

EFFECT OF LIGHTING SCHEDULE, INTENSITY AND COLOUR ON REPRODUCTIVE PERFORMANCE OF RABBIT DOES

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Abstract: In order to establish a lighting regime suitable for rabbit farms in East China, the effects of lighting schedule, intensity and colour on the reproductive performance of rabbit does were evaluated by three experiments, respectively. In experiment 1, does were exposed to different lighting schedules: 16L:8D-continuous, 16L:8D-18d (6 d before artificial insemination (AI) to 12 d post-AI), 16L:8D-6d (6 d before AI to the day of AI) and 12L:12D-continuous. In experiment 2, does were exposed to different light intensities: 40 lx, 60 lx, 80 lx and 120 lx. In experiment 3, does were exposed to different light colours: white, yellow, blue and red. For all experiments, conception rate, kindling rate and pre-weaning mortality were calculated; litter size at birth, litter weight at birth, litter size at weaning, litter weight at weaning and individual kit weight at weaning were recorded. Results showed that none of the reproductive parameters of does were affected by the application of 16L:8D-18d lighting schedule compared with the continuous 16L:8D group ($P>0.05$). Moreover, rabbits does exposed to 80 lx light performed as well as those under 120 lx light in conception rate, kindling rate, litter size (total and alive) at birth and litter weight at birth ($P>0.05$). Furthermore, the exposures of 60 lx and 80 lx light were beneficial for litter weight at weaning. In addition, red light had a positive effect, as it led to a larger litter size and litter weight at weaning and lower pre-weaning mortality than white light ($P<0.05$). In summary, a 16L:8D photoperiod with 80 lx red light from 6 d before AI to 12 d post-AI is recommended for use in breeding of rabbit does according to our results.

Key Words: rabbit doe, photoperiod, light intensity, light colour, reproduction.

INTRODUCTION

The lighting regime is applied for different purposes on rabbit farms, improving reproductive performance, increasing daily weight or improving fur quality and wool production (Szendró *et al.*, 2016). Although the natural light effect can be reduced or eliminated in rabbit barns, there may still be regional differences in the reproductive performance of female rabbits, which are related to climate, feed nutrition and management. In China, rabbits are mainly raised in Shandong, Henan and Sichuan provinces, and Shandong is located in East China. The annual average temperature is 10-16°C, the annual average amount of rain is 676 mm (56 d) and annual sunshine hours are 2491 h. However, the rabbit farms have adopted the lighting scheme used in Western European. We think it is necessary to determine if there is a more suitable lighting regime for them.

Since the 1980s, the prolongation of daily lighting duration has been shown to have a positive effect on oestrus and the reproductive performance of female rabbits (Maertens and Luzi, 1995; Mattaraia *et al.*, 2005). Mattaraia *et al.* (2005) found that a supplemental lighting schedule providing 14 h light (L)/10 h darkness (D) favoured fertility of primiparous does; thus, they recommended the adoption of such a schedule to increase productivity. Theau-Clement *et al.* (2008) provided evidence that the receptivity rate of rabbit does was higher under a 16L-8D photoperiod than under an 8L-16D photoperiod. Moreover, the practice in rational European rabbit production units is to put breeding females under artificial light for 15 to 16 h a day throughout the year, and many rabbit farms in China have copied

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this lighting schedule. However, as rabbits are active during the dark period and spend lighting hours in dark warrens, the exposure to shorter daylight may be more natural for them and can also avoid unnecessary waste of resources.

According to the recommendation of the World Rabbit Science Association, the minimum levels of light intensity in a rabbit building should be 20 lx (Hoy, 2012). In rabbit does, a sufficient level of light intensity is 30-40 lx or at least 50 lx (Szendrő *et al.*, 2016). There is limited research that has examined the effect of light intensity on breeding rabbits, and there are even fewer studies that have investigated the impact of lighting colour on rabbit does. However, for the commercially produced rabbits housed in buildings with artificial light, the duration, intensity and colour of light are very important.

Therefore, the purpose of this study was to investigate the effects of different lighting schedules, intensities and colours on the reproduction of female rabbits, to establish a standard lighting scheme for the large-scale rabbit production in East China.

