The effect of selection for growth rate and slaughter age on carcass composition and meat quality traits in rabbits[1]

P. Hernández[2], S. Aliaga, M. Pla, and A. Blasco

Departamento de Ciencia Animal, Universidad Politécnica de Valencia, Valencia 46071, Spain

ABSTRACT: The effect of selection for growth rate on carcass and meat quality was assessed by comparing selected and control populations of rabbits measured at the same stage of maturity and slaughtered at 9 and 13 wk of age. Embryos belonging to Generation 7 were frozen, thawed, and implanted in does to produce the control group. The control group was formed from the offspring of the embryos belonging to the Generation 7. Selected animals belonging to Generation 18 (S) were compared with contemporary animals of the control group (C). Carcasses were dissected and measured according to World Rabbit Science Association recommended practices. When animals were compared at similar degrees of maturity, selection for growth rate did not produce a negative effect on carcass and meat quality. There was no increase in fat content of the carcass, and there was an improvement of the meat:bone ratio with selection, with a difference between C and S groups of –0.42. However, the carcasses of S animals have 1.45% lower water-holding capacity. Carcass quality changed markedly with animal age. Heavy rabbit carcasses had lower organ percents and a higher loin percent. Dissectible and i.m. fat content were higher in older rabbits, with older animals having 0.97 and 0.79% more dissectible and i.m. fat content, respectively. Meat quality traits improved with age of slaughter, although there was an increase in glycolytic metabolism. Results from this study indicate that selection for growth rate has little effect in carcass and meat quality when rabbits are measured at the same stage of maturity.

Key Words: Carcass Quality, Genetics, Growth Rate, Meat Quality, Rabbit, Slaughter Age

 J. Anim. Sci. 2004. 82:3138–3143

Introduction

Rabbit meat is a relatively important product in Spain, France, and Italy (Colin and Lebas, 1996). Rabbits are also used as animal models for genetic experiments due to their short generation interval (6 mo), the relatively low cost of the carcasses, and the advantages of using frozen embryo control populations that cannot be produced in pigs or chickens.

Selection for growth rate is currently practiced in commercial sire lines of genetic schemes for rabbit genetic improvement (Baselga and Blasco, 1989; Lebas et al., 1996). Selection for growth rate decreases food conversion rate in all domestic species, but may also decrease carcass and meat quality. Although several experiments have investigated the effect of selection for lean growth rate on pig carcass quality (Sellier, 1998), there are few experiments comparing selected and control populations for meat quality. In pigs, it seems that selection for lean growth rate, although changing some meat characteristics, did not have consequences for meat acceptability as determined by a test panel (Cameron et al., 1999; Oksbjerg et al., 2000). In rabbits, only a few experiments have assessed the consequences of selection for growth rate on carcass and meat quality (Lukefahr et al., 1996; Piles et al., 2000; Larzul et al., 2003). It has been well established that different lines should be compared at the same stage of maturity (Taylor, 1985); however, because carcass weight is fixed by the market, one of the effects of selection for growth rate is a less mature animal at the fixed weight because the growth period has been shortened. The objectives of this experiment were to determine the effect of selection for increased growth rate by comparing animals at a similar stage of maturity and to estimate differences in maturity on carcass composition and meat quality by slaughtering at different ages a selected and a frozen embryo control population that was thawed for the experiment.

Materials and Methods

Animals

The animals used in this experiment originated from a synthetic line selected for increased growth rate from

[1]1This research was supported by CICYT AGF2000-1679 and MCYT AGL2002-04383-C02-01.

[2]Correspondence: Camino de Vera, 14. P.O. Box 22012 (phone: 34 963879756; fax: 34 963877439; e-mail: phernan@dca.upv.es).

Received March 15, 2004.

Accepted July 19, 2004.

4 to 9 wk of age (Estany et al., 1992) in the Animal Science Department of Univesidad Politécnica de Valencia. Embryos belonging to Generation 7 were frozen, thawed, and implanted in does to produce parents of the control (**C**) group. The procedure is described by Vicente et al. (1999). The C group was formed from the offspring of the embryos belonging to Generation 7 to avoid the effect of cryopreservation. Selected animals belonging to Generation 18 (**S**) were compared with animals of the C group. The C and S groups were contemporaries.

