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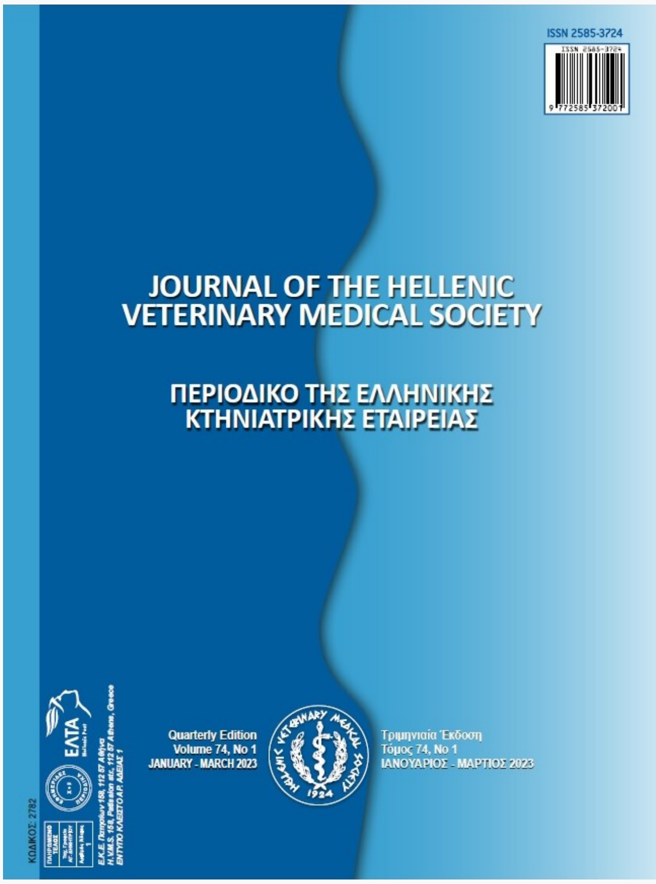

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Research article
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Effect of severe dietary restriction on growth and slaughter characteristics of non-selected growing rabbits

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ABSTRACT: This work was carried out to study the effects of dietary restriction by time-limited access to the feeders on growth performance and carcass characteristics of Algerian local growing rabbit. Forty-four weaned rabbits, 32-35 days old, were randomly divided into 2 groups, the control group (C) fed *ad-libitum* throughout the fattening period and the group with restricted access to the feeders (R). During the five post-weaning weeks, the weekly (7 days) feeding program of the R group consisted on a restriction access time (3h) to the feeders during the first 5 days and *ad libitum* feed distribution for the two remaining days of the week. Two weeks before slaughter (10 to 12 weeks of age), the rabbits from the R group were re-fed *ad libitum*. Live weight in R group was lower ($p<0.05$) at 10 weeks of age (1084.7 *vs.* 1510.7g) but similar to those of the control group at 12 weeks of age. Different daily feed intakes throughout the fattening period and similar average daily gains (R:16.25 g/d *vs.* C:22.10 g/d; $p>0.05$). The feed intake index at the end of fattening was significantly higher ($p=0.001$) in control rabbits (4.15 *vs* 3.85). Carcass yield was similar (68.07% *vs.* 65.70%) in the two groups while peri-renal fat weight was higher ($p=0.002$) in control rabbits (27.17 *vs* 13.67g). The results of the present study indicate the economic interest of feed restriction strategy by limiting access to feeders, what should be promoted and made widely known to rabbit farmers.

Keywords: Rabbit; temporal feed restriction; fattening; zootechnical performances.

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INTRODUCTION

The rabbit farming industry is subject to several challenges that make it difficult to manage. One of the main constraints encountered in rabbit farming is the pre- and post-weaning mortality (Rashwan and Marai, 2000), often reported in Algerian rabbit farms (Kadi et al., 2005) and frequently caused by digestive disorders (Rosell and De la Fuente, 2009). Digestive disorders have multiple origins including metabolic disorders, infections, lack of hygiene, feed imbalance and the weaning's stress: These constraints hinder the development and profitability of rabbit farms.

In order to reduce rabbit morbidity and mortality, farmers overuse drugs and especially antibiotics for prevention and treatment of their animals. This practice leads to increased costs of prophylaxis but may be a potential serious threat to public health through emergence of resistance to some antibiotics (Barton, 2000; Landers et al., 2012). The favourable impact of temporary feed restriction on the digestive health of growing rabbits was highlighted and widely reviewed by Gidenne et al. (2012b).

