Factors Affecting Weight of Kits Between Birth and Weaning in Rabbits

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Abstract. *The objective of this study was to analyze the effects of season of birth, physiological status of females, parity order, nest quality, place of birth, occurrence of cannibalism in litter, and sex of kits on their body weight at birth and growth in a preweaning period. A total of 1696 rabbit kits born during 3 parities and from 82 rabbit does were used in this study. The survival rate ranged from 88.57% at birth to 74.41% at weaning. Survivor kits always presented a higher body weight than the dead kits regardless of the study period. Kits born in autumn were significantly heavier at 5 days (93.73 g vs 88.54 g;P < 0.05) and at 7 days (119.58 g vs 110.94 g; P < 0.05) than those born in summer. Except at birth, kits gestated in non-lactating females had a significantly higher body weight compared with those gestated in lactating females, over all the preweaning period (P < 0.05). Regarding parity order, at birth, kits born from nulliparous were lighter than those born from primiparous (42.52 g vs 49.80 g; P < 0.05) or multiparous (42.52 g vs 53.20 g; P < 0.05). Kits born from primiparous females maintained their superiority in terms of weight compared with those born from nulliparous females throughout the experiment period. However, kits born from primiparous females had a similar weight compared with those born from multiparous females over the entire study period. Kits born in a nest of poor quality had a higher body weight at birth and at 7 days compared with those born in a nest of intermediate (53.09 g vs 46.88 g and 126.91 vs 106.03; P < 0.05, respectively) or excellent qualities (53.09 g vs 45.56 g and 162.91 g vs 112.85 g; P < 0.05, respectively). However, at 35 days, kits born in a nest of excellent quality were heavier (P < 0.05). The kits' body weight was higher when born on cage than into nest (at birth, 52.25 g vs 44.76 g, at 5 days, 96.62 vs 85.65 g, at 7 days, 120.29 vs 110.24 g and at 14 days, 206.35 g vs 193.69 g). From 21 days, weights and weight gains became similar between both places of birth. In regard to occurrence of cannibalism in litter, the individual weight of kits was higher at birth when a kit was born in litter with cannibalism (52 g vs 45.02 g; P < 0.05). Up to the second week, the body weights of kits were higher when they were born in a litter that did not exhibit cannibalism at birth. Male kits were heavier than female kits only at birth (47.61 g vs 46.48 g; P < 0.05). In conclusion, the kits' body weight during the preweaning period was mainly affected by lactation status, parity order of the dam, and occurrence of cannibalism in litter.*

Introduction

Breeding programs have focused on the genetic improvement of litter size, considered as the most important trait for evaluating doe productivity (García and Argente, 2020). However, increasing litter size has not been as successful as expected in increasing the total number of live weaned rabbits, due to increased mortality of kits between birth and weaning (Prayaga and Eady, 2001; Lenoir *et al.,* 2012). This mortality is mainly related to a lower body weight of kits at birth resulting from the increasing litter size, two traits negatively correlated (Belabbas *et al.,* 2023).

Several studies have reported that kit birth weight is directly related to rabbits' *in utero*, postnatal mortality and growth (Martínez-Paredes *et al.,* 2018; Agea *et al.,* 2019; Belabbas *et al.,* 2023). Therefore, the selection for the within-litter uniformity was proposed to reduce mortality related to lower birth weight (Garreau *et al.,* 2008).

In prolific species such as rabbits, the weight of a rabbit kit at birth is determined by its genotype, maternal effects (age and body weight of does, parity order, reproductive rhythm, nutritional status and uterine environment) and environmental effects (ambient temperature, food quality and breeding

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management) (Szendrö *et al.,* 2019; Farouk *et al.,* 2022). However, its growth and survival in the preweaning period are mainly related to the mothering abilities like milk yield and nest construction (Ludwiczak *et al.,* 2021; Belabbas *et al.,* 2023) and to the environmental effects (litter effects, season of birth and temperature) (Marco-Jiménez *et al.,* 2017; Pałka *et al.,* 2018; Zapletal *et al.,* 2021).

At birth, individual weight of rabbit kits is about 60–70 g, although it can range from 35–90 g (Di Meo *et al.,* 2004). Rabbit growth is linear, with an average daily gain of 11 g to 13 g per day in a litter of 10 kit rabbits during the first three weeks. From the 25th, growth accelerates to reach an average gain of 35 g to 38 g per day when the proportion of solid pelleted diet becomes significant. During lactation, the birth weight of a kit rabbit increases very quickly, from 71 g at birth to 394 g at 21 days (Ludwiczak *et al.,* 2021).

It should be noted that the factors affecting body weight and growth of kits were studied at specific dates (birth or weaning). However, few studies have analysed these factors from birth to weaning. Moreover, there are few studies on the effect of mother abilities (nest quality and cannibalism in litter) on the growth of kits during the preweaning period. This study aimed at investigating the effect of season of birth, lactation status of the dam and its parity order, nest quality, occurrence of cannibalism in litter, birth place and sex of kits on their growth during the preweaning period.

Material and methods

Ethics statement

All experiment procedures involving animals were approved by the scientific council of the Biotechnology Laboratory of Animal Reproduction (code BR-001-17; date of approval 05/01/2017), part of the Institute of Veterinary Sciences at the University of Blida 1 (Blida, Algeria).

Animals

All animals came from the ITELV2006 line. This line was created as a part of an agreement to transfer biological material for experimental purposes between the Institute of Animal Breeding (ITELV, Algeria) and INRA (France) by means of inseminating does from a local Algerian rabbit population with the semen of bucks from the INRA2666 synthetic line (Brun *et al.,* 2004). This line has been maintained in discrete generations without selection and avoiding inbreeding. More details of this line can be found in Ezzeroug *et al.* (2020).