Animals were raised in collective cages (50 × 80 × 33 cm) with eight individuals each, and fed a commercial diet (barley and wheat as the primary grains, wheat bran, barley straw, and alfalfa hay as the fiber source) formulated for growing rabbits (16% DM CP, 15.5% crude fiber, 3.4% DM fat). Animals were chosen from litters of at least six born alive, and only one male and one female were chosen from each litter. Sixty animals were slaughtered at 9 wk of age and 60 at 13 wk of age, representing 30 from each selection line. Animals were slaughtered at the abattoir on the farm; thus, they did not suffer stress due to transport. Animals were electrically stunned and bled, and no fasting was practiced.

Carcass Characteristics

Carcasses were prepared as recommended by the World Rabbit Science Association (Blasco and Ouhayoun, 1996) by removing the skin, the distal parts of the tail, fore and hind legs, urogenital organs, and the digestive tract. Hot carcasses were suspended in a ventilated area for 30 min, and then were chilled at 3 to 4°C until 24 h postmortem. These carcasses contained the head, liver, lungs, thymus, esophagus, heart, and kidneys, which were removed to obtain the "reference" carcass, which only contained meat, fat, and bone.

The following traits were recorded: live weight; chilled carcass weight (**CCW**); reference carcass weight (**RCW**); head weight; liver weight; kidney weight; thymus, trachea, esophagus, lung, and heart weight; and dissectible fat weight of the reference carcass (perirenal and scapular).

Reference carcasses were divided into technological joints as indicated by the World Rabbit Science Association (Blasco and Ouhayoun, 1996). Retail cuts obtained were weighed and consisted of the following: forelegs; thoracic cage; loin; hind part. From the hind part, a hind leg was carefully dissected to separate bone (**HLBW**) from edible meat.

The following ratios were calculated: dressing out percent (100 × CCW/live weight); head percent (100 × head weight/CCW); liver percent (100 × liver weight/CCW); kidney percent (100 × kidney weight/CCW); set of thoracic viscera percent (100 × thymus, trachea, esophagus, lung, and heart weight/CCW); dissectible fat percent (100 × dissectible fat weight of the reference carcass/RCW); forelegs percent (100 × foreleg weight/RCW); thoracic cage percentage (100 × thoracic cage weight/RCW); loin percent (100 × loin weight/RCW); hind part percent (100 × hind part weight/RCW); bone percentage of the leg (100 × HLBW/hind leg weight); and meat-to-bone ratio of the hind leg (**M/B**; hind leg edible meat weight/HLBW).

Color (lightness, L*; redness, a*; yellowness, b*) of the carcasses was measured on the surface of the fourth lumbar vertebra of the left side using a CR300 Minolta Chromameter (Minolta Camera, Osaka, Japan).

Meat Quality Variables

The muscle pH was measured at 24 h postmortem in longissimus lumborum (**LL**) muscle at the level of the fourth lumbar vertebra of right side and recorded with a Crison MicropH 2001 (Crison Instruments, Barcelona, Spain), using a combined electrode penetrating 3 mm.

Water-holding capacity (**WHC**) was studied in a sample of meat of the seventh lumbar vertebra. A sample of intact meat weighing 300 ± 5 mg was placed on a previously desiccated and weighed (0.0001 g accuracy) 7-cm disk of Whatman No. 1 filter paper. After weighing, the paper with meat was placed between two Plexiglas plates and a load of 2.25 kg was applied for 5 min. Areas of meat spot (**M**) and released juice (**T**) were then carefully drafted on clear plastic for a permanent record, and the damp paper filter was rapidly weighed after removing the compressed meat. The mean of two replicates was used in analysis. Water-holding capacity was estimated as the M/T ratio (×100) of the areas (Pla and Apolinar, 2000). The percentage of released water was calculated as the ratio of the percentage of weight of released water ([damp paper – filtered weight] – [dry paper – filtered weight]) to intact meat.

Meat color was measured at the sixth lumbar vertebra section of the LL muscle. The parameters L*, a*, and b* were recorded as previously indicated.

Meat dissected from a hind leg was ground in a domestic grinder and scanned with a monochromator (model 5000, NIR Systems Inc., Silver Spring, MD) to measure CP, crude fat, and moisture content by applying calibration equations previously calculated (Pla et al., 2003).

Enzymatic Activity

A portion of the longissimus lumborum, between the sixth and the seventh lumbar vertebra, and the biceps femoris (**BF**) muscles was taken from the right side of the carcasses, vacuum-packed in aluminum bags, and frozen at –20°C until required.