At the end of 2011 in Europe, new strategies to preserve animal health are introduced. Feed restriction and strategies to limit the ingestion of young rabbits were used to minimize digestive disorders and reduce post-weaning mortality by increasing feed efficiency (Gidenne et al., 2012b; Birolo et al., 2016; Alabiso et al., 2017; Birolo et al., 2020). This strategy is associated with the reduction of feed costs (Maertens, 2009) and improving feed efficiency (Gidenne et al., 2017, 2019; Martignon et al., 2021) without impairing growth, slaughter and carcass traits (Birolo et al., 2021). However, the feeding-restriction strategies and levels are not completely unified and continue to be studied (Birolo et al., 2021; Martignon et al., 2021; Tůmová et al., 2022a, 2022b; Zhuang et al., 2022).

In Algeria, rabbit breeding has seen an important evolution in recent years. The Algerian rabbit breeding sector is represented by the tradition and family farms, which have a large place in the market despite their poor performance (Saidj et al., 2013), and by modern farms characterized by an intensification of production systems, where housing and feeding conditions are improved. Feeding in this second type of breeding is an essential parameter on which the profitability of the breeding depends. Indeed, feeding cost may represent 70% of total production costs (Maertens, 2009).

Several research projects have been conducted in Algeria to improve the quality of rabbit feed for growing rabbits (Kadi, 2012; Guermah, 2016; Djellal, 2019) and for rabbits does (Saidj et al., 2016, 2019). The objective of the present work is to assess the effects of dietary restriction, by time-limited access to the feeders, on growth performance and carcass characteristics of growing rabbits issued from non-selected line of Algerian local populations.

MATERIALS AND METHODS

Ethical approval

Due to the lack of animal ethics commission in Algeria, the authors followed the regulations applied in Liege University, Belgium.

Animals and breeding conditions

The trial was carried out in the rabbitry of the Technical Institute of Livestock, Baba Ali, Algiers, Algeria. The building is composed of two separate compartments, one for the maternity ward and the other for the fattening rabbits. The cages (62cm x 48cm x 40cm) were arranged in flat-deck. Each cage was equipped with a metal feeder with a capacity of 4 kg. The distribution of feed was manual. The watering system was automatic and *at libitum*. The light program of 8h/16h of darkness had been implemented. The temperature and ventilation were controlled. No specific sanitary prophylaxis plan was applied.

The rabbits (n=44) belonging to the Algerian local population (colored phenotype), weaned between 32 and 35 days of age, were identified by tattooing. The animals were equally divided into 2 groups (3 or 4 per cage): a control group (C, n=22) with *ad libitum* feeding on 24-hours, and an experimental group (R, n=22) with a restricted feeding program. During the five post-weaning weeks, the weekly (7 days) feeding program of the R group consisted of limiting access to the feeders to only 3 hours/day (from 9:00 am to 12:00 noon) during the first 5 days (from Sunday to Thursday) and *ad libitum* feed distribution for the 2 remaining days of the week (Friday and Saturday). Two weeks before slaughter (10 to 12 weeks of age), the rabbits from the group R were re-fed *ad libitum*.

The type of pelleted feed used is the mixed one. Its chemical composition (Table 1) was determined according to Fernández-Carmona et al. (2005).

Table 1: Ingredient and chemical composition of experimental diets

Formulation	%	Chemical composition	% of DM
Alfalfa	35	Dry mater (DM)	90.88
Wheat bran	12	Crude fibre (CF)	13.64
Corn	8	Crude protein (CP)	15.58
Soybean meal	24	Crude ash	10.32
Soybean oil	11	Ether extract (EE)	2.5
Calcium	4	Digestible energy (DE kcal/kg DM)*	2318
Monocalcic phosphate	2		
Salt	1		
Minerals and vitamins	3		

*Digestible energy was estimated according to the equation of Fekete and Gippert (1986):
DE (kcal/ kg DM) = 4253 - 32.6 (CF %) - 144.4 (Total ash).

Measured parameters

During the fattening period (from the 5th to the 12th week of age), body weights and feed intake were measured. Weight gain and feed efficiency were calculated. One day after the last weighing at 12 weeks of age, slaughter was performed by bleeding. The yield and characteristics of the carcass were determined according to Blasco et al. (1993). In addition, measurements were made on the different segments of the digestive tract: the length and full and empty weight of the stomach, small intestine, caecum, proximal and distal colon, according to the delimitations reported by Gallois (2009).

Statistical analysis

The different results were expressed by mean ± standard error. Data were analyzed by the GLM model using SAS software (2005) to compare the two groups C and R (control and restricted). Differences were considered significant at ($p<0.05$) and tend at $0.05 < p <0.10$.

