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EFFECT OF EARLY FEED RESTRICTION ON PERFORMANCE AND HEALTH STATUS IN GROWING RABBITS SLAUGHTERED AT 2 KG LIVE-WEIGHT

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Abstract: The effect of a time-limited access to the feeders (8 h per d from 9:30 to 17:30) on fattening performance and health status was studied in rabbits reared until 2 kg live-weight as typical in the Spanish market. For this purpose, the same diet (10.5 MJ digestible energy/kg, 38.9% neutral detergent fibre and 18.4% crude protein on dry matter basis) was used over two consecutive trials. A total of 192 growing rabbits (96 in each trial) were weaned at 35 d and assigned to 2 different feeding treatments (continuously fed *ad libitum* or restricted from 35 until 49 d). In the first trial, feed restriction reduced daily feed intake (94.3 *vs*. 74.2 g; $P<0.001$), daily weight gain (43.6 *vs*. 27.1 g; $P<0.001$) and impaired feed conversion rate (FCR) (2.28 *vs*. 2.92, $P<0.001$) in the first 14 d after weaning. Later on, no feed restriction was applied and a compensatory growth was observed in previously restricted rabbits (44.8 *vs*. 54.8 g/d; $P<0.001$). Early restricted rabbits did not reach the Spanish commercial weight (2 kg) at 63 d of age and weighed less than full-fed rabbits (1989 *vs*. 1888 g; $P=0.001$). Moreover, feed restriction did not improve FCR in the whole fattening period (2.56 on average). The second trial was extended until 70 d to permit restricted rabbits to attain market weight. However, at that age, live weight of restricted rabbits was also lower than that of rabbits always fed *ad libitum* (2285 *vs*. 2101 g; $P=0.001$). In the first trial, no health problem was recorded (average mortality 1.04%) whereas in the second trial feed restriction allowed both mortality (25.6 *vs*. 6.34%, $P=0.017$) and morbidity (41.4 *vs*. 12.7%, $P=0.004$) to decrease. The higher number of losses in the second trial made economic FCR differ from scientific FCR (3.63 *vs*. 2.89, on average) in the 35–70 d period. Moreover, morbidity increased heterogeneity of fattening performance. In conclusion, the interest of feed restriction in Spanish fattening rabbit farms is mitigated by the conventional market weight. Nevertheless, in a context with high rates of digestive troubles, a time-limited access to the feeder enhances health status on the farm and could justify the short delay necessary to reach slaughter weight.

Key Words: fattening rabbits, feed conversion, feed restriction, growth performance, health status.

INTRODUCTION

The effects of feed restriction have been broadly studied in pigs (Lovatto *et al*., 2006), poultry (Tumova *et al*., 2002) and even in human beings (Polivy, 1996). Indeed, feed restriction has frequently been suggested as a strategy to improve feed efficiency either in broiler chickens (Lee and Leeson, 2001) or turkeys (Skrivan and Tumova, 1995) and, in recent years, as a means to reduce mortality in intensive rearing of chickens (Acar *et al*., 1995; Lippens *et al*., 2000).

Likewise, feed restriction is a common technique in rabbit farming since rabbit breeders commonly limit feed intake of does in order to avoid excessive fattening and enhance reproductive results (Rommers *et al*., 2006). Works tackling feed restriction in growing rabbits are also numerous. Most of them dealt with

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animal growth and organ development (Lebas and Laplace, 1982; Perrier, 1998), meat or carcass quality (Dalle Zotte *et al*., 2005; Tumova *et al*., 2006) or feed efficiency (Maertens and Peeters, 1988; Maertens, 2008). However, studies on the effect of feed restriction on mortality of fattening rabbits are rather scarce (Boisot *et al*., 2003; Gidenne *et al*., 2009a,b) and many of them were carried out before the European ban on antibiotic growth promoters and the onset of new digestive diseases (Castelló and Gurri, 1992; Jerome *et al*., 1998). Besides, most latter studies were conducted in France, where field practices differ from Spain in several important aspects such as market age/weight and strains.