Housing, feeding and management

The females were housed individually in wired flat-deck cages (30 height × 40 width × 70 length cm) in a building equipped with a cooling system. They were submitted to a constant photoperiod with 16 hours of light and 8 hours of dark. They were fed *ad libitum* a standard commercial pelleted diet (16% crude protein, 15% crude fiber and 2.6% ether extract) and water was available *ad libitum*.

Females (n = 82) followed a semi-intensive reproductive rhythm: first mating at 20 weeks of age, with subsequent 42-day reproductive cycles. Natural mating was performed using adult males of the same line (7–10 months), within a rhythm of 2 matings per week.

Four days before the presumed date of parturition, a cleaned and disinfected nest boxes were placed. On the day of parturition, early in the morning (at 8:00 am), the nest boxes were checked and the place of kindling (inside the nest or on cage) and the presence of cannibalism in kits were noted. We considered that cannibalism had taken place when at least one kit had been devoured by its mother.

The nest quality was evaluated according to Blumetto *et al.* (2010). This evaluation consists of judging only the extent to which the female uses her hair for nest building. Three categories were considered: poor, nest contains very little or no hairs; intermediate, > 50% of the nest had material covered with hair; excellent, nest filled with hairs that occupy the entire nest box.

At birth, the litter size was recorded and kits (n = 1696) were individually identified, sexed and weighted. Afterwards, the litter size, individual body weights of alive kits, and survival rates were recorded at 0, 5, 7, 14, 21, 28, and 35 days for the three first parities. The survival rate was calculated as the number of alive kits at different dates per the total number of kits at birth. The increment of body weight was calculated as the weight difference between two given dates. The litters were not standardized and kits were reared by their dams up to weaning (35 days of age).

The study was carried out from June to November 2017. In Table 1, the temperature and relative humidity for each month are shown. Summer runs from June 1 to August 31, and autumn from September 1 to November 30.

Statistical analysis

The kits' body weight was analyzed using the following model:

$$Y_{ijklmnop} = \mu + S_i + Lj + P_k + N_l + CNm + Bn + SX_o + + c_{ijkmnop} + e_{ijklmnop}$$

where μ is general mean, S_i is the effect of season (2 levels: summer and autumn), L_j is the effect of lactation status (2 levels: lactating and non-lactating females), P_k is the effect of parity order (3 levels: nulliparous, females that give birth for the first time; primiparous: females that give birth for the second time; and multiparous: females that give birth for the third time), N_l is the effect of the nest quality (3 levels: poor, intermediate and excellent), CN_m is the effect of cannibalism (2 levels: presence and absence), B_n is the effect of birth place (2 levels: nest or cage), SX_o is the effect of sex (2 levels: male and female), $c_{ijkmnop}$ is the random effect of the common litter, and

Table 1. Temperature and relative humidity by month

		Temperature Outside (°C)		Temperature Inside (°C)		Relative Humidity Inside (%)	
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Summer	June	25	30	22	28	21	82
	July	27	39	26	33	21	80
	August	30	35	28	36	23	80
	Average	27.3	34.7	25.3	32.3	21.7	80.7
Autumn	September	24	30	22	27	19	83
	October	21	27	20	23	21	79
	November	16	21	19	23	20	68
	Average	20.3	26.0	20.3	24.3	20.0	76.7

$e_{ijklmnop}$ is the error. The interactions between factors were not included in the statistical model because they were not significant. The body weight and the weight gain were analyzed with the number of kits total new-born and kits born alive as covariates. The mixed procedure of the SAS statistical package was used for these analyses (SAS Institute, 2024).

Results

The survival rate ranged from 88.57% at birth to 74.41% at weaning. The weights of born alive and dead kits at birth were 52.57 g and 38.21 g, respectively. Regardless of the study period, the weight of alive kits was always greater than that of the dead kits (Fig. 1).

Factors affecting weight of kits

Effect of season

The evolution of kit individual body weight from birth to weaning and according to the season is presented in Fig. 2. At parturition, the individual body weights of kits were not significantly affected by the season of birth. However, during their first week of life (between birth and 7 days), kits born in autumn had a significantly higher body weight compared with those born in summer (93.73 g *vs* 88.54 g and 119.58 g *vs* 110.94 g, respectively, at 5 days and 7 days of age; $P < 0.05$). These differences remained significant when the body weight was corrected by the number of total new-borns. Between 14 days and 35 days of age, no difference was found between the two studied seasons.

Effect of lactation

At birth, the individual body weights of kits were similar between lactating and non-lactating females (Fig. 3). Lactation affected significantly the growth of kits at 5 days and 7 days, and kits born from non-lactating females had a higher body weight and weight gain (94.19 g *vs* 88.07 g at 5 days and 119.85 g *vs* 110.68 g at 7 days for the body weight and 38.74 g *vs* 33.52 g from birth to 5 days and 24.75 g *vs* 22.52 g from 5 days to 7 days for weight gain; $P < 0.05$). The same observations were noted in the following weeks. The kits born from non-lactating females had higher

