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PRENATAL FACTORS AFFECTING THE PROBABILITY OF SURVIVAL BETWEEN BIRTH AND WEANING IN RABBITS

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Abstract: The aim of this study was to analyse the relationships between kit birth weight and litter size with kit survival from birth to weaning, and to estimate the effects of place of birth, nest quality, cannibalism, lactation, parity order, season and sex. A total of 1696 kits from 82 females of the ITLEV2006 synthetic line were used in this study. A logistic regression was performed. Kit birth weight was directly related to the probability of the kit's survival from birth to weaning, and increasing birth weight by one gram increased the likelihood of kit survival by 8% to 10% ($P<0.001$). In line with the decrease in birth weight of kits as the number of kits at birth increases, litter size showed a negative relationship to the probability of survival from birth to weaning, and increasing the litter by one kit at birth decreased the probability of survival of the kits by 5% to 9% ($P<0.05$). Regarding effects, cannibalism events in the litter decreased the probability of survival of the kits in the first week of life ($P<0.01$). Being born in the cage decreased the probability of survival of the kits from birth to weaning, and kits born outside the nest had a lower chance of survival than those born inside the nest ($P<0.01$). The order of parturition had a positive effect on probability of survival of the kits from 5 days of age to weaning ($P<0.05$). Female kits had a lower chance of survival than male kits, but only until 5 days of age ($P<0.01$). The lactation status displayed a negative effect on the probability of survival of the kits in the first week of life, and kits gestated in lactating females had a lower chance of survival than those gestated in non-lactating females ($P<0.05$). In conclusion, the probability of kit survival in the first days after parturition was affected mainly by its weight at birth, litter size, cannibalism events, place of birth of kit, parity order, sex and lactation status, while the probability of kit survival at weaning was directly related to its weight at birth, litter size, place of birth of kit and parity order.

Key Words: maternal behaviour, nest, preweaning survival, rabbits, weight.

INTRODUCTION

In rabbit farms, profitability is directly related to the sale of rabbits that reach slaughter weight. Litter size is therefore one priority selection trait in breeding programmes for maternal lines (Prayaga and Eady, 2000; Cartuche *et al.,* 2014). It should be noted that selection for this trait has been successful and has led to an increase in the number of liveborn rabbits per litter (García and Argente, 2020).

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However, increasing litter size may decrease the individual birth weight of the rabbits due to a negative correlation between both traits (Gómez *et al.,* 1998; Poigner *et al.,* 2000a; Prayaga and Eady, 2002). Several studies have reported that kit birth weight is directly related to rabbits' survival and growth rate, being an economically important trait in rabbit production (Metzger *et al.,* 2011; Martínez-Paredes *et al.,* 2018; Agea *et al.,* 2019).

Preweaning deaths of rabbit kits occur mainly from the first 12 h after parturition (54%) until the end of the 1st week of age (70%) (Partridge *et al.,* 1981; Gualterio *et al.,* 1988). Moreover, the nest quality is important for newborn kits rabbits, as it is positively correlated with the survival rate (Canali *et al*., 1991; Matics *et al.,* 2002). According to González-Redondo and Zamora-Lozano (2008), 85% and 92% of kits born in the nest with no hair or straw, respectively, were cannibalised by wild animals.

Individual birth weight of rabbit kits is about 60-70 g, although it can range from 35-90 g (Di Meo *et al.,* 2004). Low body weight would be related to higher mortality and lower weight gain (see review by Szendrö *et al.,* 2019). Elmaghraby and Elkholya (2010) reported that the mortality between 1 and 21 d of age doubled in kits born with a lower than 60 g weight in comparison to those born with a higher weight.

Furthermore, within large rabbit litters, competition among littermates for dam's milk is intensive (Bautista *et al.,* 2008), which increases the probability of death by starvation of weak kits of lower body weight (Elmaghraby and Elkholya, 2010).

In addition, the death of kits in the preweaning period is also related to the season, parity order of the female and its physiological status. In this regard, a higher percentage of dead kits was found in winter than in spring (El-Ashram *et al.,* 2020), in multiparous rather than nulliparous females (Rashwan and Marai, 2000) and in lactating rather than non-lactating females (Rebollar *et al.,* 2009).

The objective of this study was to analyse the relationships between birth weight of kit and litter size with kit survival at birth, at 5, 7, 14, 21, 28 d and at weaning and to estimate the effects of kit birthplace, nest quality, occurrence of cannibalism, lactation, parity order, season and sex.

MATERIALS AND METHODS

The present study was approved by the Scientific Council of Biotechnology Laboratory of Animal Reproduction, University Blida1, Institute of Veterinary Sciences, Algeria.

Animals and housing

In total, 82 nulliparous rabbit does derived from the synthetic line ITELV2006 were used in this experiment. The breeding programme and the characteristics of this line were previously described by Ezzeroug *et al.* (2020). Does were housed individually in flat deck cages (30 height×40 width×70 length cm) with a controlled light/dark cycle (16L:8D) throughout the experimental period. They had *ad libitum* access to a standard commercial pelleted diet named Ouchefoune and distributed by Ouchefoun group (16% crude protein and 15% crude fibre) and water was available *ad libitum* from nipple drinkers.

