

BODY MORPHOMETRIC DEVELOPMENT DURING GROWTH AND MATURITY OF COLOURED DWARF RABBITS AVAILABLE IN THE ITALIAN MARKET

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Abstract: This study was designed to measure the live performance of “coloured dwarf” rabbits available in the Italian market during both the growing and adult maintenance periods to provide new insights on this breed, with specific regard to the gender effect. A further objective was to identify the morphometric characteristics of the selected population and compare them to the standard breeding requirements. Body weight (BW) and body morphometric development were monitored in 145 “coloured dwarf” rabbits (80 males and 65 females) during 2 different periods: 7-21 wk of age (growth) and 28-45 wk of age (adult-maintenance). The animals were housed in individual cages and fed *ad libitum* with a commercial pelleted diet. Individual BW and feed consumption were measured twice a week to determine weight gain, feed intake and feed conversion index, whereas the health status was monitored daily. At 20 and 45 wk of age, the skin fold width and body measurements were taken on each rabbit at predefined anatomical points. The body measurements included: body length (BL), ear length (EL), head height (HH), shoulder width (SW), rump width (RW), forehead width (FHW), head width (HW), tibia width (TW), thoracic circumference (TC), abdominal circumference (AC) and 3 body indices: RW/BL, TC/BL, AC/BL. At 20 wk of age, the body weight of females (F) was heavier than that of males (M) (F: 1.630 vs. M: 1.542 g, $P<0.001$) and this significant difference was also maintained during the maintenance phase of the study (F: 1.953 vs. M: 1.850 g; $P<0.001$ at 45 wk). Interestingly, up to 20 wk of age average feed intake was higher and weight gain more rapid in F than M, whereas from 40 wk of age onwards the situation was reversed, as M registered a higher average feed intake ($P<0.05$). At 45 wk of age, the skin fold width was thicker in M than in F (M: 4.28 vs. F: 3.56 mm; $P<0.001$). All body measurements were affected by age and almost all of them also by gender, with the exception of BL, EL, FHW and TC/BL. Females presented higher AC and lower FHW than M at 45 wk (AC: 29.5 vs. 27.8 cm; $P<0.01$ and FHW: 4.13 vs. 4.25 cm; $P<0.05$). Males showed higher mean values than F for HW at both 20 and 45 wk of age (4.64 vs. 4.29 and 4.34 vs. 4.18 cm; $P<0.01$, respectively). Males also showed a lower RW/BL index at 20 wk (27.8 vs. 29.7; $P<0.05$). During the first 20 wk of age, 9 rabbits died from digestive problems, whereas 13 were culled for either digestive or respiratory problems and 5 for teeth problems. These findings showed a clear sexual dimorphism in live performance of the selected population of “coloured dwarf” rabbits, which may justify the use of diversified diets according to the gender. Moreover, adult BW and EL exceeded the Italian breed standards for “coloured dwarf” rabbits. Animals also showed a high degree of variability, suggesting that the use of uncontrolled selection and crossbreeding to satisfy the increasing demand for this breed in the market may place the standard breed at risk.

Key Words: coloured dwarf rabbit, age, gender, growth, morphometric measurements.

INTRODUCTION

In recent years, the rabbit has become more popular as a pet animal. In Germany, UK and USA, many dwarf breeds of rabbits have been used as companion animals (Santomá *et al.*, 1989). Moreover, the breeding of pet rabbits has become very advanced. However, in Italy, the breeding of these animals is quite new and there is a general lack

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of knowledge. Information on nutrient requirements and feeding practices are often based on studies that relate to the rabbit as a laboratory animal (NRC, 1977) or as farmed for meat (Lebas, 1987), even though commercial animals have higher nutritional requirements and a much shorter lifespan than pet rabbits. The pet rabbit is now as enconced in households as cats and dogs and most veterinarians regularly see domestic rabbits living up to 10 yr (Lennox, 2010). Nevertheless, little information is available on the nutritional requirements and feeding practices for dwarf rabbits (Lowe, 2010; Ricci *et al.*, 2010).

The pet rabbit, like the broiler rabbit, has nutritional requirements that change with its physiological state, and diet plays a particular role in the animal's development. Studying the live performances of dwarf rabbits from weaning to adult age could yield useful information for feed manufacturers to design specific diets for dwarf rabbits with the aim of maintaining animal health and wellbeing. In addition, the interest in obtaining dwarf rabbits as pet animals has led to the development of many new phenotypes, often derived from indiscriminate crossbreeding. According to the data provided by the Italian Association of Rabbit Breeders (ANCI, 2011) in Italy there are only 35 farms rearing the "coloured dwarf" rabbit and belonging to breeders adhering to the ANCI. Considering the increasing demand for this dwarf rabbit breed, the authors' hypothesis is that uncontrolled crossbreedings may occur and most animals sold in the Italian pet market may not meet standard breed requirements.