Muscle extracts were obtained by homogenizing 2 g of muscle in 15 mL of phosphate buffer, pH 7.25, and were then centrifuged at 15,000 rpm (27,000 × *g* max) for 20 min at 5°C (Ansay, 1974). Two 1.5-mL aliquots of the supernatant were stored at –20°C for analysis within 1 wk. The enzymatic activity was quantified by continuous kinetics using a spectrophotometer (model

Table 1. Differences between selection (S) and control (C) groups and age of slaughter (13 wk – 9 wk) for carcass characteristics in rabbits selected by growth rate

Trait[a]	Mean	CV, %	C – S	SE (C – S)	Sig[b]	Age	SE	Sig[b]
LW, g	2,908	10.3	–118	55	*	1,072	55	***
CCW, g	1,718	10.7	–53	34	ns	752	34	***
DoP, %	58.7	2.9	0.22	0.31	ns	4.5	0.31	***
HP, %	7.99	6.9	0.009	0.10	ns	–0.78	0.10	***
LvP, %	5.61	16.8	–0.23	0.17	ns	–2.3	0.17	***
KiP, %	1.02	9.7	–0.037	0.018	*	–0.27	0.018	***
LHP, %	2.13	14.0	–0.025	0.054	ns	–0.45	0.054	***
RCW, g	1,428	11.1	–46	29	ns	686	29	***
DFaP, %	3.00	27.7	0.33	0.16	*	0.97	0.16	***
FLP, %	16.6	3.7	0.019	0.11	ns	–0.42	0.12	***
TP, %	12.2	6.7	0.21	0.15	ns	–0.36	0.15	*
LoP, %	31.6	3.3	–0.59	0.20	**	1.2	0.20	***
HPP, %	36.7	2.7	–0.16	0.19	ns	–1.2	0.19	***
M/B	5.92	13.4	–0.42	0.15	**	0.99	0.15	***
L*	54.0	4.7	–1.5	0.50	**	–1.2	0.50	*
a*	2.46	45.1	0.85	0.21	***	–1.5	0.22	***
b*	–1.03	–184	1.4	0.37	***	–1.2	0.37	**

[a]LW = live weight; CCW = chilled carcass weight; DoP = dressing out percent; HP = head percent; LvP = liver percent; KiP = kidneys percent; LHP = set of organs consisting of thymus, trachea, oesophagus, lung and heart percent; RCW = reference carcass weight; DFaP = dissectible fat percent; FLP = forelegs percent; TP = thoracic cage percentage; LoP = loin percent; HPP = hind part percent; M/B = meat/bone ratio; L* = lightness of carcass surface; a* = redness of carcass surface; b* = yellowness of carcass surface.
[b]Significance levels: ns = not significant, $P > 0.05$; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

UV-1601, Shimadzu Co., Tokyo, Japan) at 340 nm to monitor the oxidation rate of NADH (fructose-1,6-diP aldolase or aldolase, EC 4.1.2.13) or the reduction rate of NADP (NADP-isocitrate dehydrogenase or **ICDH**, EC 1.1.4.41). Aldolase activity was measured using the MPR 3 aldolase 123 838 Roche kit (Roche Diagnostics Corp., Indianapolis, IN). The ICDH activity was determined with isocitrate and NADP in the presence of Mn^{2+}. Enzyme activities are expressed as moles of substrate per gram of muscle hydrolyzed in 1 min.

Statistical Methods

Dependent variables were fitted to a model, including group (C and S) and age (9 and 13 wk) as fixed effects. Interactions were not included in the model because almost all interactions were nonsignificant, and some of those reaching significance were expected just by chance. Data analysis was carried out applying the GLM procedure of SAS (SAS Inst., Inc., Cary, NC).

Results and Discussion

Carcass Quality Traits

No differences were found in carcass weight and dressing out percent (Table 1). There was a small difference in kidneys percent, with higher values in selection group. No differences between S and C groups were found for the remainder of the different organ percents. For retail cuts percents, the S line had a slightly higher loin percentage than C line and no differences were found for the rest of the retail cuts percents.

A 0.33% lower content of dissectible fat percentage was found in the S group. Piles et al. (2000) found similar differences. In a mouse experiment, McCarthy (1980) found that selection for growth rate decreased fat content in the selected line at 5 wk of age. This result is expected because the amount of energy retained in a gram of meat is much lower than in a gram of fat tissue; however, selection for increased growth rate produced an increase in carcass fat content in poultry (Crawford, 1990) and in pigs at slaughter age (Clutter and Brascamp, 1998). Whittmore (1986) explained that this is a consequence of an increase of appetite. When the amount of energy ingested per day is too high, fat tissue growth is favored. In the rabbit, selection for increased growth rate does not seem to produce an increase in fat deposition and in fat percentage of the meat.