Does were first mated at 18 wk of age and thereafter 10 d after parturition. Natural mating was performed with males from the same generation as females. Females that did not accept males were mated again 7 d afterwards. Pregnancy testing was carried out by abdominal palpation on day 12 after mating. Four days before parturition, the plastic nest boxes (28 height×30 width×40 length cm) were cleaned, dried in the sun, disinfected and put in place, containing wood chips to allow the female to build her nest. The kits were reared by their dams up to weaning (35 d of age). Adoptions were not practised.

On the day after parturition, early in the morning (at 7:30 a.m.), the nest quality was evaluated using a points system (0: poor, nest contains very little or no hairs. 1: intermediate, nest with a medium amount of hair. 2: excellent, nest filled with hairs that occupy the entire nest box). This evaluation consists of judging only the extent to which the female uses her hair for nest building. The place of kindling was noted (inside of the nest or in the cage). The presence of cannibalism was also noted. We considered that cannibalism had taken place when at least one kit had been devoured by its mother.

Table 1: Temperature and relative humidity by month.

		Temperature Outside (ºC)		Temperature Inside (ºC)		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

A total of 1696 kits born were individually identified, weighted and sexed within 24 h after birth. The total number of kits at kindling, number of liveborn, number of live kits and survival of kits at 5, 7, 14, 21, 28 d and at weaning were recorded.

The study was conducted from June to November 2017. Table 1 shows the temperature and relative humidity by month. Summer runs from June 1 to August 31, and autumn from September 1 to November 30. Tables 2 and 3 display the distribution of the number of dead and live kits and the percentage of dead kits by litter size and individual birth weight, respectively. Table 4 shows the distribution of the number of kits dead and alive at birth, at 5, 7, 14, 21, 28 and 35 d of age by individual birth weight (g).

Statistical analysis

Relationships among the litter size and the individual weight of kit at birth with the survival at birth, at 5, 7, 14, 21 and 28 d post-parturition and at weaning were analysed by logistic regression. The model included place of birth (with two levels: inside or outside of nest), nest quality (with three levels: excellent, intermediate, and poor quality), cannibalism (with two levels: presence and absence of cannibalism), the physiological status of female at mating (with two levels: lactating and non-lactating females), parity order (with three levels: first, second and third parturition), season (with two levels: summer and autumn) and sex effects. The LOGISTIC procedure of the SAS statistical package was used (SAS Institute, 2022).

Table 2: Distribution of the number of dead and live kits and percentage of dead kits by litter size.

Litter size	Total number of kits dead at birth	Total number of kits alive at birth	Percentage of dead kits (%)
≤ 3 kits at birth	9	22	29.0
4 kits at birth	6	30	16.7
5 kits at birth	2	93	2.1
6 kits at birth	2	112	1.7
7 kits at birth	23	96	19.3
8 kits at birth	36	196	15.5
9 kits at birth	22	284	7.2
10 kits at birth	11	239	4.4
11 kits at birth	21	201	9.5
12 kits at birth	20	88	18.5
13 kits at birth	9	43	17.3
≥14 kits at birth	10	121	7.6

Table 3: Distribution of the number of dead and live kits and percentage of dead kits by individual birth weight.

Individual weight at birth (g)	Total number of kits dead at birth	Total number of kits alive at birth	Percentage of dead kits (%)
< 24	51	27	65.4
24–29	15	41	26.8
30-34	10	61	14.0
35–39	15	127	10.6
40-44	11	178	5.8
45–49	13	224	5.5
50-54	10	215	4.4
55-59	13	206	5.9
60-64	7	174	3.8
65-69	9	116	7.2
>7> 70	6	167	3.5

RESULTS

Probability of kit survival including litter size in the model

Table 5 shows the effects of cannibalism, nest quality, place of birth, order of parturition, season, sex and lactation status, together with litter size as a covariate, on the probability of kit survival from the first hours after birth to 35 d of age. All effects, except nest quality and season, had an influence on the probability of kit survival during lactation.

Cannibalism events in the litter decreased the survival probability of the kits in the first week of life. Kits born in a litter with cannibalism events had a chance of survival between 55 and 67% lower than those born in litters without cannibalism events ($P<0.01$).

Being born in the cage decreased the probability of survival of the kits from the first hours after birth to 35 d of life. Kits born outside the nest had a chance of survival between 39 and 67% lower than those born inside the nest ($P<0.01$).

The order of parturition had a positive effect on the probability of survival of the kits from 5 d of life to 35 d of life; each increase by one unit in the order of parturition raised the chance of survival of the kits between 34 to 72% ($P<0.05$).

Table 4: Distribution of number of kits dead and alive at birth, at 5, 7, 14, 21, 28 and 35 d of age by individual birth weight (g).

	< 25	25–29	30-34	35–39	40-44	45–49	50-54	55-59	60-64	65-69	>70
Dead at birth (n=160)	51	15	10	15	11	13	10	13	7	9	6
Alive at birth (n=1536)	27	41	61	127	178	224	215	206	174	116	167
Alive at 5 d (n=1520)	21	40	60	126	178	224	213	205	173	115	165
Alive at 7 d (n=1432)	7	24	47	113	170	217	206	203	169	114	162
Alive at 14 d (n=1307)	6	16	43	102	14	193	193	186	165	98	158
Alive at 21 d (n=1280)	6	16	42	100	144	188	184	184	163	96	157
Alive at 28 d (n=1265)	5	15	42	96	140	185	183	183	163	96	157
Alive at 35 d (n=1259)	4	16	36	86	141	185	176	189	160	109	157

Table 5: Summary of multiple binary logistic regression analysis for survival between birth and weaning in rabbits considering litter size at birth.