The aim of this study was to measure the live performance of "coloured dwarf" rabbits during the growing and adult maintenance periods to provide new insights on this breed, with specific focus on the gender effect. A further objective was to measure the body morphometric development of the animals in order to identify the morphometric characteristics of the "coloured dwarf" rabbits commonly available in our market and compare them to the standard breeding requirements.

MATERIALS AND METHODS

Animals, housing, and experimental design

The experiment was approved by the Italian Ministry of Education, University and Research, and all animals were treated humanely according to the principles stated by Directive 2010/63/EU of the European Parliament and Council of 22 September 2010 on the protection of animals used for scientific purposes (European Union Directive, 2010).

The study was carried out at the experimental rabbitry of the University of Padova (Italy) using 145 "coloured dwarf" (Italian Association of Rabbit Breeders: ANCI) rabbits (80 males and 65 females) at 6 wk of age, which were purchased from a commercial breeder. The animals were weighed, sexed, housed individually in cages, and allowed 1 wk to adapt to the new environment. Rabbits were reared under typical controlled environmental conditions during the entire experimental period.

The study was divided into 2 phases: a growing period (from 7 to 21 wk of age) and an adult maintenance period (from 28 to 45 wk of age). During the growing period, dwarf rabbits were housed individually in fattening cages (240×400×280 mm), whereas for the adult period a total of 118 rabbits (61 males and 57 females) were individually housed in pens (620×500 mm) with open tops.

The cages were made of galvanised wire net, whereas pens were provided with plastic slats, and both were equipped with feeders and automatic drinkers. Pens were more suited for larger adult rabbits.

The rabbits were fed *ad libitum* a commercial pellet (first phase: 10.4 MJ digestible energy (DE)/kg, 16.1% crude protein, 14.4% crude fibre; second phase: 9.8 MJ DE/kg, 17.1% crude protein, 17.4% crude fibre). The choice of changing the diet at the 28th wk of age was basically made to provide animals with a feed more suited for adult rabbits in maintenance. The feed was weighed and distributed twice a week. To determine individual feed consumption, unconsumed feed was weighed before offering the new meal.

From the 22nd to the 28th wk of age animals were not handled, so data recording was suspended. In this period rabbits received the first phase-diet.

Performance traits and health status

Individual body weight (BW) and feed consumption were measured twice a week to determine the average daily weight gain (ADG). Feed intake (FI) and feed conversion index (FCI) were then calculated.

Health status was monitored to detect morbidity and mortality. The criterion used to identify morbidity was the daily detection of digestive troubles (signs of diarrhoea) and respiratory diseases, whereas teeth conditions were checked at the time of animal weighing. Morbid animals (sick or with severe teeth problems) were culled.

Body measurements and indexes

At 20 and 45 wk of age, the individual fattening status was measured, gauging the skin fold width using a digital calliper (0-150 mm - Juwel), and individual body measurements were taken. The body measurements were done at predefined anatomical points using the digital calliper and a measuring tape (cm). For the measurement procedures, the rabbits were put on a table and the same person measured the animals during the experiment. If the measuring process was disturbed, it was repeated.

The measurements included:

- 1) two distance measurements (cm): body length (BL) was measured from atlas to the first coccygeal vertebra; ear length (EL) was taken from the bottom to the top of the ear;
- 2) one height measurement (cm): head height (HH) was taken from forehead to the mandible;
- 3) four width measurements (cm): shoulder width (SW) was measured between the outermost points of the shoulder blades; rump width (RW) was measured between the outermost points of thighs; forehead width (FHW) corresponds to the distance between two points above the orbital cavities; head width (HW) corresponds to the distance between the external corners (angles) of the orbital cavities;
- 4) one width measurements (mm): tibia width (TW) was taken at the midpoint of the right tibia;
- 5) two circumference measurements (cm): thoracic circumference (TC) was measured behind the shoulder blades; abdominal circumference (AC) was taken at the level of the 7th lumbar vertebra.

Using these body measurements, a total of 3 body compact indexes were calculated to define the general conformation of the animals: 1: rump width/body length (RW/BL); 2: thoracic circumference/body length (TC/BL), and 3: abdominal circumference/body length (AC/BL).