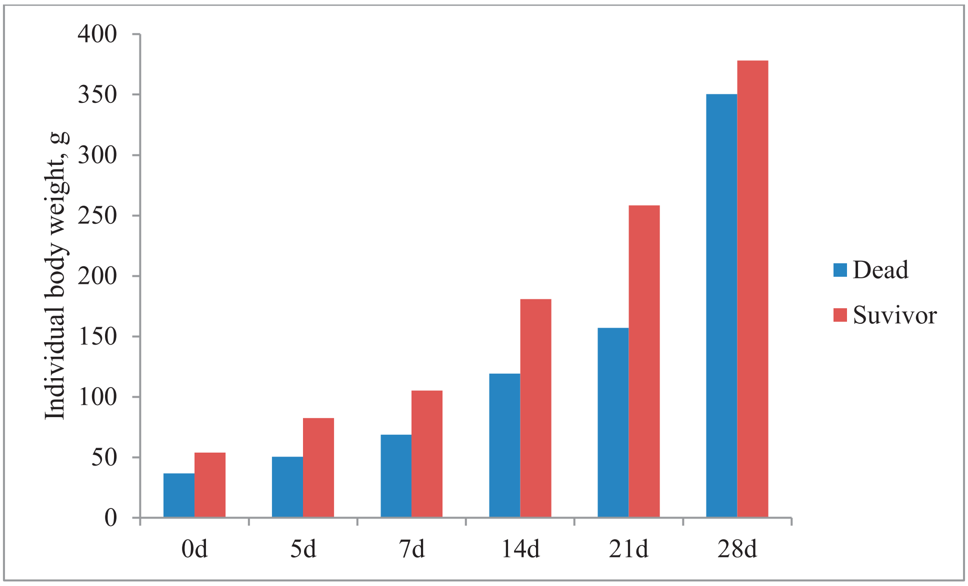

Fig. 1. Weight evolution for survivor and dead kits from birth to 28 days

Table 2. Number of observations (N), means, and standard deviations (SD) of survival, body weight and its increment from birth to weaning and for each week (Appendix)

Traits	N	Mean	SD	Minimum	Maximum
Survival at birth 0 d, %	1696	88.57	23.78	0	100
Survival at 5 d, %	1431	83.69	24.74	0	100
Weight increment 0–5 d (alive), g	1431	27.45	15.77	–32.01	83.49
Weight increment 0–5 d of kits death at 7 d, g	50	9.56	15.16	–8.66	51.88
Weight increment 0–5 d of kits alive at 7 d, g	1381	28.10	15.42	–32.01	83.49
Survival at 7 d, %	1381	81.07	26.18	0	100
Weight increment 5–7 d (alive), g	1381	20.89	12.58	–32.17	124.10
Weight increment 5–7 d of kits death at 14 d, g	69	7.10	10.69	–18.54	36.25
Weight increment 5–7 d of kits alive at 14 d, g	1312	21.61	12.25	–32.17	124.10
Survival at d 14, %	1312	77.45	27.91	0	100
Weight increment 7–14 d (alive), g	1312	74.48	33.69	–34.82	230.60
Weight increment 7–14 d of kits dead at 21 d, g	28	34.34	23.07	–13.38	85.51
Weight increment 7–14 d of kits alive at 21 d, g	1284	75.35	33.36	–34.82	230.60
Survival at 21 d, %	1284	75.80	28.46	0	100
Weight increment 14–21 d (alive), g	1284	75.96	39.25	–32.80	290.70
Weight increment 14–21 d of kits dead at 28 d, g	18	13.39	37.04	–32.80	103.85
Weight increment 14–21 d of kits alive at 28, g	1266	76.85	38.57	4.72	290.70
Survival at 28 d, %	1266	74.84	29.21	0	100
Weight increment 21–28 d (alive), g	1266	119.82	56.13	–18.95	415.51
Weight increment 21–28 d of kits dead at 35 d, g	7	118.84	152.57	–18.95	403.20
Weight increment 21–28 d of kits alive at 35 d, g	1259	119.83	55.29	8.30	415.51
Survival at 35 d, %	1259	74.41	29.37	0	100
Weight increment 28–35 d (alive), g	1259	187.53	91.16	–59.20	535.60

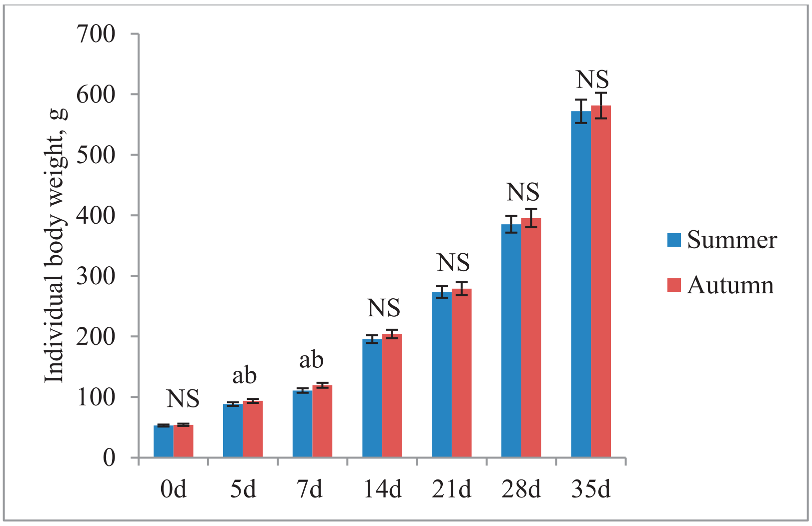

Fig. 2. Evolution of kits body weight according to the season of birth.
Individual body weight at 0 (birth), 5, 7, 14, 21, 28 and 35 days (weaning).
a and b: different letters indicate statistically significant differences ($P < 0.05$). NS: not significant.