	At birth		5 d		7 d		14 d		21 d		28 d		35 d	
	Coeff.	OR	Coeff.	OR	Coeff.	OR	Coeff.	OR	Coeff.	OR	Coeff.	OR	Coeff.	OR
Cannibalism	–1.09^{b}	0.33	–0.96^{b}	0.38	–0.79^{a}	0.45	–0.50	0.60	–0.45	0.63	–0.42	0.65	–0.40	0.66
Nest quality	0.28	1.32	–0.20	0.81	–0.13	0.87	–0.29	0.74	–0.24	0.78	–0.26	0.77	–0.20	0.81
Place of birth	–1.09^{b}	0.33	–0.82^{b}	0.44	–0.68^{b}	0.50	–0.49^{a}	0.61	–0.55^{a}	0.58	–0.67^{b}	0.51	–0.67^{b}	0.51
Order of parturition	0.29	1.34	0.48^{a}	1.62	0.54^{b}	1.72	0.38^{a}	1.46	0.36^{a}	1.43	0.38^{a}	1.45	0.35^{a}	1.42
Season	–0.07	0.93	–0.25	0.78	–0.26	0.77	–0.16	0.85	–0.07	0.93	0.06	0.94	0.01	1.01
Sex	–0.37^{a}	0.68	–0.32^{a}	0.73	–0.20	0.81	–0.02	0.97	0.07	1.07	0.08	1.08	0.09	1.09
Lactation	–0.64^{a}	0.52	–0.77^{b}	0.46	–0.66^{b}	0.51	–0.26	0.77	–0.17	0.84	–0.13	0.87	–0.12	0.88
Litter size at birth	–0.04	0.95	–0.06^{a}	0.94	–0.08^{b}	0.92	–0.08^{c}	0.91	–0.08^{c}	0.92	–0.08^{b}	0.92	–0.08^{b}	0.92

Coeff: Coefficient de regression (β). OR: Odds ratio $^{a}P<0.05$. $^{b}P<0$. $^{c}P<0.001$.

The sex variable showed a negative effect on the probability of survival of the kits from the first hours after birth to 5 d of life; female kits had between 27 and 32% lower chance of survival than male kits ($P<0.01$).

Lactation status displayed a negative effect on the probability of survival of the kits from the first hours after birth to 5 d of life, and kits gestated in lactating females had a 48 to 54% lower chance of survival than those gestated in non-lactating females ($P<0.01$).

Litter size was negatively related to the probability of survival of the kits from 5 d of life to 35 d of life (Table 5, Figure 1), as a consequence of the decrease in the weight of kits when the number of rabbits born at birth increased (Figure 2). Increasing the litter by one kit at birth decreased the probability of survival of the kits by 5 to 9% ($P<0.05$).

Probability of kit survival including individual weight of kit at birth in the model

Cannibalism, nest quality, order of parturition, season and sex effects did not influence the probability of kit survival during lactation when the model included kit birth weight (Table 6).

Next, the significant effects of birth place, lactation status and birth weight will be presented. The place of birth of the kits in the cage was negatively related to the probability of survival of the kits from the first hours after birth to 35 d of life ($P<0.001$). Kits born outside the nest had a 63 to 87% lower chance of survival than those born inside the nest ($P<0.01$). Figure 3 shows that kits with 45 g birth weight had a probability of survival at birth of 90% if born inside the nest, and only 60% if born in the cage. The survival probability was reduced if the kit was born in the cage from

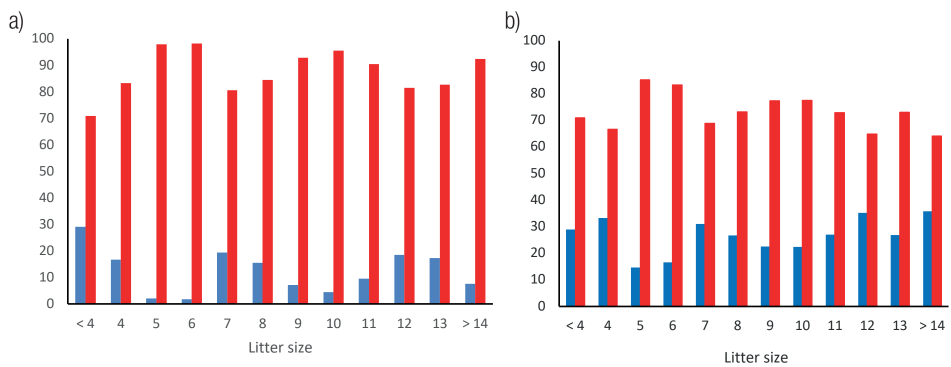

Figure 1: Percentage of kits dead and alive at birth (a) and at 35 d of age (b) according to litter size. ■ % Dead kits; ■ % Alive kits.