MATERIALS AND METHODS

Animals and experimental design

Experiments were carried out on a commercial rabbit farm in Qingdao (Shandong). Qingdao is located in East China, at a northern latitude of 35°35'-37°09', with large annual variations in photoperiod length. Ambient temperature in the housing facility ranged from 16-28°C, with a relative humidity of 50-75%. Does were kept in single-level individual cages with an area of 0.75 m²/doe and a height of 0.4 m. During each experiment, does were fed *ad libitum* a commercial feed mixture consisting of 16.0% crude protein, 10.5 MJ metabolisable energy and 15.5% crude fibre. Water was also supplied *ad libitum*.

Experiment 1: 5-6 mo old nulliparous Hyla does, with 3.5-4.5 kg of live body weight, were randomly divided into four groups and placed in rabbit houses with different lighting schedules (Figure 1). Group 1 (16L:8D-con) was the control group, in which a 16-h lighting period was applied continuously throughout the experiment (6:00-22:00; n=184). In Group 2 (16L:8D-18d), a 16-h lighting period was used from 6 d prior to AI until 12 d post-AI (n=179), being the lighting period 12 h for the other days. In Group 3 (16L:8D-6d), a 16-h lighting period was used from 6 d prior to AI to the day of performing AI (n=193), being the lighting period 12 h for the other days. In Group 4 (12L:12D continuous), a daily 12 h light was applied throughout the experiment (6:00-18:00; n=199). This experiment lasted for 84 d (from July to October). In this experiment, 80 lx white light was used, which is the intensity and colour most used in Chinese rabbit farms. The light intensity is based on the height of rabbit eyes in the middle of the cage and was measured by photometer DT-8808 (China Everbest Machinery Industry Co., Ltd, China).

After Experiment 1, the lighting period for all does was returned to 16 h per day for more than one month. This was designated the blank period (Figure 1). Its purpose was to restore the female rabbits affected by different photoperiods to an identical physiological state. Experiments 2 and 3 were carried out almost at the same time and used a mixed population of primiparous and nulliparous rabbits. The primiparous rabbits (total number 755) were the rabbits used

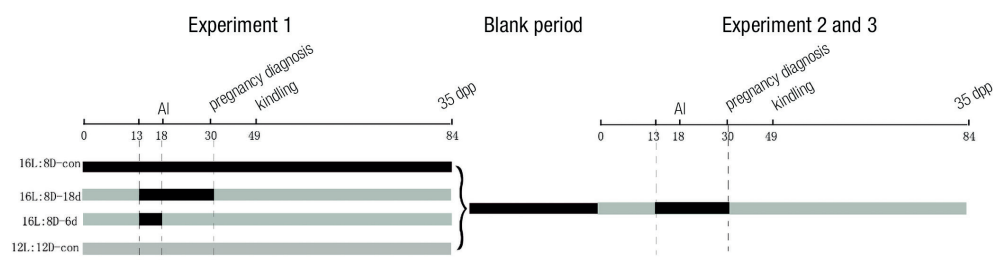


Figure 1: Schematic diagram of lighting schedule. Black cross bars indicate the 16L:8D photoperiod; grey cross bars indicate the 12L:12D photoperiod. AI: artificial insemination; con: continuous. dpp: days post parturition.

in Experiment 1, and the nulliparous rabbits (total number 460) were 5-6 mo old with 3.5-4.5 kg of live body weight. All rabbits were randomly divided into groups. In Experiment 2, does were exposed to lights of 40 lx (n=158), 60 lx (n=148), 80 lx (n=157) and 120 lx (n=159), respectively. The lighting schedule was 16L:8D-18d (Figure 1), based on the results of Experiment 1. And the light was white, which is the colour most used in rabbit farms. In Experiment 3: does were respectively exposed to white (n=146), yellow (n=150), blue (n=148) and red (n=149) colours of light. The lighting schedule was 16L:8D-18d (Figure 1), based on the results of experiment 1. Moreover, light intensity was 80 lx, which is the intensity most used in rabbit farms. Both experiments also lasted for 84 d (from November to February of the following year).