Statistics analysis

All data were statistically analysed using the SAS (2004) software package (version 9.2). Analysis of Variance was used to determine the effect of gender [males (M) and females (F)] on performance traits, and skin fold width, whereas the effect of gender, age (20 vs. 45 wk), and their interaction were assessed on body measurements and indexes. A statistical significance was verified at $P < 0.05$.

RESULTS AND DISCUSSION

Figure 1 shows the body weight evolution of the M and F “coloured dwarf” rabbits included in the study during the growth and adult maintenance periods. Up to 18 wk of age, no gender effect was evident, but from then on the average F body weight was significantly higher than that of M ($P < 0.05$). Specifically, at 20 wk of age F weighed 1.630 g and M 1.542 g ($P < 0.001$), and the significant difference was maintained until the end of the experiment (F: 1.953 vs. M: 1.850 g at 45 wk; $P < 0.001$).

For meat production, rabbits are slaughtered around 10-12 wk of age in case of hybrids, and around 14 wk of age when slow growing populations are used (Paci *et al.*, 2013). In both cases, the slaughter age range is before the onset of the time of sexual dimorphism, so a gender effect is rarely if ever observed.

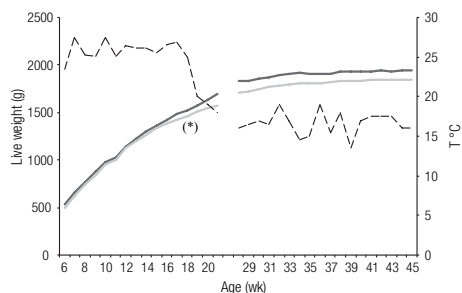


Figure 1: Live weight during the trial. — Females; — Males; - - - Temperature (°C). * From 19th wk of age onwards: $P < 0.05$.

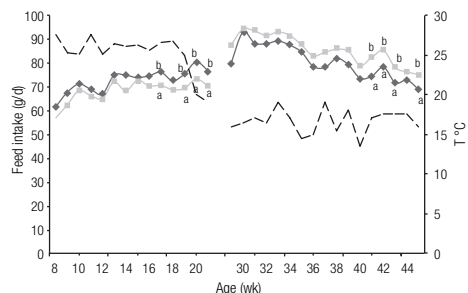


Figure 2: Feed intake during the trial. —◆ Females; —■ Males; - - - Temperature (°C). a,b: $P < 0.05$.

In hybrid commercial rabbits the sexual dimorphism is expressed by a heavier weight of females, but this is never evident before the 15th wk of age (Ouhayoun, 1984); the same situation was observed in our population of “coloured dwarf” rabbits, but at an older age.

It should be noted that body weights at 45 wk of age (Table 3), when animals are unquestionably adults, exceeded the standard values of the standard “coloured dwarf” breed in Italy (ANCI, 2011). In our study, “coloured dwarf” males and females reached 1.850 and 1.950 g of body weight, respectively ($P < 0.001$), well above the breed standard adult body weight, which is less than 1.500 g, irrespective of the gender.

Figure 2 highlights FI levels during the 2 experimental phases. In the first phase, from the 17th to the 21st wk of age, F consumed more feed than M rabbits ($P < 0.05$), whereas in the second phase, and particularly from 40 wk of age onwards, the situation was reversed, as M registered higher FI than F ($P < 0.05$).

ADG linearly decreased up to 35 wk of age, then stabilised (Figure 3). Gender differences were observed ($P < 0.05$) only at the onset of sexual development and specifically F showed higher ADG values than M between the 16th and 20th wk of age. However, at 45 wk of age M had thicker skin fold width than F (4.28 vs. 3.56 mm, respectively; $P < 0.001$) and the width increase was 14.5 vs. 3.7% (M vs. F, respectively; $P < 0.05$) (Table 1).

The gender difference for FCI was not detected during the first phase (Figure 4). From the 16th wk of age onwards, FCI worsened but again no gender difference was observed, even though significant differences were observed at the same time in FI, body weight and skin fold width.

Considering that M are less precocious and maintained a lower body weight than F from the 18th wk of age onwards, and considering also that feed intake was higher in M than in F during the second phase of the study, it can be hypothesised that, at the maintenance level, the daily energy intake in M is more oriented towards fat storage rather than maintenance of other tissues. This could also explain why the skin fold width was thicker in M than F dwarf rabbits at 45th wk of age. The relationship between skin fold width and body fatness has never been demonstrated in rabbits before, but this hypothesis cannot be excluded. Based upon these findings, the feeding of “coloured dwarf” rabbits should be specific according to their physiological state (growth or maintenance) and gender.