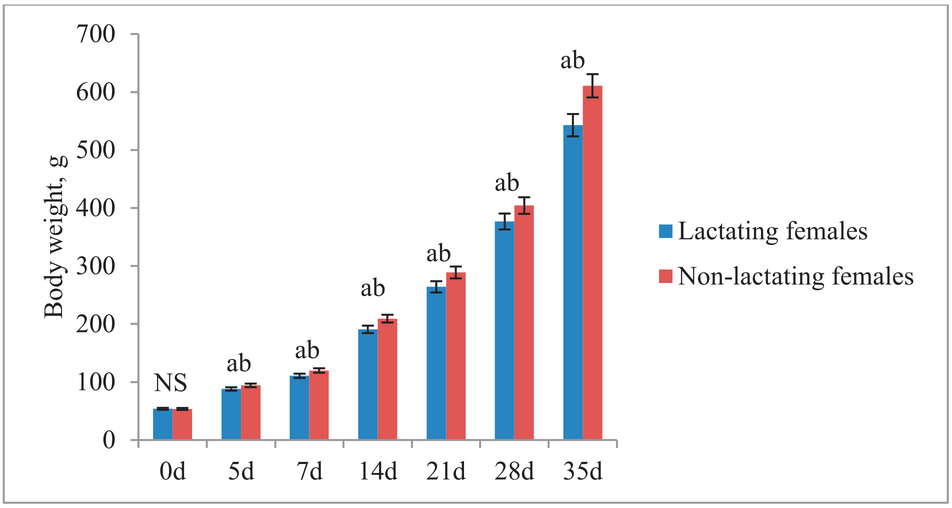

Fig. 3. Evolution of kits' body weight in lactating and non-lactating females.
Individual body weight at 0 (birth), 5, 7, 14, 21, 28 and 35 days (weaning).
a and b: different letters indicate statistically significant differences ($P < 0.05$). NS: not significant.

weight gains than those born form lactating females (92.27 g *vs* 81.09 g from 7 days to14 days, 79.66 g *vs* 72.11 g from 14 days to 21 days, 117.26 g *vs* 113.29 g from 21 days to 28 days and 201.73 g *vs* 172.99 g from 28 days to 35 days; $P < 0.05$). The differences noted for individual weight and weight gains lost their significance when they were corrected by the number of total new-borns.

Effect of parity order

At parturition, individual weight of kits born from multiparous females was significantly heavier than those born from primiparous females (Fig. 4) (53.20 g *vs* 49.80 g; $P < 0.05$) and those born from nulliparous females (53.20 g *vs* 42.52 g; $P < 0.05$). The differences did not disappear when the body weight was corrected by the number of total new-borns.

Between 5 and 7 days of age, the evolution of body weight and weight gains of the kits born from multiparous and primiparous females became comparable. However, the kits born from nulliparous females were significantly lighter than those born from primiparous females (83.01 g *vs* at 5 days and 105.04 g *vs* 118.58 g at 7 days) and those born from multiparous females (83.01 g *vs* 97.09 g at 5 days and 105.40 *vs* 121.81 g at 7 days). The same differences were noted for the weight gains between birth to 5 days and between 7 days to 14 days.

Between 14 days and 21 days of age, the differences recorded between the parities tend to persist. Kits born from nulliparous females were always lighter than those born from nulliparous and multiparous (respectively 170.86 g *vs* 211.33 g and 217.96 g at 14 days and 220.93 g *vs* 298.7 g and 311.3 g at 21 days; $P < 0.05$). However, the kit body weights were comparable between primiparous and multiparous

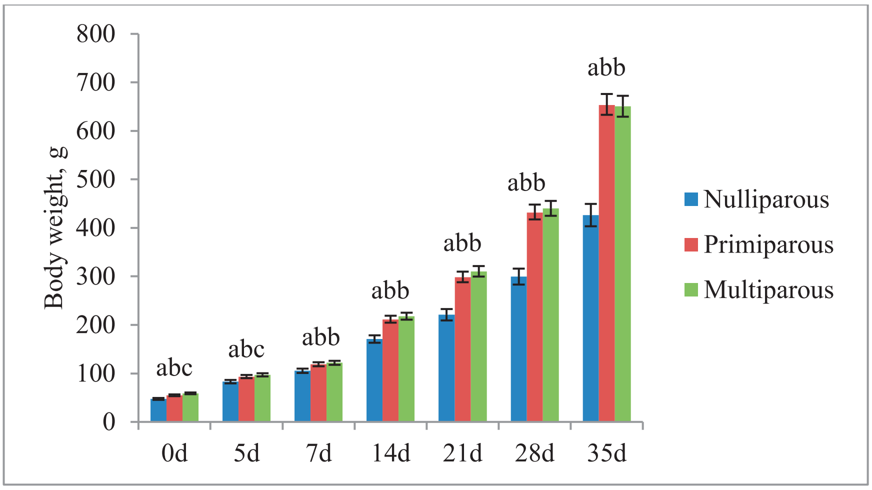

Fig. 4. Evolution of kits' body weight according to the parity of the dams.
Individual body weight at 0 (birth), 5, 7, 14, 21, 28 and 35 days (weaning).
a, b, c: different letters indicate statistically significant differences ($P < 0.05$).

females for the same dates. Furthermore, the kits born from nulliparous females showed significantly lower weight gains compared with those born from primiparous (68.75 g *vs* 94.82 g between 7 days and 14 days and 50.54 g *vs* 86.93 g between 14 days and 21 days) and multiparous females (68.75 g *vs* 96.45 g between 7 days and 14 days and 50.54 g *vs* 90.18 g between 14 days and 21 days). In contrast, kit weight gains were comparable between primiparous and multiparous females for the same dates. It should be noted that when the number of alive kits was used as a covariate, the differences for individual body weight and weight gain remained significant ($P > 0.05$).