For all the experiments, AI was performed on the 18 d of experiment and ovulation was induced by intramuscular injection of LHR-A3 (1 μ g, Ningbo Second Hormone Factory, China). Pregnancy diagnosis was performed by palpation on the 30 d of experiment (12 d post insemination). Conception rate was calculated as the number of pregnant does over the total number of inseminated does and multiplied by 100. On the day of kindling, total litter size, alive litter size and litter weight were recorded and the kindling rate (the number of kindled does/ the number of inseminated does and multiply by 100) was calculated. After birth, the litter were equalised within groups according to the average number of kits born alive (maximum 10 kits). At the day of weaning (35 d post parturition), the litter size, litter weight and individual kit weight were also recorded, and pre-weaning mortality was calculated as follows: number of kits dead at weaning divided by total number of kits born \times 100.

Statistical analysis

The data on litter size (total and alive), litter weight and individual weight were expressed as means \pm standard error. One-way repeated analyses of variance (ANOVAs, SPSS software version 17.0) with post hoc Bonferroni were used to compare data. At the same time, conception and kindling rates and pre-weaning mortality were analysed by non-parametric tests based on chi-square. A *P* value of <0.05 was considered statistically significant.

RESULTS AND DISCUSSION

The most commonly used lighting schedule in rabbit farms is a continuous 16L:8D photoperiod, which was used as a control group in this experiment. As shown in Table 1, none of reproductive parameters was significantly affected when the duration of 16L:8D photoperiod was shortened from 84 days (whole course) to 18 days (*P*>0.05). This indicates that a daily lighting period of 16 hours from 6 days before AI to 12 days after AI is enough for the breeding of rabbit does. It will save more electricity than the continuous 16L:8D lighting schedule. That is why we used this

Table 1: Influence of photoperiod on the reproductive parameters of rabbit does, litter size and kit weight during lactation (% or mean \pm standard error).

	16L:8D-con	16L:8D-18d	16L:8D-6d	12L:12D-con
No. of AI	184	179	193	199
Conception rate (%)	76.1 ^{ab}	77.1 ^{ab}	78.8 ^b	68.8 ^a
No. of kindling does	125	106	131	113
Kindling rate (%)	67.9 ^b	59.2 ^{ab}	67.9 ^b	56.8 ^a
Total litter size at birth (n)	8.95 \pm 0.32	8.78 \pm 0.35	8.52 \pm 0.30	8.52 \pm 0.33
Alive litter size at birth (n)	8.60 \pm 0.33	8.34 \pm 0.36	7.83 \pm 0.29	8.21 \pm 0.35
Litter weight at birth (g)	560.5 \pm 28.0 ^a	610.4 \pm 18.3 ^{ab}	645.4 \pm 14.0 ^b	616.4 \pm 11.0 ^b
Litter size at weaning (n)	7.44 \pm 0.10 ^b	7.18 \pm 0.10 ^{ab}	7.14 \pm 0.12 ^a	6.87 \pm 0.13 ^a
Litter weight at weaning (kg)	7.05 \pm 0.14 ^b	6.74 \pm 0.10 ^b	6.73 \pm 0.13 ^b	6.26 \pm 0.13 ^a
Individual weight at weaning (g)	961 \pm 13 ^b	947 \pm 14 ^{ab}	947 \pm 13 ^{ab}	916 \pm 15 ^a
Pre-weaning mortality (%)	16.9	18.3	16.2	19.4

12L:12D-con: continuous 12L:12D photoperiod for entire experiment (84 d); 16L:8D-con: continuous 16L:8D photoperiod for entire experiment (84 d); 16L:8D-18d: 16L:8D photoperiod for 18 d (from the 13th day to the 30th day); 16L:8D-6d: 16L:8D photoperiod for 6 d (from the 13th day to the 18th day).

