.* coloured) of the female, of the male mated, the season of mating with three levels (February–May: before hot season, June–September: hot season, October–January: after hot season), the year of mating (2006–2010) within season, the physiological status of the doe at mating (five levels: nulliparous, lactating or non-lactating primiparous, lactating or non-lactating multiparous), and the interactions two by two between all these effects. On this subsample (2908 data for receptivity), where coat colour of the male was recorded, there was no significant effect of the coat colour of the male nor any significant two by two interactions on any of the analysed traits.

Table 2
Effect of dam coat colour and season on reproductive performance of rabbit does: least-square means and statistical significance of fixed effects (P value, female within phenotype random effect used as an error term).

	Dam coat colour		Season of mating			
	Coloured – white*	P	Before (February–May)	Summer (June–September)	After (October–January)	P
Dam weight at presentation (g)	−146 ± 17	0.056	3316 ± 12[a**]	3182 ± 13[b]	3247 ± 17[c]	<0.001
Receptivity (%)	−3.3 ± 2.4	0.450	53.2 ± 1.7[a]	45.0 ± 1.9[b]	39.0 ± 1.6[c]	<0.001
Fertility (%) of receptive does	+2.5 ± 3.8	0.570	65.9 ± 2.8[a]	53.6 ± 3.2[b]	56.3 ± 2.8[b]	0.001
Weaning rate (%)	+10.0 ± 4.6	0.058	72.7 ± 3.6[a]	74.0 ± 4.4[a]	61.9 ± 4.0[b]	0.035
Total litter size at birth	+0.67 ± 0.23	0.028	7.31 ± 0.18	6.85 ± 0.22	6.94 ± 0.19	0.112
Alive litter size at birth (all litters born)	+1.27 ± 0.30	0.001	6.36 ± 0.23[a]	5.70 ± 0.28[b]	5.72 ± 0.25[b]	0.037
Alive litter size at birth (with at least 1 born alive)	+0.90 ± 0.25	0.004	6.99 ± 0.19[a]	6.24 ± 0.23[b]	6.76 ± 0.21[a,b]	0.025
Survival rate at birth % (all litters born)	+10.8 ± 3.3	0.006	84.1 ± 2.6	79.9 ± 3.2	79.0 ± 2.8	0.245
Survival rate at birth % (with at least 1 born alive)	+4.7 ± 1.7	0.016	93.4 ± 1.4[a]	88.3 ± 1.7[b]	94.2 ± 1.5[a]	0.010
Litter size at weaning (litters with at least 1 born alive)	+1.04 ± 0.32	0.003	4.39 ± 0.25[a]	3.59 ± 0.30[b]	3.43 ± 0.28[b]	0.006
Survival rate at weaning % (litters with at least 1 born alive)	+7.4 ± 4.2	0.125	61.3 ± 3.3[a]	57.6 ± 4.0[a,b]	48.2 ± 3.6[b]	0.008
Litter size at weaning (litters with at least 1 weaned)	+0.62 ± 026	0.029	5.98 ± 0.21[a]	5.00 ± 0.25[b]	5.46 ± 0.24[a,b]	0.003
Survival rate at weaning % (litters with at least 1 weaned)	−1.0 ± 2.7	0.728	83.7 ± 2.1[a]	78.3 ± 2.6[b]	76.7 ± 2.4[a,b]	0.034

* Difference between coloured and white females ± standard error of the difference.
** Least square mean ± standard error. On a line, means with different letters are significantly different ($P < 0.05$).

2.2.2. Final statistical model

In a second step, these non-significant effects (male coat colour and all interactions) were discarded, enabling us to use the complete set of data (3564 for receptivity) with a statistical model including the above defined fixed effects of female coat colour, season of mating, year of mating within season, physiological status of the doe at mating; it also included the random effect of female within coat colour, which was also used as residual effect to test the significance of the coat colour effect.

3. Results and discussion

The average reproductive performance observed in this herd was rather low: average fertility was 62%, mean litter size was 7 young at birth, 6.6 born alive and 5.4 weaned (Table 1). These results are in agreement with previous studies of this local population in different conditions (Zerrouki et al., 2003, 2005; Belhadi, 2004; Daoud-Zerrouki, 2006; Gacem et al., 2009; Lebas et al., 2010).