Effect of nest quality

The evolution of individual body weight, from birth to weaning and according to the nest quality, is presented the Fig. 5. The body weight of kits was significantly higher when they were born in a nest of poor quality compared with those born in a nest of intermediate (53.09 g *vs* 46.88 g; $P < 0.05$) and excellent qualities (53.09 g *vs* 45.56 g; $P < 0.05$). This difference remained significant when the body weight was corrected by the number of total new-born kits.

At 5 days and 7 days of age, the kits born in a nest of poor quality were always significantly heavier than those born in a nest of intermediate or excellent qualities. The difference remained significant even when the body weight was corrected by the number of kits born alive. On the other hand, the body weights of kits born in a nest of excellent or intermediate qualities were comparable.

Weight gain recorded between birth and 5 days varied significantly between the three nest categories. The kits born in a nest of poor quality showed a significantly higher weight gain compared with those born in a nest of intermediate quality (43.32 g *vs* 29.47 g; $P < 0.05$) and those born in a nest of excellent quality (43.32 g *vs* 35.61 g; $P < 0.05$). No difference was found among categories of nests for weight gain measured between 5 days and 7 days.

Between 7 and 35 days of age, the evolution of individual body weight and weight gain was comparable between the 3 nest categories. However, at 35 days, kits born in a nest of excellent quality were heavier compared with those born in a nest of intermediate quality (611.88 g *vs* 561.87 g; $P < 0.05$). This difference lost its significance when the number of alive kits was used as a covariate. Weights were comparable between kits born in a nest of poor and excellent qualities on the one hand and intermediate quality on the other hand. The same results were observed for weight gain from 21 days to 28 days and 28 days to 35 days.

Effect of birth place

In this study, the body weight of kits born outside the nest was significantly higher than those born in the nest (52.25 g *vs* 44.76 g; $P < 0.05$) (Fig. 6). This difference remained significant when the weight was corrected by the number of total new-borns. The same results were noted for the body weight at 5 days and 7 days and also for the weight gain from birth to 5 days. However, when the number of total new-born kits was used as covariable, the difference between kits born inside a nest or in a cage disappeared.

At 14 days, kits born in a cage were always heavier than those born in the nest (206.35 g *vs* 193.69 g; $P < 0.05$). This difference remained significant when the number of alive kits was introduced as a covariate in the statistical model. The weight gain between 7 days and 14 days was comparable between kits born in a nest or in a cage. From 21 days , weights and weight gains became similar between both places of birth.

Effect of cannibalism

The evolution of individual body weights

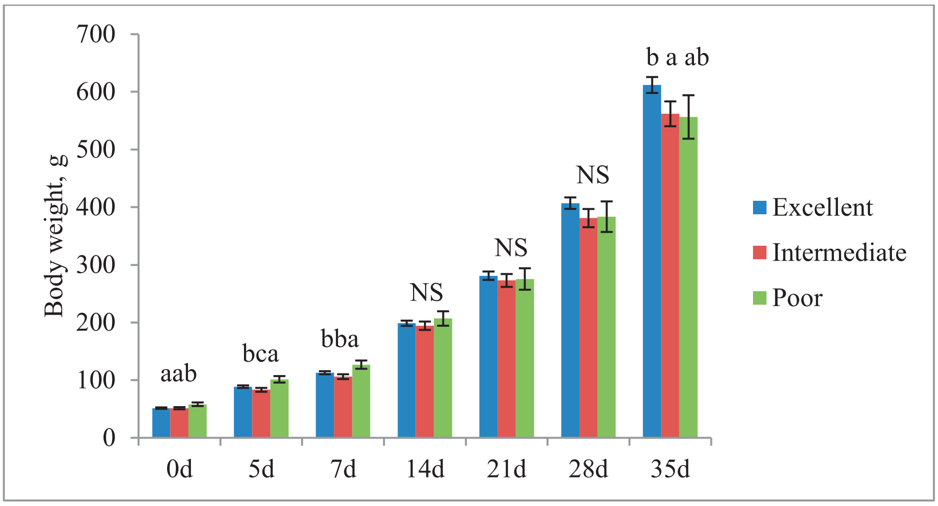

Fig. 5. a, b, c: different letters indicate statistically significant differences ($P < 0.05$). NS: not significant.

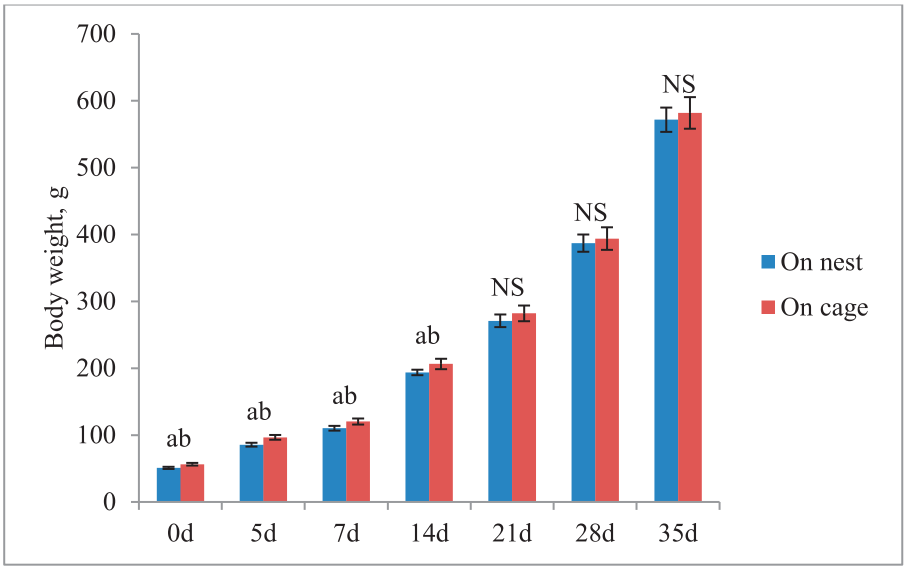

Fig. 6. Evolution of kits' body weight according to the location of birth.
Individual body weight at 0 (birth), 5, 7, 14, 21, 28 and 35 days (weaning).
a and b: different letters indicate statistically significant differences ($P < 0.05$). NS: not significant.