^{a,b}Means not sharing superscript in the same row, indicate *P*<0.05.

schedule in the following experiments 2 and 3. The group with a light duration reduced to 6 days (16L:8D-6d) showed similar litter weight at birth to 16L:8D-18d and 12L:12D-con ($P>0.05$) but different to 16L:8D-con ($P<0.05$). However, after the application of a continuous 12L:12D lighting schedule, the kindling rate, litter size, litter weight and individual kit weight at weaning were all depressed compared with the control group ($P<0.05$), although litter weight at birth was slightly increased ($P<0.05$). Its influence of kindling rate agreed with an investigation that kindling rate of Rex rabbit was decreased with the decrease of light duration from 14 to 12 h (Uzcategui and Johnston, 1992). Furthermore, this result partially confirmed a previous study where kit weight at weaning was reduced when does were submitted to a 12L:12D photoperiod compared with a 16L:8D photoperiod (Mousa-Balabel and Mohamed, 2011). However, different from our result, they found decreases in conception rate, litter size at birth and pre-weaning mortality after the application of a 12L:12D photoperiod. We think these differences were probably caused by the difference in breed of rabbit, sample size and the mating procedure. They used 10 White New Zealand rabbit for each group and adopted a natural way of mating (Mousa-Balabel and Mohamed, 2011). In the present result, total litter size at birth and alive litter size at birth were not obviously changed ($P>0.05$). However, photoperiod could play a role in these two reproductive parameters, as long as more extreme light durations are applied. For example, Gerencsér *et al.* (2011) detected that an 8-h lighting period (extended by an additional 1 h) decreased litter size at kindling compared to continuous light for 16 h.

Matics *et al.* (2016) compared a very high (150-200 lx) and a very low (10-20 lx) light intensity and showed that after five reproduction cycles, no difference was found in kindling rate, but the litter sizes (total born, kits born alive and alive at 21 d) differed by 3-7% in favour of the higher light intensity. In the present study, conception rate, kindling rate, litter size (total and alive) and litter weight at birth of 80 lx group and 120 lx group were higher than those of 40 lx group ($P<0.05$, Table 2). In addition, litter weight and individual weight at weaning were elevated by 60 lx and 80 lx light over 40 lx light ($P<0.05$, Table 2). However, light that is too strong can also have an adverse effect, as 120 lx light significantly decreased litter size at weaning compared with 60 lx and 80 lx light ($P<0.05$, Table 2), and also caused higher mortality ($P<0.05$, Table 2). The pre-weaning mortality of 40 lx group was the lowest among groups, which was probably due to its smaller litter size at birth, and each kit could get more milk and care from the mother. According to the above results, the light intensity of 80 lx is recommended, which is consistent with the intensity used in most rabbit farms.

There is little research on the effect of light colour on rabbit reproduction. Gerencsér *et al.* (2011) investigated the effect of blue and white light on the performance of rabbit offspring, and a difference was found only in litter weight at 23 d. The different influences of light colour are primarily due to their different wavelengths. White light is a mixture of lights in all frequency bands. Red, yellow and blue light have a wavelength of 622-770 nm, 577-597 nm and

Table 2: Influence of light intensity on the reproductive parameters of rabbit does, litter size and kit weight during lactation (% or mean±standard error).

	40 lx	60 lx	80 lx	120 lx
No. of AI	158	148	157	159
Conception rate (%)	62.0 ^a	70.9 ^a	86.6 ^b	87.4 ^b
No. of kindling does	87	101	132	131
Kindling rate (%)	55.1 ^a	68.2 ^b	84.1 ^c	82.4 ^c
Total litter size at birth (n)	8.41±0.39 ^a	9.37±0.27 ^b	10.09±0.24 ^c	9.94±0.22 ^c
Alive litter size at birth (n)	8.20±0.41 ^a	8.75±0.32 ^a	9.84±0.26 ^b	9.39±0.26 ^b
Litter weight at birth (g)	560.5±28.0 ^a	610.4±18.3 ^{ab}	645.4±14.0 ^b	616.4±11.0 ^b
Litter size at weaning (n)	7.35±0.10 ^{ab}	7.49±0.07 ^b	7.43±0.07 ^b	7.17±0.08 ^a
Litter weight at weaning (kg)	7.04±0.17 ^a	7.51±0.11 ^b	7.54±0.09 ^b	7.10±0.07 ^a
Individual weight at weaning (g)	948±15 ^a	1002±9 ^b	1013±6 ^b	998±9 ^b
Pre-weaning mortality (%)	12.6 ^a	20.0 ^b	26.3 ^c	27.9 ^c

The primiparous Hyla does were randomly divided into four groups. They were exposed to a 16L:8D-18d photoperiod with the light intensity of 40, 60, 80 and 120 lx, respectively.