The aim of this work was therefore to quantitatively evaluate the effect of a feed restriction, performed by a temporary time-limited access to the feeder, on productive performances and health status of fattening rabbits reared until 2 kg live weight (LW).

MATERIALS AND METHODS

Animals and housing

This study was approved by the Ethics Committee of the Polytechnic University of Madrid. Rabbits were handled according to the principles for the care of animals in experimentation (Spanish Royal Decree 1201/2005).

Two consecutive trials were conducted at the experimental facilities of the Polytechnic University of Madrid. In each trial, 12 different multiparous New Zealand×Californian does with a litter size of eight kits were chosen. The 96 mixed-sex rabbits originating from these litters were weaned at 35 d of age (LW 800±9.90 and 807±10.7 g for rabbits of the first and second trial, respectively), moved to a separate building and housed individually in flat-deck cages measuring 600×250×330 mm. Rabbits were slaughtered at 63 d of age in the first trial and at 70 d of age in the second trial. Kits were always kept under controlled environmental conditions (room temperature between 16 and 24ºC; with a 12 h photoperiod; light was switched on at 7:30).

Before the beginning of the first trial, the cages, walls, ceiling and floor were cleaned using high pressure water containing a detergent (RM806 ASF, Alfred KärcherGmbH & Co. KG) and disinfected spraying a disinfectant active against Gram(+) and Gram(−) bacteria, spores, virus, fungi and micoplasms (Sanivir Plus®, Bioplagen, S.L.). Between the first and the second trial, the fattening farm was not disinfected in order to impair hygienic conditions. Before the second trial, a gas welding torch was passed over the cages to burn remaining hairs and then cages were only washed.

Feeding programme

A common diet (Table 1) meeting the essential nutrient requirements of fattening rabbits (De Blas and Mateos, 1998) was used in both trials. At the beginning of each trial, weanling rabbits from each litter were split into 2 homogeneous groups. Thus, 4 rabbits were fed *ad libitum* during the whole fattening period whereas the other four remaining rabbits were fed only 8 h a d (from 09:30 to 17:30) for 14 d after weaning. Afterwards, no feed restriction was applied. Water was always available *ad libitum* throughout both trials. Neither feed nor drinking water was medicated with antibiotics, but the feed contained an anticoccidial drug (diclazuril).

Growth performance and health status

In both trials, all 96 rabbits were used to determine growth performance. To this end, feed consumption and live weight were individually recorded at weaning and on 14, 28 and 35 d of the fattening period (this

Table 1: Diet ingredients and chemical composition.

Ingredients, %		Chemical composition, % DM	
Lucerne hay	33.0	Dry matter (DM)	89.8
Sunflower meal	17.0	Ash	10.0
Barley grain	16.0	Crude protein	18.4
Wheat bran	15.0	Ether extract	4.34
Beet pulp	8.00	Starch	16.0
Wheat straw	3.00	Neutral detergent fibre[2] (NDF)	38.9
Dried distillers grains with solubles	3.00	Acid detergent fibre[2]	22.8
Lard	1.50	Acid detergent lignin[2]	5.46
Calcium carbonate	1.20	Lysine[3]	0.900
Sodium chloride	0.50	Sulphur amino acids[3]	0.620
Sodium bicarbonate	0.20	Threonine[3]	0.686
Magnesium sulphate	0.20	Gross energy, MJ/kg DM	17.3
Monocalcium phosphate	0.70	Digestible energy[4], MJ/kg DM	10.5
L-Lysine	0.20		
Mineral and vitamin premix[1]	0.50		

[1]Premix provided by Trouw Nutrition España S.A. (Madrid, Spain): mineral and vitamin composition (mg/kg diet): Mg, 290; Na, 329; S, 275; Co, 0.7; Cu, 10; Fe, 76; Mn, 20; Zn, 59.2; I, 1.25; Choline, 250; Riboflavin, 2; Niacin, 20; Vitamin B6, 1; Vitamin K, 1; Vitamin E, 30 IU/kg; Thiamine, 1; Vitamin A, 10000 IU/kg, Vitamin D3, 1500 IU/kg, Diclazuril, 1. [2]Samples for sequentially analysed NDF were assayed with a heat stable amylase and expressed exclusive of residual ash. [3]Values calculated from FEDNA (2003). [4]Value estimated according to De Blas *et al*. (1992).

latter age only in the second trial). Thus, daily feed intake, daily weight gain and feed conversion rate (FCR) were calculated for these different periods.