Table 1: Skin fold width measured at 20 and 45 wk of age in dwarf rabbits.

	Sex		P-value	RSD
	M	F		
Skin fold width at 20 th wk (mm)	3.76	3.62	0.225	0.70
Skin fold width at 45 th wk (mm)	4.28	3.56	<0.0001	0.53
Skin fold width change (mm)	0.48	-0.01	<0.001	0.71
Skin fold width change (%)	14.5	3.7	<0.05	21.3

RSD: Residual Standard Deviation; No. of rabbits: 136 at 20 and 116 at 45 wk of age. NS: not significant.

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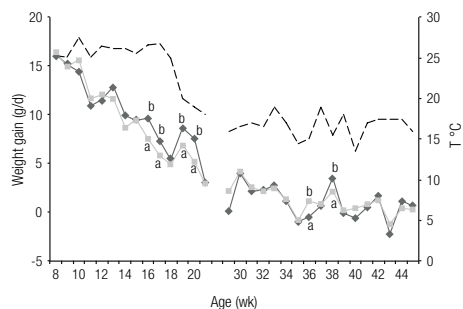


Figure 3: Daily weight gains during the trial. —◆— Females; —■— Males; - - - Temperature (°C). a,b: $P < 0.05$.

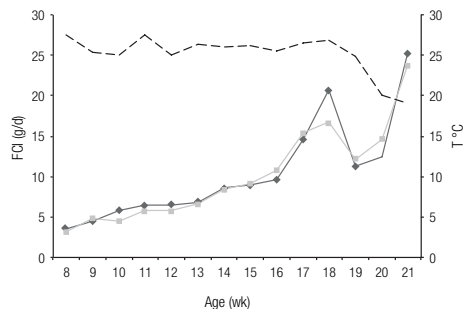


Figure 4: Feed conversion between 7-21 wk of age. —◆— Females; —■— Males; - - - Temperature (°C).

Table 2 presents the health status of rabbits during the growing period. Among the culled rabbits, 5.5% were F and 13.1% were M. Nine rabbits (3 F and 6 M) died from digestive complications, whereas 13 rabbits were culled for either digestive or respiratory problems and 5 rabbits had overgrown teeth. Teeth problems were also seen in 42 different rabbits (19 F and 23 M) throughout the adult phase, but this did not lead to an animal being culled. Dental diseases seen in pet rabbits, including dwarf rabbits, are attributed to excessive inbreeding of the animals, inadequate nutrient supply (Ricci *et al.*, 2010) or to the rounded shape of the head and failure of the teeth to occlude or align properly, especially in dwarf ram rabbits.

The effects of age, gender, and their interaction on body weights and body measurements and indexes are shown in Table 3. As expected, all traits were affected by age and almost all body measurements and indexes were also influenced by gender. In general, and irrespective of gender, the more the age increases, the more body weight increases and body composition varies accompanied by concomitant changes in the animal's appearance. These changes are explained by the allometry of growth of tissues and organs, which leads to modifications in the rabbit morphology (Ouhayoun, 1998; Dalle Zotte, 2002).

Concerning the head measurements, as age increased, M showed higher mean values for HW than F at both 20 and 45 wk of age (4.34 vs. 4.18 and 4.64 vs. 4.29 cm, respectively; $P < 0.01$). Almost all the traits were affected by gender, with the exception of BL, EL, FHW, TC/BL. In addition, a significant age \times gender interaction was detected for AC ($P < 0.01$), FHW ($P < 0.05$), HW ($P < 0.01$), and RW/BL ($P < 0.05$) (Table 3). In particular, for AC and FHW, a gender difference was found only at the 45th wk of age, with F presenting higher AC and lower FHW than M (AC: 29.5 vs. 27.8 cm; FHW: 4.13 and 4.25 cm; F vs. M). It is noteworthy that at 20 wk of age M was less compact than F in the rump region (RW/BL: 27.8 vs. 29.7; $P < 0.05$) and that this difference disappeared at the 45th wk of age (RW/BL: M, 29.5 vs. F, 29.9; $P > 0.05$).

By maturity, the population showed clear sexual dimorphism, with BW and EL exceeding the values considered standard for the "coloured dwarf" breed (standards body weight ranges from 1.000 to 1.250 g and 1.500 g is considered the maximum for the "coloured dwarf" rabbit; whereas maximum ear length is 6 cm) (ANCI, 2011). The

Table 2: Causes of culling dwarf rabbits from 7 to 21 wk of age.