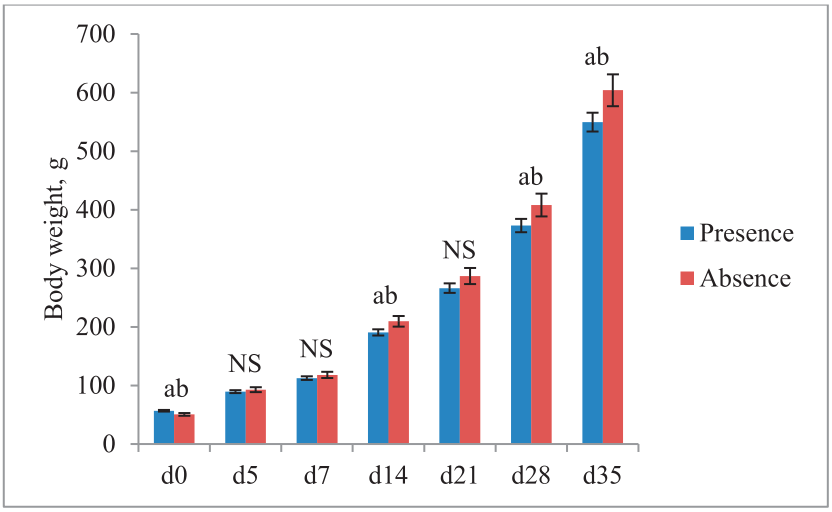

Fig. 7. Evolution of kits' body weight according to the occurrence of cannibalism in litter.
Individual body weight at 0 (birth), 5, 7, 14, 21, 28 and 35 days (weaning).
a and b: different letters indicate statistically significant differences ($P < 0.05$). NS: not significant.

according to the occurrence of cannibalism event in litter is presented the Fig. 7. At birth, the individual weight of kits was higher when the kit was born in litter with cannibalism (52 g *vs* 45.02 g; $P < 0.05$). These differences persisted even when the weight was corrected by the number of total new-born kits.

In contrast to the individual weight of kits at 5 days, which did not differ significantly between litters with and litters without cannibalism, weight gain between birth and 5 days was higher in litters without cannibalism phenomena (40.33 g *vs* 31.94 g; $P < 0.05$). This difference persisted even when the number of total new-borns was added as covariable to the statistical model.

The individual body weight at 7 days and weight gain between 5 days and 7 days were similar between litters with and without cannibalism. At 14 days, individual body weight and weight gain between 7 days and 14 days were significantly higher for kits born in litters that did not have cannibalism at parturition ($P < 0.05$). When the body weight was corrected by the number of alive kits, the difference measured between the two groups (absence or presence of cannibalism) disappeared for the individual body weight at 14 days, but persisted for the weight gain between 7 days and 14 days.

Individual body weight of kits at 21 days and weight gain between 14 days and 21 days of age showed no difference between litter recording occurrence of cannibalism or not.

The body weight at the age of 28 days, 35 days and the weight gain between 28 days and 35 days were significantly higher for rabbits born in a litter that did not exhibit cannibalism at birth. When these three traits were corrected by the number of alive kits, the differences noted disappeared. Furthermore, weight gain between 28 days and 35 days was noted related to the occurrence of cannibalism at birth.

Effect of sex

The body weight of male kits was slightly higher than that of female kits at birth (47.61 g *vs* 46.48 g; $P < 0.05$) (Fig. 8). However, for the rest of the period, the body weights and weight gains were similar between both sexes.

Discussion

The individual body weight of kits born alive was similar to that obtained by Sid *et al.* (2018), but lower than that measured by Boudour *et al.* (2020) on the same line of rabbits. In addition, the weight of survivor kits and their weight gains were higher than those of dead kits regardless of the study period. Our results are in agreement with the literature (Belabbas *et al.,* 2023). Heavier kits are always successful to get a teat during the short nursing time, they grow better and survive longer compared with lighter kits (Agea *et al.,* 2019). It was also reported that the lightest kits are likely to die very quickly or, if they survive, they will have a lower probability of survival after weaning (Gyovai *et al.,* 2004). Moreover, the lower birth weight is associated with a higher risk of hypothermia and