The meat-to-bone ratio of the leg, which is the best predictor of the M/B ratio of the carcass (Hernández et al., 1996), was 0.4 higher in the S group. The effect of selection on carcass color was significant, with a higher L* and lower a* and b* in the S group than in the C group.

The differences between slaughter age on dressing out percent and carcass characteristics are shown in Table 1. Carcass quality changes markedly with age. Live weight and carcass weight (CCW and RCW) were higher in older animals. The organ percentages (head percent, liver percent, kidney percent, set of thoracic viscera percent) were higher at 9 wk of age, corresponding with their lower degree of maturity. The allometric coefficients of these organs usually decrease with growth. Fat tissue develops late (Cantier et al., 1969;

Table 2. Differences between selection (S) and control (C) groups and age of slaughter (13 wk – 9 wk) for meat quality traits in rabbits selected by growth rate

Trait[a]	Mean	CV, %	C – S	SE (C – S)	Sig[b]	Age	SE	Sig[b]
pH LL	5.77	2.1	–0.051	0.026	*	0.040	0.026	ns
PRW, %	32.1	5.0	–1.2	0.34	***	–0.82	0.34	*
WHC, %	29.8	10.8	1.5	0.68	*	1.8	0.67	**
LL L*	48.8	6.7	0.065	0.60	ns	–2.0	0.60	**
LL a*	4.70	24.2	0.48	0.21	*	–0.87	0.21	***
LL b*	1.79	56.2	0.31	0.19	ns	–1.3	0.19	***
HL protein, %	20.9	1.7	0.18	0.066	**	0.44	0.07	***
HL fat, %	3.59	25.9	0.29	0.17	†	0.79	0.17	***
LH moisture, %	74.1	1.4	–0.48	0.19	*	–0.94	0.19	***

[a]pH LL = muscular pH of the longissimus lumborum (LL); PRW = percentage of released water of muscle LL; WHC = water-holding capacity of muscle LL; LL L* = lightness of the muscle longissimus; a* = redness of the muscle longissimus; b* = yellowness of the muscle longissimus; HL protein, fat, moisture = percentages of crude protein, crude fat, and moisture of meat of a hind leg.
[b]Significance levels: ns = not significant = $P > 0.05$; †$P < 0.10$; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Deltoro and López, 1985) and animals at 13 wk of age had a higher fat percent than animals at 9 wk of age, which is consistent with other studies (Parigi-Bini et al., 1992; Lebas et al., 2001). A higher fat content is a disadvantage in using more mature animals because fat is sold with the whole carcass, and it is more expensive to produce than meat, but nevertheless the amount of fat in rabbit carcasses is very small, and this does not represent a problem.

Although rabbit carcasses are usually commercialized as a whole, commercialization in retail cuts is increasing in importance, with the loin and the hind part being the most valuable cuts. Animals 13 wk of age had higher loin percents than did 9-wk-old animals. Conversely, the forelegs, thoracic cage, and hind part percents were lower at 13 wk of age. The M/B of the leg was approximately 1% higher in 13-wk-old animals, which is in agreement with the results of Deltoro and López (1986). Age had some effect on carcass color measurements (Table 2), with 9-wk-old animals having higher values of L*, a*, and b*.

Meat Quality Traits

Table 2 shows the means of different descriptors of meat quality traits. The S line had a slightly higher LM pH than the C line. In contrast, S line had an inferior WHC and a higher percentage of released water than the C line. In a similar experiment in rabbits, comparing different generations of the same line, Piles et al. (2000) also found a lower WHC in selected animals. Regarding the color measurements, no differences between groups were found for L* and b* coordinates, whereas the C group showed higher values of a* coordinate. The chemical composition of the hind leg was scarcely affected by selection for growth rate. The S group showed lower protein content and higher water content than the C group, but these differences were not of practical importance. No clear differences in fat percentage of the hind leg between C and S lines were found (0.3%; $P < 0.10$). Piles et al. (2000) did not find clear differences in fat content of the hind leg between a control group and a group selected for increased growth rate.

No differences were found in pH of LL muscle between 9 and 13 wk of age (Table 2). The WHC improved with increasing age (higher WHC and lower percentage of released water at 13 than 9 wk of age). In addition, differences in color measurements were found with the increase of age. Animals at 9 wk of age had higher values of L*, a*, and b* than animals at 13 wk of age. These lower values in older animals could be a consequence of a decrease in oxidative metabolism in LM during growth. Ouhayoun et al. (1983) observed that as the age increased, the oxidative metabolism and the myoglobin level decreased. Moreover, the higher percentage of released water in younger animals may be related to the higher value of L* coordinate because lighter meat is associated with more exudative meat.