Furthermore, all animals were controlled for mortality and morbidity twice a day. Morbidity rate was the percentage of live animals that showed any of the following symptoms: prostration, bloated abdomen, relatively low body weight, diarrhoea or mucus under the cage. The presence of a morbid animal was counted only once, even if morbidity signs appeared several times on the same animal.

Evaluation of environmental hygiene

Dust samples were collected over the air extractors in the fattening farm at the beginning, on 14 d and at the end of each of the two fattening periods. All samples were analysed according to the ISO 7937 Standard (1997) to enumerate *Clostridium perfringens*. As described by Romero *et al*. (2009a), five dilutions per sample were plated on agar tryptose sulphite supplemented with antibiotic D-cycloserine (Byrne *et al*., 2008) and then incubated at 37ºC in anaerobic jars. In addition, the 10-fold diluted solution was previously heated to 75ºC for 15 min to estimate the concentration of spores in the samples.

Analytical methods

Chemical analyses of the experimental diet were conducted in triplicate. AOAC procedures (2000) were used to determine dry matter (930.15), ash (967.05), Dumas N (968.06), ether extract (920.39) and starch (996.11). Content of neutral detergent fibre was determined using the Mertens method (2002) whereas acid detergent fibre and acid detergent lignin were measured according to the official method (973.18) of the AOAC (2000). All fibre analyses were done sequentially and corrected by ash content of acid detergent lignin residue. Gross energy was determined in an adiabatic calorimeter and digestible energy was estimated according to De Blas *et al*. (1992).

Statistical analysis

Growth performance data were analysed as a completely randomised design with feeding programme as the main source of variation by using the GLM procedure of SAS (SAS Institute, 1990). In the analyses of growth traits, litter was used as a block effect and weaning weight as a linear covariate.

Mortality and morbidity results were analysed using generalised linear models (McCullagh and Nelder, 1989) with the GENMOD procedure of SAS (SAS Institute, 1990). The statistical analysis of mortality and morbidity rates was carried out using a binomial distribution and the link function was the logit transformation, ln $(\mu/1-\mu)$, where μ was the mean value of the corresponding rate. The effect of the feeding programme was included as an explanatory variable and the litter effect was counted in the analysis using the repeated statement of the GENMOD procedure.

RESULTS AND DISCUSSION

In the first trial (Table 2), the 16 h withdrawal of feeders reduced feed intake by 21.3% (from 94.3 to 74.2 g/d; P<0.001) in the first 14 d after weaning. Similarly, Szendro *et al*. (1988), Jerome *et al*. (1998) and Foubert *et al*. (2007) achieved a quantitative feed restriction of 20.5, 19.6 and 26.1%, respectively, by limiting the access to feeders to 8 h daily.

An eating time of 8 h was chosen for this work as previous authors (Szendro *et al*., 1988; Castelló and Gurri, 1992) who let rabbits eat longer did not manage to restrict their feed intake. In fact, Castelló and Gurri (1992) suggested limiting the eating time to at least 10 h. In order to have a greater feed restriction effect, it was also thought that feeders should be withdrawn during the hours of darkness as feed consumption of rabbits starts to increase at 15:00, reaches a peak at 20:00 and remains at high levels

Table 2: Effect of feeding programme on growth performance in the first trial[1].