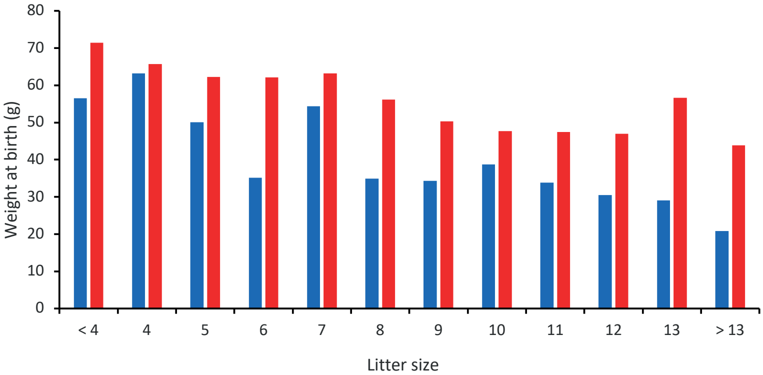

Figure 2: Effect of litter size at birth on birth weight in live and dead kits. ■ Dead kits; ■ Alive kits.

97 to 11% for birth weight higher than 70 g and lower than 25 g, respectively. The effect of the place of birth on the probability of kit survival was maintained until weaning (see Figure 4).

Lactation status displayed a negative effect on the probability of survival of the kits at 5 d of life and at 7 d of life. Kits gestated in lactating females had a chance of survival 42 to 49% lower than those gestated in non-lactating females (P<0.05).

Birth weight was positively related to the probability of survival of the kits from the first hours after birth to 35 d of life (Table 6, Figure 5); increasing birth weight by one gram raised the probability of survival of the kits by 8 to 10% (P<0.001).

DISCUSSION

Cannibalism effect

Correct development of maternal behaviour is characterised by the absence or the low incidence of abnormal behaviours such as cannibalism of the newly-born kits (Selzer *et al.,* 2004; González-Mariscal, 2007). In our study, the occurrence of cannibalism in the litter decreased the probability of kit survival. This finding could be related to the absence of milk ingestion immediately after birth. It was reported that the first suckling allows the kit to save fat tissue, and thus significantly increase its chances of survival (Coureaud *et al.*, 2000). Moreover, kit stress related to the occurrence of cannibalism in its litter can cause anorexia, and consequently reduces the probability

Table 6: Summary of multiple binary logistic regression analysis for survival between birth and weaning in rabbits considering weight at birth.

	At birth		5 d		7 d		14 d		21 d		28 d		35 d	
	Coeff.	OR	Coeff.	OR	Coeff.	OR	Coeff.	OR	Coeff.	OR	Coeff.	OR	Coeff.	OR
Cannibalism	–0.45	0.64	–0.28	0.75	–0.09	0.91	0.19	1.21	0.21	1.23	0.22	1.26	0.25	1.28
Nest quality	0.54	1.71	–0.20	0.81	–0.11	0.89	–0.33	0.71	–0.26	0.77	–0.28	0.75	–0.20	0.81
Place of birth	–1.87[c]	0.15	–1.58[c]	0.20	–1.36[c]	0.26	–0.99[c]	0.37	–1.02[c]	0.36	–1.16[c]	0.31	–1.15[c]	0.32
Order of parturition	–0.15	0.86	0.03	1.03	0.12	1.12	–0.05	0.95	–0.05	0.95	–0.02	0.98	–0.04	0.96
Season	0.09	1.09	–0.21	0.81	–0.31	0.73	–0.25	0.78	–0.14	0.87	–0.13	0.87	–0.06	0.94
Sex	–0.27	0.76	–0.25	0.79	–0.12	0.89	0.08	1.08	0.19	1.21	0.21	1.23	0.21	1.24
Lactation	–0.49	0.61	–0.66[a]	0.51	–0.53[a]	0.58	–0.05	0.95	0.03	1.03	0.07	1.07	0.08	1.08
Weight at birth	0.08[c]	1.09	0.09[c]	1.10	0.09[c]	1.10	0.08[c]	1.09	0.08[c]	1.08	0.08[c]	1.08	0.08**	1.08

Coeff: Coefficient de regression (β). OR: Odds ratio. [a]P<0.05. [b]P<0.01. [c]P<0.001.

of survival (Vicente *et al.,* 1995). It should be noted that this phenomenon is responsible for 0.5 to 26% of preweaning mortality in rabbit (Leone-Singer and Hoop, 2003; El-Ashram *et al.,* 2020) and is due to insufficient drinking water around parturition time (Bergaoui, 1992; Rashwan and Marai, 2000).

Place of birth effect

Kits born in the nest had a higher probability of survival at birth and in the later stages of life than those born in a cage. Kits are born hairless and unable to maintain their body temperature against the cold, and the nest provides the kits with a warm and protective environment (Hull, 1965, Blumetto *et al.,* 2010). Hypothermia represents the second most frequent cause of death during the postnatal period (17%; Rosell, 2005). In addition, 2 or 3 d before parturition, rabbit appeasing pheromone is secreted by the doe in the belly skin, and is mainly present in the fur that the doe pulls out to prepare her nest (Bouvier and Jacquinet, 2008). This pheromone is responsible for appeasement and grouping of the progeny, which allows for keeping them warm. Moreover, cage born kits miss their first suckling, and Argente *et al.* (1999) reported that the probability of survival is reduced when the first suckling is missed, as the does nurse their kits only once a day after parturition.