^{a,b,c}Means not sharing superscript in the same row, indicate $P<0.05$.

Table 3: Influence of light colour on the reproductive parameters of rabbit does, litter size and kit weight during lactation (% or mean \pm standard error).

	white	yellow	blue	red
No. of AI	146	150	148	149
Conception rate (%)	76.9	78	80	78.1
No. of kindling does	98	113	108	97
Kindling rate (%)	67.1	75.3	73.0	65.1
Total litter size at birth (n)	10.39 \pm 0.26 ^b	9.60 \pm 0.25 ^a	10.48 \pm 0.26 ^b	10.41 \pm 0.25 ^b
Alive litter size at birth (n)	9.99 \pm 0.26 ^b	9.01 \pm 0.30 ^a	9.94 \pm 0.26 ^b	10.08 \pm 0.27 ^b
Litter weight at birth (g)	670.7 \pm 14.5	629.2 \pm 17.8	671.1 \pm 17.1	685.6 \pm 12.3
Litter size at weaning (n)	7.24 \pm 0.10 ^a	7.59 \pm 0.06 ^{bc}	7.41 \pm 0.09 ^{ab}	7.78 \pm 0.05 ^c
Litter weight at weaning (kg)	7.44 \pm 0.12 ^a	7.82 \pm 0.09 ^{bc}	7.60 \pm 0.11 ^{ab}	8.04 \pm 0.08 ^c
Individual weight at weaning (g)	1026 \pm 8	1029 \pm 8	1025 \pm 8	1033 \pm 7
Pre-weaning mortality (%)	30.3 ^c	20.9 ^a	29.3 ^c	25.3 ^b

The primiparous Hyla does were randomly divided into four groups. They were exposed to a 16L:8D-18d photoperiod with the light colour of white, yellow, blue and red, respectively.

^{a,b}Means not sharing superscript in the same row, indicate $P < 0.05$.

435-450 nm, respectively. According to our result, light colour had no evident influence either on the conception rate and kindling rate of rabbit does or on the individual weight of kits at weaning ($P > 0.05$, Table 3). However, yellow light significantly depressed litter size (total and alive) at birth compared with the other three colours ($P < 0.05$, Table 3). Red light had a better effect on litter size and litter weight at weaning than blue and white light ($P < 0.05$, Table 3). This was beyond our expectations, as the colour vision of the rabbit is limited so that they can only detect the wavelengths between blue and green (Nuboer, 1985). The function of red light may be due to its high biological permeability, caused by its long wavelength. It is known that lights of different wavelengths have different degrees of absorption, scattering and reflection by biological media and tissues. Red light, due to its long wavelength, has the highest bio-penetrability (Li *et al.*, 2016). It has been used to stimulate neural activity and improve brain function in brain photobiomodulation therapy (Salehpour *et al.*, 2018). Recent studies have also shown that it alters the inflammation and immune response, as well as promoting healing in several tissues (Li *et al.*, 2016; Shi *et al.*, 2018). Therefore, the red light may enter the cerebral cortex or other tissues of the rabbit and cause complex biological reactions, leading to a positive impact on their health. Undoubtedly, further studies are necessary. The pre-weaning mortality was the lowest in the yellow group, which was probably due to its smaller litter size at birth as well. Considering that the majority of Chinese rabbit farms are using white light now, we recommend trying to replace it with a red light.

The influence of light on kits is potentially through different pathways according to different developmental stages. Because rabbit kits open their eyes at 10 d of age (Abdo *et al.*, 2017) and eat solid food from 16 to 18 d (Gidenne and Fortun-Lamothe, 2002), before that time, light induces a difference in kit growth that is probably caused by the different milk yields of rabbit does; however, after that time, light induces weight difference in kits, which may be due to the change in their feed intake. As reported, there were several studies about light affecting feed intake of young rabbits. For example, according to Reyne *et al.* (1978), when a dark period of 10 h was increased to 16 h, daily feed intake of growing rabbits was increased.

CONCLUSIONS

In this study, we used a large number of rabbit does (>140/group) and proved that a 16L:8D photoperiod for 18 d (from 6 d before AI to 12 d post-AI) with an 80 lx red light is the best lighting programme for the reproduction of female rabbits in East China.

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