RESULTS

Growth performance

At the beginning of the trial, the development of the rabbits' body weight was similar for both C and R groups (Table 2). From week 7 onwards, the weight of the rabbits in C group was significantly ($p <0.05$) higher than in R group. Throughout the period of dietary restriction, the difference in weight between

Table2: Effect of restricted feeding on growth performance of rabbits

Live weight (g)	C (Control) n=22	R (Restriction) n=22	P-value
W5	509.3 ± 30.50	530.5 ± 32.60	0.64
W6	656±37.60	618±40.18	0.49
W7	888 ± 40.87	700 ± 47.11	0.005
W8	1089±38.43	795±48.41	<.0001
W9	1248±45.06	917±58.17	0.0001
W10	1510±65.46	1084±93.75	0.002
W11	1611 ± 67.36	128 ± 96.47	0.014
W12	1801 ± 83.66	1557 ± 108.98	0.099
Weight gainW5-W10	859 ± 42,98	682 ± 53,35	0.33
Weight gainW10-W12	1626 ± 72,16	1308 ± 99,73	0.48
Weight gain W5-W12	1058 ± 51,11	785 ± 65,71	0.25
DLWG: W5-W12	22.1 ± 4,39	16.3 ± 5,60	0.20

W: Week, DLWG : Daily Live Weight Gain

Table 3: Effect of restricted feeding on feed intake and feed efficiency of rabbits

Feed intake(g)	C (control)	R (Restriction)	P-value
W5- W10	84 ± 18.8	53 ± 10.7	0.012
W10 -W12	142 ± 26.5	91 ± 18.8	0.021
W5-W12	113 ± 39.5	72± 26.2	0.036
Feed efficiency			
W5 - W10	3.38 ± 0.83	3.32 ± 0.95	0.59
W10 - W12	4.15 ± 0.76	3.85 ± 0.89	0.001
W5 - W12	3.51 ± 0.78	3.32 ± 0.77	0.96
Conversion Index	1.66 ± 0.38	1.22 ± 0.94	0.043

the two groups remained significant and by week 10 reached 1510.7g for C group and 1084.7g for R group (p=0.002). The weight difference between the two groups decreased at 12thweek to reach respectively 1801 and 1557g for C and R groups (p=0.099), the weight of R rabbits tended to be 13.5% lower. Even though however, results were not significantly different, probably due to the size of the simple.

During the restriction period, a significant difference was observed between the two groups with an average intake of 84g for the control group *vs.* 53g for the restricted one (Table 3). The intake of the rabbits from the R group remained significantly lower than that of C group, even during the period of voluntary feed intake.

However, the feed conversion ratio results in the total fattening period showed that there was a significant effect of restriction on total animal performance (p= 0.043). R group appears to have higher feed efficiency than C group with the lowest feed conversion index.

Slaughter traits

The results didn't show significant difference (p>0.05) either on average live weight or on the components of slaughter yield (Table 4). Dietary restriction does not induce any difference on skin weight, organ weights (lungs, heart, kidneys, digestive tract) or pre-scapular fat. The full digestive tract weight of rabbits from R group (325g) was higher compared to rabbits from C group (288g).

Table 4: Effect of restricted feeding on slaughter traits of rabbits.

Parameters	C (Control)	R (Restriction)	P-value
Live weight(g)	1707±84.7	1664.5±127.1	0.78
Hot carcass weight (g)	1103±53	1021±79.5	0.41
Lungs weight (g)	160±10.04	148±15.06	0.51
Liver weight (g)	79.4±8.58	92.9±12.87	0.40
Kidneys weight (g)	0.92±0.08	1.11±0.12	0.22
Full digestive tract weight (g)	288±23.22	325±34.82	0.39
Cold carcass weight (g)	1038±54.10	964±81.15	0.49
Pre scapular fat weight (g)	8.00±1.05	8.84±1.57	0.67
Peri renal fat weight (g)	27.2±1.83	13.7±2.75	0.002
Carcass yield	68.1±3.51	65.7±2.81	0.26
Liver weight/cold carcass weight	6.8±1.34	8.3±2.20	0.15
Kidney weight/cold body weight	1.29±0.34	1.4±0.19	0.54
Skin weight /body weight	9.5±1.81	8.9±0.78	0.53
Full Digestive tube/body weight	16.7±3.56	19.9±2.72	0.14

Table 5: Digestive segments characteristics of rabbits at 12 weeks of age.