We have noted that higher body weight at birth significantly increased the individual probability of survival for cage born kits. According to Vicente *et al.* (1995), kits with higher body weight at birth have better corporal reserves and thermoregulatory capacity, which reduce their prenatal mortality. Also, heavy kits at birth have better sensory-motor development than their lighter siblings (Bautista

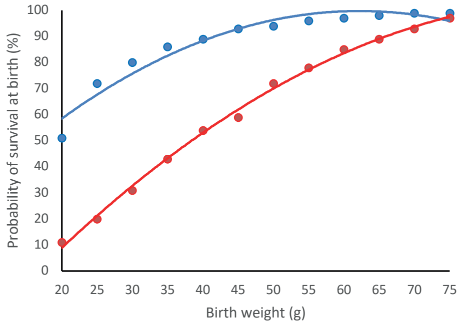

Figure 3: Relationship between survival at birth and individual birth weights for the place of birth (nest or cage). ■ On nest; ■ On cage.

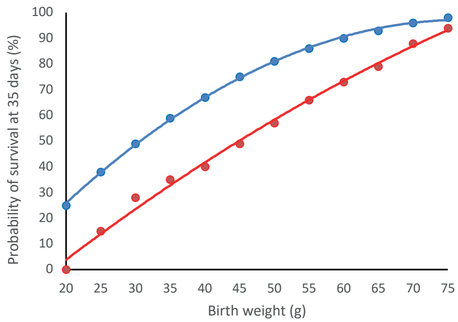

Figure 4: Relationship between survival at 35 d of age and individual birth weights for the place of birth (nest or cage). ■ On nest; ■ On cage.

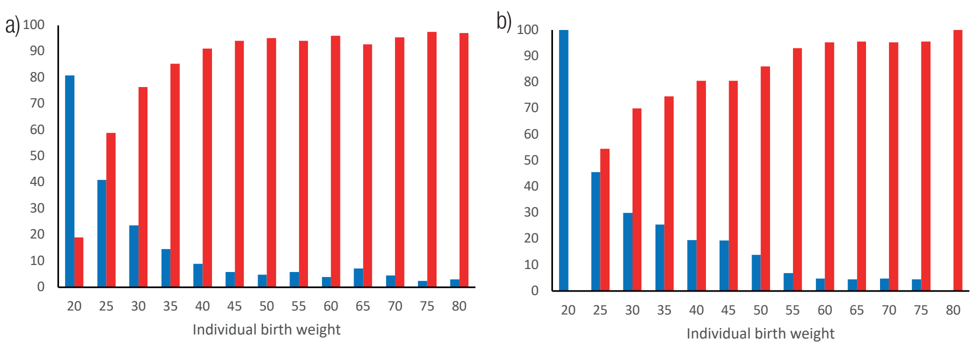

Figure 5: Percentage of kits dead and alive at birth (a) and at 35 days of age (b) according to birth weight. ■ % Dead kits; ■ % Alive kits.

et al., 2005). It should be noted that stress suffered by does in the peripartum or disturbance during birth caused does to give birth on the cage floor and abandon their litters (Rashwan and Marai, 2000; González-Redondo, 2010).

Parity order effect

The parity order of the female has shown a significant effect on kit survival, which increases when the female advances in its parity. Several studies have shown the effect of parity order on mortality and for different genotypes (Kpodekon *et al.,* 2006; Ouyed *et al.,* 2007). Primiparous females present lower mortality than multiparous ones (Briens, 2011). However, Ouyed *et al.* (2007) reported a double mortality rate in the first parity than in the subsequent parities. Similarly, the number of rabbits missing the first suckling is higher in primiparous than in multiparous females (18 *vs*. 9%), and consequently, mortality is also higher between birth and 10 days of life depending on the order of parity (Coureaud *et al.,* 2000). It also seems that the locomotor capacity of newborn kits from multiparous does is better than that of kits born from nulliparous ones (Verga *et al.,* 1986), allowing for good competition during suckling.

Kit sex effect

The sex variable showed a negative effect on the probability of survival and female kits had a lower chance of survival than male kits. Bolet *et al.* (1996) reported higher body weight in kits of male sex, which can increase their probability of survival by increasing their energy reserve and thermoregulatory capacity (García-Ximénez *et al.*, 1995). In our study, the kit weight was similar between both sexes. The bibliography regarding male weight and the sex of kits is contradictory. Agea *et al.* (2019) reported that the body weight at birth is similar between kits of male and female sex. However, Bolet *et al.* (1996) reported that male kits are heavier at birth and maintain their superiority until weaning.

Lactation status effect

Kits gestated in lactating females had a lower chance of survival than those gestated in non-lactating females. When rabbit does are simultaneously pregnant and lactating, they are undergoing a nutritional deficit which affects the probability of the kits' survival (Xiccato *et al.,* 2004; Rebollar *et al.,* 2009). Moreover, Fortun-Lamothe *et al.* (1999) reported that milk production resulted in fewer nutrients and energy being used for the growth of foetuses at 28 d of age, and consequently, reduced their probability of survival by reducing their energy reserve (García-Ximénez *et al.*, 1995).