Feed intake level	*Ad libitum*	Restricted[2]	SEM[3]	*P*-value
First two weeks after weaning (35 to 49 d of age)				
ADFI, g	94.3	74.2	1.77	<0.001
ADG, g	43.6	27.1	1.19	<0.001
FCR	2.28	2.92	0.12	<0.001
Last two weeks of the fattening period (49 to 63 d of age)				
ADFI, g	131	133	2.44	0.59
ADG, g	44.8	54.8	1.24	<0.001
FCR	3.00	2.48	0.078	<0.001
Whole fattening period (35 to 63 d of age)				
ADFI, g	112	104	1.82	0.003
ADG, g	44.0	40.4	0.75	0.001
FCR	2.55	2.56	0.029	0.81
Live weight at 63 d, g	1989	1888	20.3	0.001

[1]Average mortality rate amounted to 1.04%. [2]Feeders were daily withdrawn from 17:30 to 09:30. [3]Standard error mean (n = 48 rabbits). ADFI: Average daily feed intake. ADG: Average daily gain. FCR: Feed conversion rate.

during most of the night (Lebas *et al*., 1996). However, even though Jerome *et al*. (1998) found that feed restriction was more effective when rabbits were fed in daylight, some other studies (Szendro *et al*., 1988; Weissman *et al*., 2009) did not find great differences in feed intake between rabbits restricted during the day or during the night.

In the present work, limited access to the feeders also reduced weight gain (43.6 *vs*. 27.1 g/d; P<0.001) and impaired FCR (2.28 *vs*. 2.92, P<0.001) in the first two weeks after weaning. Compensatory growth was observed in previously restricted rabbits in the realimentation period (49 to 63 d) since, in this period, the latter rabbits gained more weight than never restricted rabbits (44.8 *vs*. 54.8 g/d; P<0.001). Compensatory growth after a period of feed restriction is a constant feature in realimented rabbits (Ledin, 1984; Maertens and Peeters, 1988; Tumova *et al*., 2002). In the whole fattening period (35 to 63 d), feed restriction reduced both feed intake (112 *vs*. 104 g/d; P=0.003) and weight gain (44.0 *vs*. 40.4 g/d; P=0.001) so that FCR was not enhanced (2.56 on average). On the contrary, Gidenne and Feugier (2009) reported an improvement in FCR (from 2.78 down to 2.55, P<0.001) by using a feeding programme similar to that of the present study (three-week restriction of 20% in rabbits weaned at 34 d). Likewise, Szendro *et al*. (1988) stated that it was possible to improve feed conversion up to 13% with time-restricted feeding. However, the results of the present work are consistent with those of other studies (Ledin, 1984; Perrier, 1998; Tumova *et al*., 2002) which found that feed conversion of restricted and then realimented rabbits was similar to that of rabbits continuously fed *ad libitum* when considering the entire fattening period. Finally, live weight at 63 d was lower for rabbits that had been restricted at the beginning of the trial (1989 *vs*. 1888 g; P=0.001). In fact, in most studies early restricted rabbits did not reach the same weight as full-fed rabbits by the end of the growth period. Thus, Gidenne *et al*. (2009a,b) found that live weight of restricted rabbits (restriction of 20 or 25%) at 70 d of age was respectively 3.84 or 6.01% (P<0.01) lower than that of rabbits continuously fed *ad libitum*. Furthermore, Ledin (1984) needed to postpone 15 d the end of the experiment to obtain the same live weight for all rabbits. Tumova *et al*. (2002) were probably the only work where no a lower weight for restricted rabbits at the end of the fattening period was found. This case could be explained by the shortness of the restriction period (only one week) which was followed by a realimentation period that lasted 35 d at least.

In the second trial (Table 3) of the present work, live weight at 63 d was also greater for *ad libitum* fed rabbits (1997 *vs*. 1829 g; P=0.002). Besides, it should be noted that the final weight of early restricted rabbits (1829 g) was below the common Spanish market weight (2 kg at 63 d of age). Consequently, slaughter age was deferred to 70 d in the second trial in an attempt to achieve the commercial objective. At 70 d of age, both groups of rabbits weighed more than 2 kg on average even though statistical differences continued to be detected (2285 *vs*. 2101 g; P=0.001). Perrier (1998) also applied a feed restriction of 2 wk in 35 d old weaned rabbits and needed to extend the fattening period of restricted rabbits by 3 d in order to reach the average body weight that *ad libitum* fed rabbits had at 63 d.