3.1. Dam coat colour

There was a significant effect of dam coat colour (white, i.e. Albino or Himalayan *vs.* coloured) on most reproductive traits, except for receptivity and fertility. We note that testing the coat colour effect using females within the phenotype as a random effect instead of the residual increases the accuracy of the test (by taking into account the variability between females within coat colour) and decreases the value of *P* (Tables 1 and 2).

In 850 kindlings, litter size of coloured females was higher by 0.67 kits born ($P = 0.028$), 1.27 born alive ($P = 0.001$) and 1.04 weaned ($P = 0.003$). If we consider only litters with at least one young born alive, or one young weaned, to discard accidental events (littering on the fence, death of the doe, etc.), the difference was lower but significant (+0.90, $P = 0.004$ for live litter size at birth and +0.43, $P = 0.029$ for litter size at weaning) (Table 2). The survival rate at birth was significantly higher in coloured than in white females (86.7% *vs.* 75.8% of all litters born, $P = 0.006$). There was no significant difference for the survival rate in weaned litters, but the proportion of litters weaned was higher in coloured than in white does (73.9% *vs.* 64.5%, $P < 0.075$). In rabbits, up to now and contrary to other species, scarce effects of major genes on litter size have been found, such as a relation with the κ casein gene polymorphism (Bolet et al., 2007), or with a single-nucleotide polymorphism in the progesterone receptor gene (Peiró et al., 2008).

In this experiment, an effect of genes near the gene C on litter size and viability was found. In this population, the c or ch alleles (Albino and Himalayan) are associated with unfavourable effects of these supposed genes. By

Table 3
Effect of physiological status of does on their reproductive performance.

	Nulliparous	Primiparous		Multiparous		P
		Non-lactating	Lactating	Non-lactating	Lactating	
Dam weight at presentation (g)	3015 ± 18[a*]	3281 ± 17[b]	3251 ± 21[b]	3335 ± 13[c]	3364 ± 14[d]	<0.001
Receptivity (%)	57.4 ± 2.4[a]	53.9 ± 2.4[a,b]	36.1 ± 3.0[c]	48.6 ± 1.9[b]	32.6 ± 2.0[c]	<0.001
Fertility (%) of receptive does	80.9 ± 3.6[a]	75.8 ± 3.7[a]	38.0 ± 5.7[c]	63.5 ± 3.1[b]	34.8 ± 3.5[c]	<0.001
Weaning rate (%)	67.0 ± 4.2[b]	71.5 ± 4.3[a,b]	57.0 ± 8.9[b]	81.5 ± 4.1[a]	70.6 ± 5.4[b]	0.054
Total litter size at birth	6.68 ± 0.20[b]	7.11 ± 0.22[a,b]	7.39 ± 0.46[a,b]	7.47 ± 0.20[a]	6.53 ± 0.26[b]	0.002
Alive litter size at birth (all litters born)	5.39 ± 0.26[b]	6.21 ± 0.28[a]	6.14 ± 0.58[a,b]	6.52 ± 0.26[a]	5.38 ± 0.34[b]	0.001
Alive litter size at birth (with at least 1 born alive)	6.28 ± 0.22[b]	6.63 ± 0.23[a,b]	7.08 ± 0.48[a,b]	7.03 ± 0.22[a]	6.29 ± 0.29[b]	0.033
Survival rate at birth % (all litters born)	78.1 ± 2.9	85.4 ± 3.1	78.9 ± 6.6	85.0 ± 2.9	77.5 ± 3.8	0.117
Survival rate at birth % (with at least 1 born alive)	92.5 ± 1.6	91.0 ± 1.6	93.0 ± 3.4	91.4 ± 1.6	91.9 ± 2.1	0.962
Litter size at weaning (litters with at least 1 born alive)	3.28 ± 0.29[b]	3.93 ± 0.30[a,b]	3.47 ± 0.62[a,b]	4.68 ± 0.28[a]	3.65 ± 0.38[b]	0.009
Survival rate at weaning % (litters with at least 1 born alive)	52.6 ± 3.8	57.2 ± 3.9	46.6 ± 8.1	65.9 ± 3.7	56.4 ± 4.9	0.085
Litter size at weaning (litters with at least 1 weaned)	5.01 ± 0.26	5.44 ± 0.27	6.01 ± 0.53	5.66 ± 0.23	5.28 ± 0.31	0.204
Survival rate at weaning % (litters with at least 1 weaned)	77.8 ± 2.7	78.0 ± 2.7	81.1 ± 5.4	81.1 ± 2.4	80.0 ± 3.2	0.896