Litter size effect role

In our study, increasing litter size decreased the probability of survival of the kits as a consequence of the decrease in body weight. Our results agree with those reported in the literature by several authors (Vicente *et al.,* 1995; Argente *et al.,* 1999).

Birth weight effect

In rabbits, birth weight is related to mortality (Elmaghraby and Elkholya, 2010), live performance throughout growth (Szendrő *et al.,* 2006), carcass traits and meat quality (Metzger *et al.,* 2011), and the reproductive performance of rabbit does (Savietto *et al.,* 2011). Our study shows that the probabilities of individual survival at birth and at weaning were related to the body weight of kits at birth, as kits with lower birth weight had a higher probability of mortality. Higher mortality of kits with lower birth weight is due to the suppression of heavier kits on the weak ones, and great competition to get a teat during the short nursing time (Poigner *et al.,* 2000b). Moreover, the lower birth weight is associated with a lower ratio of brown adipose tissue to body weight and which increases the risk of mortality by hypothermia (Dawkins and Hull, 1964). Selection for within-litter uniformity (Bolet *et al.,* 2007) or litter equalisation (Szendrő *et al.,* 1996; Di Meo *et al.,* 2004) may be a way to reduce mortality related to lower birth weight.

CONCLUSION

In conclusion, the probability of kit survival was related to their body weight at birth and litter size. Selection for within-litter uniformity could reduce many disadvantages related to lower body weight at birth. Furthermore, the probability of survival of kit in the first days of life was affected mainly by cannibalism events, place of birth of kit, parity order, sex and lactation status, while the probability of survival of kit at weaning was affected mainly by place of birth of kit and parity order. Improving management of the rabbitry to reduce stress in the *peripartum* period could reduce the occurrence of cannibalism and litter abandonment in cages, and in consequence increase the probability of kit survival.

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REFERENCES

Agea I., García M.L., Blasco A., Argente M.J. 2019. Litter survival differences between divergently selected lines for environmental sensitivity in rabbits. *Animals, 9: 603. https://doi.org/10.3390/ani9090603*

Argente M.J., Santacreu A.M., Climent A., Blasco A. 1999. Phenotypic and genetic parameters of birth weight and weaning weight of rabbits born from unilaterally ovariectomized and intact does. *Livest. Prod. Sci., 57: 159-167. https://doi.org/10.1016/S0301-6226(98)00166-3*

Bautista A., Mendoza-Degante M., Coureaud G., Martinez-Gómez M., Hudson R. 2005. Scramble competition in newborn domestic rabbits for an unusually restricted milk supply. *Anim. Behav., 70: 1011-1021. https://doi.org/10.1016/j.anbehav.2005.01.015*

Bautista A., García-Torres E., Martínez-Gómez M., Hudson R. 2008. Do newborn domestic rabbits *Oryctolagus cuniculus* compete for thermally advantageous positions in the litter huddle? *Behav. Ecol. Sociobiol., 62: 331-339. https://doi.org/10.1007/s00265-007-0420-4*

Bergaoui R. 1992. L'élevage du lapin en Tunisie peut contribuer à résoudre le problème de déficit en viande du pays. *Options Méditerranéennes - Série Séminaires, 17: 23-32.*

Blumetto O., Olivas I., Torres A.G., Villagrá A. 2010. Use of straw and wood shavings as nest material in primiparous does. *World Rabbit Sci., 18: 237-242. https://doi.org/10.4995/wrs.2010.776*

Bolet G., Esparbie J., Falieres J. 1996. Relations entre le nombre de foetus par corne uterine, la taille de portee à la naissance et la croissance pondérale des lapereaux. *Ann. Zootech., 45: 185-200. https://doi.org/10.1051/animres:19960207*

Bolet G., Garreau H., Joly T., Theau-Clément M., Falières J., Hurtaud J., Bodin L. 2007. Genetic homogenisation of birth weight in rabbits: Indirect selection response for uterine horn characteristics. *Livest. Sci., 111: 28-32. https://doi.org/10.1016/j.livsci.2006.11.012*

Bouvier A.C., Jacquinet C. 2008. Pheromone in rabbits: preliminary technical results on farm use in France. *In Proc.: 9th World Rabbit Congress, June 10-13, 2008, Verona, Italy, 303-308.*

Briens C. 2011. Mortinatalité: méthodologie diagnostiques en élevage cunicole et premier résultats. *In Proc.: 14èmes Journées de la Recherche Cunicole, 22-23 Novembre, 2011, Le Mans, France, 57-60.*

Canali E., Ferrante V., Todeschini R., Verga M., Carenzi C. 1991. Rabbit nest construction and its relationship with litter development. *Appl. Anim. Behav. Sci., 31: 259-266. https://doi.org/10.1016/0168-1591(91)90010-U*

Cartuche L., Pascual M., Gómez E.A., Blasco A. 2014. Economic weights in rabbit meat production. *World Rabbit Sci., 22:165-177. https://doi.org/10.4995/wrs.2014.1747*