Weight (g)	C (Control)	R (Restriction)	P-value
Stomach	75.3±9.26	90.6±13.90	0.38
Small intestine	52.5±4.35	59.9±6.53	0.36
Caecum	98.9±8.74	116.7±13.11	0.28
Proximal colon	24.3±4.33	23.8±6.49	0.95
Empty stomach	17.7±0.77	19.1±1.15	0.35
Empty small intestine	37.7±2.57	41.4±3.85	0.43
Empty cecum	24.3±1.46	29.0±2.20	0.099
Empty proximal colon	10.5±0.62	11.7±0.93	0.32
Distal colon	14.9±1.28	15.3±1.91	0.88
Empty distal colon	7.7±0.39	8.3±0.59	0.39
Length (cm)			
Stomach large curvature	20.7±0.84	21.2±1.26	0.74
Proximal colon	31.8±1.20	35.7±1.80	0.097
Cecum	43.5±1.55	44.7±2.32	0.67
Small intestine	275±0.10	300±0.15	0.18
Distal colon	60.7±3.21	67.0±4.81	0.29

There was no significant difference on the average cold carcass weight between the two experimental groups.

Despite higher values for the different results of the weights and lengths of the digestive organs (Table 5), no significant difference was recorded between rabbits of the control group C and those of the restricted group R.

DISCUSSION

Growth performance

The daily body weight gains and live weights reached at 12 weeks of age in this study are quite modest, characteristic of this non-selected population of local rabbits (Berchiche and Kadi, 2002) and in agreement with the findings of several previous studies with this rabbit genotype (Berchiche et al., 1996; Kadi et al., 2004; Moula et al., 2013).

The negative effect of feed restriction on weight growth during the second half of the restriction period is cancelled during the phase (10-12 weeks) when rabbits are re-fed *ad libitum*. This is the result of the compensatory growth as it has been reported in similar cases such as by Tůmová et al. (2016) and recently by Birolo et al. (2020 and 2021). It is well known that restricted feeding of rabbits improves digestibility of nutrients, induces compensatory growth and increases feed efficiency during restricted feeding period (Tůmová et al., 2006; Gidenne et al., 2012).

The results of Tůmová et al. (2007) and Matics et al. (2008) showed that the intensity of compensatory growth was related to the time of restriction and the periods of access to feeders. This effect was always observed when rabbits were freely re-fed after restriction as in Borolo et al. (2021).

However, despite the compensatory growth, the results confirmed that the weight change rates of the rabbits R group remain lower than that of the control group. This effect of restriction was observed by Gidenne et al. (2009) and Martignon et al. (2010) who found that restriction of the feeding period has a negative effect on weight growth during restriction. Gidenne and Lebas (2006) found that even after two weeks of *ad libitum* ingestion, the live weight of previously restricted rabbits remained 5 to 10% lower than controls, which was observed in the present study.

The 5-weeks dietary restriction program followed by *ad libitum* refeeding during the last two weeks of the trial resulted in a 13.5% weight reduction (C: 1801g *vs.* R:1557 g). On the other hand, in a temporary intake restriction and intermittent fasting at 8 weeks of age (end of restriction), Lebas and Laplace (1982) obtained a 5% weight reduction with weights of 2000g for C group and 1900g for R group.

The results of the present study were different from those of Romero et al. (2010) who reported weights of 1989 and 1888g respectively for *ad libitum* feeding and restricted to 6h/d and the results of Foubert et al. (2007) who obtained at the age of 12 weeks: 2526g for the control subjects (24h/d) and 2341g for 6h/d, 2413g for 8h/d and 2435g for a restriction of 10h/d. The time of restriction was found to be negatively correlated with growth.

The restriction protocol in the present trial was severe, compared to other works in the literature, in several regards: time of access to the feed was only 3 h/d, restriction period was 5 weeks but also the reduction of the compensation period to only 2 weeks (W10-W12).

The environment' effect and husbandry, as well as morbidity rates and genetic factors can influence the results obtained (Knudsen, 2015). According to the work of Foubert et al. (2007), the time of feed distribution have not a significant influence on growth, these authors applied a temporary night restriction and obtained weights at the 10th week of 2526g for rabbits fed *ad libitum* and 2341g for restricted subjects.

In the present study, the results on the growth rate of experimental rabbits were lower than those of Romero et al.(2010) which were 43g for C and 40.1g at the end of the experiment and 39.7g, 29.2g for C and R respectively during the restriction period. Gidenne et al. (2012a) pointed out that the live weight gain of rabbits increased with age and stabilized at the end of the fattening period.