	Total	Sex	
		M	F
Rabbits (No.)	145	80	65
Culled (No.)	27	19	8
Culled (%)	18.6	13.1	5.5
Reason for culling			
Death (No.)	9	6	3
Sickness (No.)	13	10	3
Teeth problems (No.)	5	3	2

Table 3: Effects of age and sex and interaction on body measurements of dwarf rabbit.

Sex (S)	Age (A)				P-value		Interaction A x S	RSD
	20 wk		45 wk		Age (A)	Sex (S)		
	M	F	M	F				
No. of rabbits	74	62	61	56				
Live weight (g)	1,542	1,630	1,850	1,953	<0.001	<0.001	0.79	231
Shoulder width (SW) (cm)	5.76	5.99	6.58	6.84	<0.001	<0.001	0.83	0.54
Rump width (RW) (cm)	8.29	8.84	9.00	9.25	<0.001	<0.001	0.07	0.68
Body length (BL) (cm)	30.0	29.9	30.6	31.0	<0.001	0.45	0.37	1.87
Thorax circumference (TC) (cm)	24.1	24.8	25.8	26.3	<0.001	<0.01	0.60	1.59
Abdominal circumference (AC) (cm)	26.0 ^c	26.2 ^c	27.8 ^b	29.5 ^a	<0.001	<0.001	<0.01	2.19
Tibia width (TW) (mm)	7.58	7.22	8.30	8.06	<0.001	<0.01	0.55	0.87
Ear length (EL) (cm)	7.75	7.65	8.22	8.10	<0.001	0.14	0.94	0.58
Forehead width (FHW) (cm)	3.86 ^c	3.87 ^c	4.25 ^a	4.13 ^b	<0.001	0.06	<0.05	0.25
Head width (HW) (cm)	4.34 ^b	4.18 ^c	4.64 ^a	4.29 ^{bc}	<0.001	<0.001	<0.01	0.25
Head height (HH) (cm)	4.82	4.76	4.98	4.88	<0.001	<0.01	0.55	0.23
Compact index 1 (RW/BL)	27.8 ^b	29.7 ^a	29.5 ^a	29.9 ^a	<0.01	<0.001	<0.05	2.54
Compact index 2 (TC/BL)	81.0	83.2	84.6	85.0	<0.001	0.10	0.25	6.30
Compact index 3 (AC/BL)	87.1	88.1	90.9	95.3	<0.001	<0.01	0.08	7.62

RSD: Residual Standard Deviation; Means with different letters in the same row within age group differ significantly ($P < 0.05$).

standard FHW is reported to be 5.5 cm in M and 5 cm in F. The measured FHW in our population fit within the proposed range, however in the ANCI document the method of FHW measurement is not reported, so we cannot rule out that 2 different procedures may have been adopted. No further information is available on the ANCI standard requirements for the “coloured dwarf” rabbit breed in terms of other body measurements or indexes, so other comparisons were not possible. However, from a morphological point of view, the body measurement results from our population may be suggestive of the influence of genetic manipulations used to produce “coloured dwarf” rabbits.

In Italy, only 35 breeders of “coloured dwarf” rabbits are currently recognised by the ANCI, mostly with few breeding animals. Moreover, roughly one-third of these breeders are found in the province of Bolzano near Austria. As these breeders may not be able to meet the growing demand for “coloured dwarf” rabbits in the Italian market, we cannot exclude that other commercial breeders may have crossbred “coloured dwarf” rabbits with other breeds to propagate their numbers and meet this demand. Therefore, our population sample, although obtained from only one commercial source, may be representative of the general condition a potential purchaser may encounter in the Italian market.

CONCLUSIONS

The “coloured dwarf” rabbits showed a clear sexual dimorphism pattern in live performance traits, resulting in heavier body weights in F than M at the end of the growing phase and by adult age. For this reason, feed companies should consider diversified diets according to their physiological state (growth or maintenance) and gender, particularly from 18 wk of age onwards. Considering that some body measurements exceeded the standard breed requirements for “coloured dwarf” rabbits and that they showed a high degree of variability, this suggests that, through the selection process and/or crossbreeding, larger breeds were likely used in its recent formation, to meet the increasing demand of the Italian market. These genetic manipulations occurring at the commercial scale, if continued, could lead to the “coloured dwarf” rabbit breed becoming endangered.

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