Coureaud G., Schaal B., Coudert P., Rideaud P., Fortun-Lamothe L., Hudson R., Orgeur P. 2000. Immediate postnatal sucking in the rabbit: Its influence on pup survival and growth. *Reprod. Nutr. Dev., 40: 19-32. https://doi.org/10.1051/rnd:2000117*

Dawkins R.J., Hull D. 1964. Brown adipose tissue and response of newborn rabbits to cold. *J. Physiol., 172: 216-238. https://doi.org/10.1113/jphysiol.1964.sp007414*

Di Meo C., Gazaneo P.M., Racca C., Bovera F., Piccolo G., Nizza A. 2004. Effect of birth weight and litter size on productive performance of rabbits. *Asian-Aust. J. Anim. Sci., 17: 1158-1161. https://doi.org/10.5713/ajas.2004.1158*

Elmaghraby A.M.M., Elkholya S.Z. 2010. Characterizing litter losses in purebred New Zealand White rabbits. *Lucrări Ştiinţifice, 54: 304-310, Seria Zootehnie.*

El-Ashram S., Aboelhadid S.M., Abdel-Kafy E.M., Hashem S.A., Mahrous L.N., Farghly E.M., Kamel A.A. 2020. Investigation of pre- and post-weaning mortalities in rabbits bred in Egypt, with reference to parasitic and bacterial causes. *Animals, 10: 537. https://doi.org/10.3390/ani10030537*

Ezzeroug R., Belabbas R., Argente M.J., Berbar A., Diss S., Boudjella Z., Talaziza D., Boudahdir N., García M.L. 2020. Genetic correlations for reproductive and growth traits in rabbits. *Can. J. Anim. Sci., 100: 317-322. https://doi.org/10.1139/cjas-2019-0049*

Fortun-Lamothe F., Prunier A., Bolet G., Lebas F., 1999. Physiological mechanisms involved in the effects of concurrent pregnancy and lactation on foetal growth and mortality in the rabbit. *Livest. Prod. Sci., 60: 229-241. https://doi.org/10.1016/s0301-6226(99)00096-2*

García M.L., Argente M.J. 2020. The genetic improvement in meat rabbits. *Lagomorpha Characteristics. https://doi.org/10.5772/intechopen.93896*

García-Torres E., Hudson R., Castelan F., Martínez-Gómez M., Bautista A. 2015. Differential metabolism of brown adipose tissue in newborn rabbits in relation to position in the litter huddle. *J. Thermal Biol., 51: 33-41. https://doi.org/10.1016/j.jtherbio.2015.03.003*

García-Ximénez F., Vicente J., Viudes-de-Castro M.P. 1995. Neonatal performances in 3 lines of rabbit (litter sizes, litter and individual weights). *Ann. Zootech., 44: 255-261. https://doi.org/10.1051/animres:19950305*

González-Mariscal G. 2007. Mother rabbits and their offspring: timing is everything. *Dev. Physchobiol., 49: 71-76. https://doi.org/10.1002/dev.20196*

González-Redondo P., Zamora-Lozano M. 2008. Neonatal cannibalism in cage-bred wild rabbits (*Oryctolagus cuniculus*). *Arch. Med. Vet., 40: 281-287. https://doi.org/10.4067/S0301-732X2008000300009*

González-Redondo P. 2010. Maternal behaviour in *peripartum* influences preweaning kit mortality in cage-bred wild rabbits. *World Rabbit Sci., 18: 91-102. https://doi.org/10.4995/wrs.2010.18.12*

Gómez E.A., Baselga M., Rafel O., Ramon J. 1998. Comparison of carcass characteristics in five strains of meat rabbit selected on different traits. *Livest. Prod. Sci., 55: 53-64. https://doi.org/10.1016/S0301-6226(98)00117-1*

Gualterio L., Valentini A., Bagliacca M. 1988. Effect of season and of parturition order on mortality rate at birth and in the nest. *In Proc.: 4th World Rabbit Congress, October 10-14, 1988, Budapest, Hungary, 247-251.*

Hull D. 1965. Oxygen consumption and body temperature of newborn rabbits and kittens exposed to cold. *J. Physiol., 177: 192-202. https://doi.org/10.1113/jphysiol.1965.sp007585*

Kpodekon M., Youssao A.K.I., Koutinhouin B., Djago Y., Houezo M., Coudert P. 2006. Influence des facteurs non génétiques sur la mortalité des lapereaux au Sud du Bénin. *Ann. Méd. Vét., 150: 197-201.*

Leone-Singer A., Hoop R. 2003. Untersuchung zur säuglingsmortalität bei mastkaninchen in der Schweiz. *Tierheilk, 145, 329-335. https://doi.org/10.1024/0036-7281.145.7.329*

Martínez-Paredes E., Rodenas L., Pascual J.J., Savietto D. 2018. Early development and reproductive lifespan of rabbit females: implications of growth rate, rearing diet and body condition at first mating. *Animal, 12: 2347-2355. https://doi.org/10.1017/s1751731118000162*

Matics Zs., Szendrő Zs., Altbäcker V., Biróné Németh E., Radnai I., Káplár I., Gyovai M., Metzger Sz. 2002. Nest building of domestic rabbits. *In Proc.: 14th Hungarian Conference on Rabbit Production, May 22, 2002, Kaposvár, Hungary, 37-41.*