The increase in feed intake with age was directly related to the increased nutritional requirements and ingestion capacity of the animals. Thus, after the restricted period, the rabbits did not compensate by ingesting larger amounts of feed than the control group. Similar observations were reported by Gidenne et al. (2012b), which explain the lack of bulimia in rabbits previously restricted by their low stomach capacity to store feed. This particularity requires the rabbit to practice many daily meals; this practice was reported by Gidienne and Lebas (2006).

Reducing daily eating time to 3 hours per day during 5 days/week during 5 successive weeks (W5-W10) had reduced significantly daily feed intake by 36 % but without impact on feed conversion which was similar in the two groups (Table 3). These results are in agreement with the ones already reported by Szendrô and Lacza-Szabo (1986) and Osman and Tawfik (1994).

In the present study, the refeeding *ad libitum* period was late (10th week of age), compared to other temporary feeding restriction protocols reported in the literature. This could possibly delay compensatory growth in the animals. Despite this extension of the restriction period, the results show no significant difference in live weight or average daily gain at the end of the fattening period between C and R groups.

The positive effect found of rationing on rabbit feed efficiency had been previously observed by several authors (Jérome et al., 1998a,, 1998b; Gidenne et al., 2009, 2012). The results showed the interest of temporary intake restriction to decrease consumption and increased total and weekly weight gain, especially during the *ad libitum* feeding period, thanks to the interaction between compensatory growth that increased daily gain, low ingestion capacity and the optimization of nutrient utilization outlined by Gidenne and Lebas (2006) in restricted subjects.

Slaughter traits

The results of skin weight, organ weights found in the current experiment were lower to the finding of Lebas and Laplace (1982). This variation is due to purely direct genetic or maternal factors.

The average proportion of skin (Table 4) was widely lower than the classical values observed for selected and commercial rabbit's lines. According to Kadi et al. (2000), this may be a characteristic of this Algerian local non-selected population.

Also, according to Berchiche and Lebas (1990), the proportion of the digestive tract in this local population was related to the amount of fiber provided by the feed as well as to the amounts ingested just before slaughter. Parigi-Bini et al. (1994) reported that the relative importance of the digestive tract weight increases with the cellulosic content of the ration. It will be noted that the digestive tract weight of R group was slightly higher than that obtained by Lebas and Laplace (1982), which was 322 g.

The average cold carcass weight was 1035g for C group and 964g for R group. The temporary restriction tended to penalize carcass yield by 6.69% but without significance ($p > 0.05$). The restricted ingestion period did not have a significant effect on cold carcass yield and warm carcass weight because it depends on live weight and the negligible effect of offal and digestive tract prior to slaughter.

The results of the average cold carcass were much lower than those recorded by Lebas and Laplace (1982), i.e. 1081 for C and 992 for R.

Lebas (1984) notes that perirenal fat is a good indicator of carcass fattening status. The results of the present study showed that rabbit's peri-renal fat weight of R group was significantly lower (49.7%) than those of C group (27.2 *vs.* 13.7g respectively for C and R groups; $p<0.05$). This result can be explained by the limitation of the animal's access to feed, which induced a decrease in feed intake, leading to a decrease in fat deposition at the abdominal level, especially around the kidneys, both in absolute value (per subject) and relative value (average of subjects). According to Birolo et al. (2016), changes in animal body composition and energy depend on the restriction level and refeeding conditions.

According to Lebas and Laplace (1982), the length of the different intestinal segments was not affected by either feeding behaviour, quantitative restriction or access time to the feeder. However, the results in this study show that caecum length increased by 4.3% under the temporary restriction effect. This present study don't showed significant variation in the organs length of the digestive tract.

CONCLUSION

The findings of this study, the first to our knowledge on this topic in local non-selected rabbits, confirmed the interest of feed restriction in rabbit farming.

The local rabbits have adapted well to the severe restriction protocol adopted and have achieved growth and slaughter performances similar to the control group, i.e., on average, an average daily gain of 19.2 g/d, a live body weight at 12 weeks of 1679 g, and a carcass yield of 66.9% but with significantly lower carcass fat. A reduction of the refeeding period, which was only 2 weeks (W11-W12) has provided better results compared to other trials carried out on improved breeds with less severe restrictions.

Thus, the strategy of feed restriction by limiting access to the feed allowed for maximum feed efficiency, with lower consumption and less fat deposition, resulting in a better economic but also social return in terms of consumer health.

These preliminary results in local rabbits lead us to propose more precise feeding recommendations, in order to optimize growth after weaning. Improving the health status as well as the economic gain of rabbit farms have always been the most important issue to manage on the rabbit farms.

CONFLICT OF INTEREST

None declared by the authors.

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