* Least square mean ± standard error. On a line, means with different letters are significantly different ($P < 0.05$).

contrast, a comparison of two local populations, one coloured, and the "white" one from Djebla cooperative, evidenced a superiority for reproduction of the "white" population over the coloured population (Gacem et al., 2009; Lebas et al., 2010). However, in their experiment, "white" and coloured animals came from different breeds, so that the difference was due more to the genetic value of populations than to a relation with coat colour. In our experiment, white and coloured does belonged to the same population.

To confirm this observation, we restricted the analysis to performance of daughters from coloured dams. In this case, we were sure that white and coloured females came from the same litters, whatever the colour of the male. The relation of litter size with coat colour of the females was confirmed (unpublished data).

3.2. Season

To take into account the whole hot season, the season effect was not based on the four calendar seasons, but on the effective hot period, i.e. from June to September, flanked by a "before hot period", from February to May, and an "after hot period" from October to January.

There was a significant effect of season on all measured traits, except for total litter size and survival rate at birth (Tables 1 and 2). Receptivity, fertility and prolificacy were significantly higher before the hot period, but were not significantly different between the hot period and after, except for receptivity, weaning rate and survival rate at birth. These results are in close agreement with those of Marai et al. (2002), Frangiadaki et al. (2003), Belhadi (2004), and Moulla and Yakhlef (2007).

The effect of season reported by Zerrouki et al. (2008); Gacem et al. (2009) and Lebas et al. (2010) on the local populations placed in controlled lighting was not as pronounced as in our study, probably because of environmental conditions, which were less controlled and more natural in our study. For example, in our experiment, receptivity and fertility were significantly higher from February to May, during lengthening days, in natural photoperiod, in agreement with the well-known effect of lighting on the induction of receptivity (Theau-Clément, 2008). On another hand, there was a significant effect of year within season so that we must place these conclusions in context.

No significant interaction between coat colour and season was evidenced in the preliminary analysis: whatever the season, litter size of coloured females was higher than that of white females. It means that the effect of coat colour was not due to a better adaptation of coloured females to hot periods.

3.3. Physiological status

Females were split into five groups: nulliparous, lactating or non-lactating primiparous and lactating or non-lactating multiparous, according to the main effects on fertility and prolificacy evidenced by Theau-Clément

(2007, 2008) with artificial insemination. We confirmed her observations concerning the favourable effect of nulliparous and the unfavourable effect of lactation on receptivity and fertility (Table 3). Total litter size at birth and litter size at weaning did not differ significantly between nulliparous and primiparous does, whatever their lactation status; it was only significantly higher in multiparous non-lactating does than in nulliparous does.

4. Conclusion

Two main points are evidenced by this experiment:

- The favourable effect of the spring period (February–May) on reproduction, whereas there is little difference between the hot (June–September) and autumn–winter (from October to January) periods. In summer, reproductive performance is depressed, but no more than during the following period. This confirms the good adaptation of this local population to hot conditions, and does not justify stopping reproduction during summer, as many farmers do.
- The original and unexpected superiority of coloured over white females (Albino or Himalayan), which carry the c or ch allele of C gene. So, the preference of farmers for white animals of this population is not justified. As there is no interaction between season and coat colour, we can conclude that it is not some environmental effect such as a better resistance to heat of coloured females, but actually a genetic association between reproduction and this locus, or more probably genes near it, which needs to be explored in more detail.

Conflict of interest

The authors report no conflict of interest to declare.

Acknowledgements

The authors thank the director and the technical staff of ITMAS for providing the experimental animals and facilities. Their thanks are also addressed to Mr. S.A. Kadi, a member of our faculty staff, for his ready and precious help.

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