Metzger S.Z., Bianchi M., Cavani C., Petracci M., Szabo A., Gyovai M., Biro-Nemeth E., Radnai I., Szendrő Zs. 2011. Effect of nutritional status of rabbit kits on their productive performance, carcass and meat quality traits. *Livest. Sci., 137: 210-218. https://doi.org/10.1016/j.livsci.2010.11.011*

Ouyed A., Lebas F., Lefrancois M., Rivest J. 2007. Performances de reproduction de lapines de races Néo-Zélandais Blanc, Californien et Géant Blanc du Bouscat ou croisées en élevage assaini au Québec. *In Proc.: 12èmes Journées de la Recherche Cunicole, 27-28 Novembre, 2007, Le Mans, France, 145 - 148.*

Partridge G.G., Foley S., Corrigall W. 1981. Reproductive performance in purebred and crossbred commercial rabbits. *Anim. Prod., 32: 325-331. https://doi.org/10.1017//S0003356100027227*

Poigner J., Szendró Zs., Lévai A., Radnai I., Biró-Németh E. 2000a. Effect of birth weight and litter size on growth and mortality in rabbits. *World Rabbit Sci., 8: 17-22. https://doi.org/10.4995/wrs.2000.413*

Poigner J, Szendró Zs., Lévai A., Radnai I., Biró-Németh E. 2000b. Effect of birth weight and litter size at suckling age on reproductive performance in does as adults. *World Rabbit Sci., 8:103-109. https://doi.org/10.4995/wrs.2000.426*

Prayaga K.C., Eady S. 2000. Rabbit farming for meat production in Australia: preliminary estimates of economic values for production traits. *Asian Australas J. Anim. Sci., 13: 357-359.*

Prayaga K.C., Eady S.J. 2002. Factors affecting litter size and birth weight in rabbits. *In Proc.: Association for the Advancement of Animal Breeding and Genetics, Vol 14.*

Rashwan A.A., Marai L. 2000. Mortality in young rabbits: a review. *World Rabbit Sci., 8: 111-124. https://doi.org/10.4995/wrs.2000.427*

Rebollar P., Pérez-Cabal M., Pereda N., Lorenzo P.L., Arias-Álvarez M., García-Rebollar P. 2009. Effects of parity order and reproductive management on the efficiency of rabbit productive systems. *Livest. Sci., 121: 227-233. https://doi.org/10.1016/j.livsci.2008.06.018*

Rosell J.M. 2005. The suckling rabbit: health, care and survival. A field study in Spain and Portugal during 2003-2004. *In Proc.: 4th International Conference on Rabbit Production in Hot Climates, February 24-27, 2005, Sharm-El-Sheik, Egypt, 1-9.*

Savietto D., Rodenas L., Martinez-Paredes E., Martinez-Vallespin B., García-Diego F.J., Fernandez C., Pascual J.J., Blas E., Cervera C. 2011. Origen genetico de la conejas, condiciones ambientales de lactancia y superviviencia de gazapos en el cebadero. *In Proc.: XXXVI Symposium de Cunicultura, Peńiscola, 12-13 May, 2011, Castellon, Spain, 65-68.*

Selzer D., Lange K., Hoy S. 2004. Frequency of nursing in domestic rabbits under different housing conditions. *Appl. Anim. Behav. Sci., 87: 317-324. https://doi.org/10.1016/j.applanim.2004.01.013*

Szendrő Zs., Palos J., Radnai L., Biro-Nemeth E., Romvari R. 1996. Effect of litter size and birth weight on the mortality and weight gain of suckling and growing rabbits. *In Proc.: 6th World Rabbit Congress, July 9-12, 1996, Toulouse, France, 365-369.*

Szendrő Zs., Gyovai M., Maertens L., Birone-Nemeth E., Radnai I., Matics Zs., Princz Z., Gerencser Zs., Horn P. 2006. Influence of birth weight and nutrient supply before and after weaning on the performance of rabbit does to age of the first mating. *Livest. Sci., 103: 54-64. https://doi.org/10.1016/j.livsci.2006.01.006*

Szendrö Zs., Cullere M., Atkári T., Dalle Zotte A. 2019. The birth weight of rabbits: influecing factors and effect on behavioural, productive and reproductive traits: a review. *Livest. Sci., 230. https://doi.org/10.1016/j.livsci.2019.103841*

Verga M., Canali E., Pizzi F., Crimella C. 1986. Induced reactions in young rabbits of dams of different parity and reared on two different nursing schedules. *Appl. Anim. Behav. Sci., 16: 285-293. https://doi.org/10.1016/0168-1591(86)90121-8*

Vicente J., García-Ximénez F., Viudes-de-Castro M.P. 1995. Neonatal performances in 3 lines of rabbit (litter sizes, litter and individual weights). *Ann. Res., 44: 255-261. https://doi.org/10.1051/animres:19950305*

Xiccato G., Trocino A., Sartori A., Queaque P.I. 2004. Effect of parity order and litter weaning age on the performance and body energy balance of rabbit dos. *Livest. Prod. Sci., 16: 239-251. https://doi.org/10.1016/S0301-6226(03)00125-8*