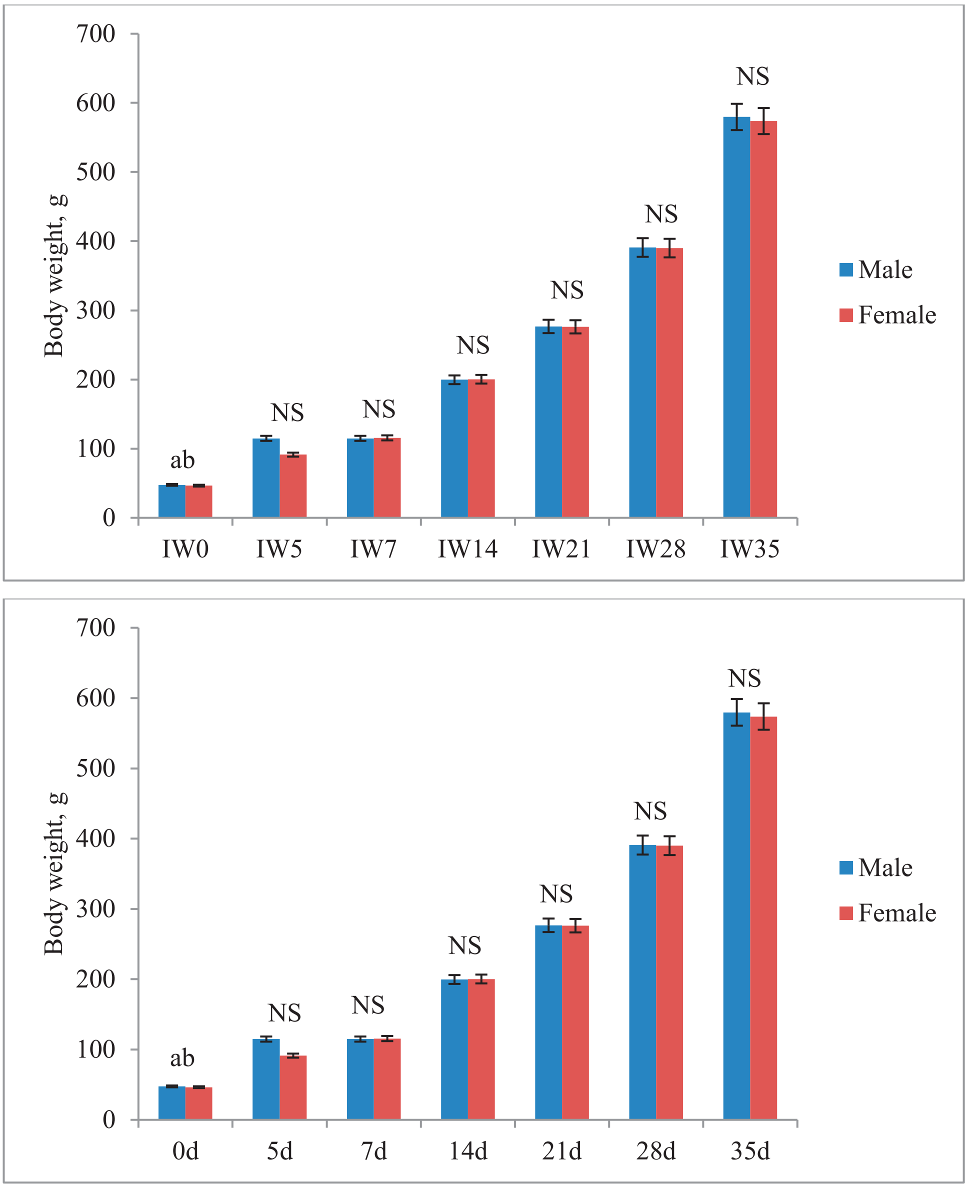

Fig. 8. Evolution of kits' body weight according to their sex.
Individual body weight at 0 (birth), 5, 7, 14, 21, 28 and 35 days (weaning). a and b: different letters indicate statistically significant differences ($P < 0.05$).
NS: not significant.

mortality related to a lower ratio of brown adipose tissue to body weight (Szendrö *et al.,* 2019).

The season had a significant effect on kits' individual body weight but only during the first week of life. Kits born in autumn were significantly higher than those born in summer. Several studies have shown a negative effect of the summer season on the weight and growth of kits, in agreement with our study (Sid *et al.,* 2018; Boudour *et al.,* 2020). This could be related to a lower weight of females in summer compared with autumn, which is itself linked to a low food intake, reducing *in utero* growth of kits (Nardone *et al.,* 2010). In addition, daily weight gain and feed intake of growing kits decreased during high temperature periods (Marai *et al.,* 2001). Elmaghraby *et al.* (2004) and Zerrouki *et al.* (2007) did not find a significant effect of season on weight and weight gains at either 28 days or weaning. Up to 21 days of age, kits are dependent on maternal milk, thus reducing the effect of season on growth (Ludwiczak *et al.,* 2021). The introduction of solid pelleted diet after may explain the differences in weight and weight gains observed between seasons (Elmaghraby *et al.,* 2004).

The effect of lactation on kits' growth was significant from the fifth day after birth, in favor of kits gestated in non-lactating females. Several studies agree that non-lactating females, at the time of mating, give a higher litter size, survival rate and growth of kits in the preweaning period (García-Ximénez *et al.,* 1995; Agea *et al.,* 2019). Castellini *et al.* (2010) reported that the deterioration in body condition of lactating rabbits can affect the viability and growth of their kits. On the other hand, our study shows that the difference in kit weights between lactating and non-lactating females is related to litter size because when the kits' body weight was corrected by the number of total new born or alive kits, the difference between females disappeared.

The parity order of the dam showed a significant effect on kits' growth over all the preweaning period, and kits gestated in nulliparous were the lightest. Our results agree with those reported by Zerrouki *et al.* (2007). Similarly, Elmaghraby *et al.* (2004) noted that multiparous females raised heavier kits at birth, but from 21 days of age, the weights did not differ between parities. However, multiparous females (2 parities and above) appeared to have more uniform litters, higher weight and body gain compared with females of other parities. Furthermore, Ouyed *et al.* (2007) indicated that only the average weight of kits at birth and at weaning varied according to the parity order. Kits weighed 13 g and 171 g more at birth and at weaning, respectively in multiparous females compared with nulliparous. This could be due to changes in the mother's physiological efficiency, in particular, those related to food and to the intrauterine environment provided during gestation with advancing of parity (Afifi *et al.,* 1988). In addition, milk production in rabbits increases with the number of parities, which is reflected on body weight gain of kits (Bakr *et al.,* 2015). Courreaud *et al.* (2000) have shown that primiparous females can react more aggressively to stimuli from their kits. This may affect their willingness to position themselves adequately over their kits to nurse them. These authors explained that undergoing a first cycle of reproduction might stimulate the function of the chemo emission system involved in the production and emission of pheromonal signals which direct teat seeking and suckling behavior in the offspring. Moreover, Bakr *et al.* (2015) have shown that milk production and maternal behavior improve with advancing of the parity number.