With low mortality rates, scientific FCR and economic FCR, which takes into account the feed consumption of dead rabbits (Maertens, 2008), present very similar values but differences arise when the number of losses increases. In the second trial of this study, in which mortality rate averaged 16.0%, economic FCR was greater than scientific FCR (3.63 *vs*. 2.89 in the whole fattening period). The higher economic FCR reflected the economical losses associated with a high mortality rate. Moreover, the high morbidity percentages obtained in the second trial had a negative effect on the homogeneity of final performances, as shown by the higher values of SEM determined in the second trial in comparison with the first one. The greater presence of morbid rabbits in the full-fed group also led to higher heterogeneity in the final weight (1997±273 *vs*. 1829±181 g at 63 d and 2285±293 *vs*. 2102±201 g at 70 d).

In the first trial, health status was good (average mortality 1.04%) without effects of the feeding programme. Nevertheless, in the second trial (Table 4), the interaction between feeding programme and

Table 3: Effect of feeding programme on growth performance in the second trial[1].

Feed intake level	*Ad libitum*	Restricted[2]	SEM[3]	*P*-value
First two weeks after weaning (35 to 49 d of age)				
ADFI, g	83.9	72.1	2.27	<0.001
ADG, g	39.7	29.2	1.35	<0.001
FCR	2.23	3.07	0.14	<0.001
Last two weeks of the fattening period (49 to 63 d of age)				
ADFI g	129	131	2.53	0.67
ADG, g	45.3	55.7	1.30	<0.001
FCR	2.89	2.36	0.084	<0.001
Usual fattening period (35 to 63 d of age)				
ADFI, g	111	102	2.01	0.004
ADG, g	43.0	40.1	1.00	0.059
FCR 35-63	2.58	2.55	0.045	0.90
Live weight at 63 d, g	1997	1829	33.5	0.002
Extended fattening period (until 70 d of age)				
FCR 35-70	2.96	2.81	0.058	0.19
Economic FCR 35-70	3.77	3.48	-	-
Live weight at 70 d, g	2285	2101	35.5	0.001

[1]Average mortality rate amounted to 16.0%. [2]Feeders were daily withdrawn from 17:30 to 09:30. [3]Standard error mean (n = 48 rabbits). ADFI: Average daily feed intake. ADG: Average daily gain. FCR: Feed conversion rate. Economic FCR takes into account feed consumption of dead animals (Maertens, 2008).

period (0–14 or 14–28 d after weaning) was significant in terms of mortality (*P*=0.024) and morbidity (*P*=0.033). Thus, when rabbits were restricted the period did not influence mortality (3.17% on average) or morbidity (6.34% on average) whereas mortality and morbidity of *ad libitum* fed rabbits decreased, respectively, from 22.9 and 33.3 to 2.70 and 8.11% in the 14–28 d period. Later on, no rabbit older than 63 d died. A very similar chronological distribution of losses after weaning was observed in previous studies (Garrido *et al*., 2009; Romero *et al*., 2009a,b).

In the present work, feed restriction allowed a reduced mortality (25.6 *vs*. 6.34%, *P*=0.017) and morbidity (41.4 *vs*. 12.7%, *P*=0.004) in comparison with animals continuously fed *ad libitum*. In fact, Gidenne *et al*. (2009a) also found that the health risk index (mortality + morbidity rates) was reduced from 27.6 to 23.6% when a 20% restriction was applied in rabbits weaned at 34 d and slaughtered at 71 d. Decreases in

Table 4: Effect of feeding programme and period on health status of rabbits in the second trial.

	Feeding programme (Fp)						
	Ad libitum		Restricted[1]		*P*-value		
Period (P)	0-14 d	14-28 d	0-14 d	14-28 d	Fp	P	Fp×P
Item							
Mortality	22.9[a]	2.70[b]	4.17[b]	2.17[b]	0.017	0.006	0.024
Morbidity	33.3[a]	8.11[b]	8.33[b]	4.35[b]	0.004	0.004	0.033

[1]Feeders were withdrawn daily from 17:30 to 09:30.
Within a row, means without a common superscript differ (*P*<0.05).

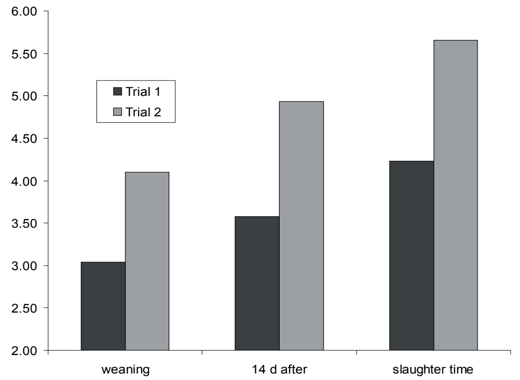

Figure 1: Evolution of the environmental count of *Clostridium perfringens* spores (log CFU/g) throughout the fattening period.

mortality rate could be even greater when restricted intake was 60 or 75% of that of *ad libitum* rabbits (reduction around 9.5 percentage points, Boisot *et al*., 2003; Gidenne *et al*., 2009b). The latter works were carried out in France, thereby justifying the spread of feed restriction as a strategy to reduce mortality in French fattening farms. According to Tudela (2008), 80% of French rabbit farmers commonly resort to feed restriction. On balance, results of the present study are consistent with those of the cited works.

Average mortality rates (1.04 and 16.0% in trial 1 and 2, respectively) were in keeping with the environmental enumeration of *C. perfringens* spores (Figure 1) as the environmental count measured 14 d after weaning was higher in the second trial compared to the first one (4.93 *vs*. 3.56 log CFU/g). This parallelism was also detected in previous research (Romero *et al*., 2009b) and highlights the need for proper hygiene on fattening farms (Garrido *et al*., 2009). Indeed, Licois *et al*. (2003) managed to reproduce Epizootic Rabbit Enteropathy in healthy rabbits with air samples collected in farms that had housed ill animals. The greater presence of *C. perfringens* spores in the dust samples of the second trial could partly explain the increase in mortality as high counts of *C. perfringens* have been associated with the appearance of clinical symptoms of this disease (Dewrée *et al*., 2007; Romero *et al*., 2009a).

The reduction in fattening mortality in restricted rabbits could be explained by a decrease in the flow of nutrients that reach the caecum and thus by a lower proliferation of pathogen bacteria. In fact, the higher digestibility coefficients detected by Lebas (1979), Ledin (1984) and Szendro *et al*. (1988) in restricted rabbits may lead to lower nutrient flows in the caudal part of the ileum. Moreover, Gidenne and Feugier (2009) found that a feed restriction of 20% increased the caecal concentration of volatile fatty acids (from 65.9 up to 84.8 mmol/L when feed restriction ranged from 0 to 40%), and acidified caecal contents (5.64 *vs*. 5.99, $P<0.001$) while enhancing bacterial fibrolytic activity (5.0 *vs*. 10.6 μmol reducing sugar/g DM per h, $P<0.05$). This acidification could help reduce the caecal count of prospective harmful bacteria since some of them such as *C. perfringens* are sensitive to pH levels (EFSA, 2005).

CONCLUSIONS

The practical implementation of feed restriction in Spanish fattening rabbit farms is mitigated by the conventional market weight as restricted rabbits weighed less than 2 kg at 63 d of age. Nevertheless, in a context with high incidence of digestive troubles, a time-limited access to the feeder enhances health status on the farm and could justify the seven-day delay necessary to reach slaughter weight.

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