At the first week of age, kits born in a nest of poor quality were heavier compared with those born in intermediate or excellent nest quality. Our findings are in contradiction with those noted by Canali *et al.* (1991) who reported that kits born in a nest of excellent quality showed a higher body weight at 5 days of age. A lower weight of kits born in a nest of excellent quality would be linked to factors other than nest quality. Indeed, birth weight is affected by a numerous *in utero* factors, in particular, the number of blood vessels reaching each implantation site (Belabbas *et al.,* 2012), position and available uterine space for each fetus (Bautista *et al.,* 2015), female weight before mating (Jimoh *et al.,* 2017), parity order (Apori *et al.,* 2014) and litter size (Lenoir *et al.,* 2012). Moreover, birth weight plays an important role in growth and survival of kits in the preweaning period (Bautista *et al.,* 2005). Mucino *et al.* (2009) have reported that heavier kits compete more effectively for maternal milk, occupy a proper warm site in the middle of a nest to maintain body temperature and grow faster. These findings might suggest that the higher weight of kits has compensated the unfavorable effect of poor nest quality on kits' development during the first 5 days of life. It should be noted that the absence of nest construction in rabbits varies between 2.3% and 9% (Szendrô *et al.,* 1996). This phenomenon is not related to a lack of experience of the female, but may be due to specific stimuli such as endocrine changes, environmental factors like the season of kindling (González-Redondo, 2010), and genetic factors including breed which appears to be linked to hormonal sensitivities to estrogen and prolactin (González-Mariscal *et al.,* 2007). From 14 days, the body weights and weight gains became comparable between the three nest categories, then higher for the kits born in a nest of excellent quality, which is in agreement with Canali *et al.* (1991).

In our study, heavier kits were found in a cage at birth, which corroborates the findings of Briens (2011). This author noted a higher weight when kits were born outside of the nest. However, when the number of total kits born was used as a covariate, we did not find any significant difference between weights of kits born in a cage or in a nest. This indicates that the difference in weights may be linked to the litter size, which is in agreement with literature (Olateju and Chineke, 2022).

During the first two weeks of age, the differences in body weights initially noted persisted. This is related to the higher birth weight of kits born in a cage, which favors better growth. Similarly, weight gains between birth and 5 days were higher in kits born outside the nest. However, from 7 days onwards, the weight gains measured between the different dates became comparable, as a consequence of a reduced effect of birth weight on growth. In fact, regardless of the place of birth, when litter is placed in the nest, the kits are subjected to the same environmental conditions, their growth depends on their mother's milk production and their ability to ingest a sufficient quantity of milk during the short suckling period (Martínez-Paredes *et al.,* 2018).

The occurrence of cannibalism in litter was associated with higher body weights of kits at birth, which could be related to the different factors affecting body weight at birth rather than to the occurrence of cannibalism in litter. It should be noted that cannibalism is often reported in litters with heavy kits, responsible of dystocia and stress for the female at kindling (González-Redondo, 2010). Despite their higher birth weight, at 5 days and 7 days, kits born in litter that showed cannibalism had a similar weight compared with those born in litter without cannibalism. However, the weight gains from birth to 5 days were higher for kits born in litter that presented cannibalism. From t 14 days of age, weights and weight gains recorded at different dates were higher for kits born in litter without cannibalism at birth. To the best of our knowledge, there are no researches studying the effect of cannibalism at parturition on the subsequent development of the litter. Our results suggest that rabbits surviving after cannibalism, in spite of their higher weight, did not have higher weight gain. This seems to be related to the stress caused on the day of birth. In fact, stress in rabbits can cause anorexia. Cannibalism is also linked to the lack of experience of females, primiparous rabbits being the most affected (González-Redondo *et al.,* 2010). The inhibition of cannibalistic behavior with mutilation and consumption of protruding parts or the whole body of the kits is part of the development of the maternal instinct in domestic or wild rabbits. González-Redondo *et al.* (2010) reported that in certain lines of rabbits, females are very nervous or have a poorly developed maternal instinct with a tendency to ignore or devour their kits. In these cases, the construction of the nest for the new-borns is often neglected and contains little or no straw or hair.

Males were heavier than female kits only at birth. Bolet *et al.* (1996) indicated that males were significantly heavier than females at birth (4 g). They maintained their superiority at weaning (19.3 g), although their growth rate was only significantly greater during the first two weeks. In contrast, Agea *et al.* (2019) reported that weight at 4 days of age was comparable between the two sexes. Also, Szendro *et al.* (1996) showed that differences in weight between males and females only became significant at 12 weeks of age in favor of females.

Conclusion

In conclusion, the weight of kits during the preweaning period was affected mainly by lactation. Indeed, lactating females had heavier kits than those of non-lactating females during all the lactation period. Besides, the parity order of the dam affected the kits' body weight, and multiparous females always had heavier kits compared with nulliparous. Finally, occurrence of cannibalism in litter reduced the body weight of kits at 28 days and at weaning. Increased delivering-mating interval and reducing stress in the *peripartum* period could reduce the effect of pregnancy-lactation overlap and the occurrence of cannibalism and litter abandonment in cages.

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Conflict of interests

Authors declare no conflict of interest.

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