The chemical composition of hind leg meat was also affected by age. There was an increase in protein and fat content and a decrease in water content with the increase of age. Several authors have reported an increase in lipid content and a loss of water content with increasing rabbit age (Gondret et al., 1998a,b; Hernández et al., 1998; Cavani et al., 2000).

Metabolic Enzyme Activities

The metabolic traits of the muscle were determined by measuring the aldolase and ICDH. The activities of these enzymes in LL and BF muscles are shown in Table 3. Similar values for these activities were reported by other authors (Dalle Zotte and Ouhayoun, 1995; Dalle Zotte et al., 1996). No differences were found between C and S lines for aldolase and ICDH activities, nor for aldolase:ICDH ratio in LL or BF. Based on these results, we cannot conclude that selection for growth rate affected the muscle metabolic activity.

Age had a significant effect on the activity of metabolic enzymes (Table 3) in LL and BF muscles. The

Table 3. Differences between selection (S) and control (C) groups and age of slaughter (13 wk – 9 wk) for muscle enzymatic activity of rabbit selected by growth rate

Trait[a]	Mean	CV, %	C – S	SE (C – S)	Sig	Age	SE	Sig[b]
LL aldolase, IU/g	830	17.3	–46	36	ns	25	37	ns
LL ICDH, IU/g	4.45	19.0	–0.30	0.21	ns	–1.5	0.21	***
LL A/ICDH	197	24.5	0.99	12	ns	74	12	***
BF aldolase, IU/g	610	20.9	–45	34	ns	–58	34	ns
BF ICDH, IU/g	5.68	17.5	–0.036	0.25	ns	–1.7	0.25	***
BF A/ICDH	112	24.4	–4.4	7.4	ns	24	7.4	**

[a]A/ICDH = aldolase activity, ICDH activity, and the ratio of aldolase/ICDH of the longissimus lumborum (LL) and biceps femoris (BF) muscles.
[b]Significance levels: ns = not significant, $P > 0.05$; **$P < 0.01$; ***$P < 0.001$.

ICDH activity decreased between 9 and 13 wk of age, whereas no change was observed in aldolase activity in either muscle. An increase of the aldolase/ICDH ratio with age was observed as a consequence of the decrease in ICDH activity. Several authors have pointed out an increase in the glycolytic pathway in growing rabbits. In fact, our results are in agreement with those reported by Dalle Zotte and Ouhayoun (1995), who found an increase of the aldolase activity only between 28 and 56 d, which then remained constant until 84 d. They also found a regular decrease in the ICDH activity between 28 and 84 d of age. Similar results were also reported by Dalle Zotte et al. (1996).

In conclusion, our results confirm that selection for growth rate did not produce a negative effect on carcass quality at the same stage of maturity because there was no increase in fat content of the carcass and there was an improvement in the meat-to-bone ratio. Meat quality at the same stage of maturity was affected little by selection, only producing a decrease in water holding capacity. However, carcass weight is fixed by the market, and animals selected for increased growth rate will shorten the growth period and will reach slaughter weight at a younger age. We found a clear effect of slaughter age in carcass and meat quality traits. The effect of selection changing maturity at slaughter age will be positive for some traits and negative for some other traits. Younger animals had a poorer dressing out percent, but carcasses also had a lower fat content. Loin percent was lower in younger animals, but hind legs part percent was higher. Meat-to-bone ratio was poorer in younger animals. Meat quality was also affected, with younger animals having lower lipid content in the meat and some differences in color.

Implications

Selection for growth rate has little effect in carcass and meat quality when rabbits are measured at the same stage of maturity, but such selection produces a practically relevant effect because of the younger age at which animals reach slaughter weight. Younger animals have a lower dressing out percent, and their carcasses will have a lower fat content than older animals. Younger animals will have less meat relative to bone than older animals. Selected animals, because they will be younger, will have lower lipid content in the meat and some differences in color.

Literature Cited

Ansay, M. 1974. Développment biochimique du muscle de foetus bovin 3. Enzymes et differentiation. Ann. Biol. Anim. Bioch. Biophys. 14:105–116.

Baselga, M., and A. Blasco. 1989. Mejora genética del conejo de producción de carne. Mundiprensa, Madrid, Spain.

Blasco, A., and J. Ouhayoun. 1996. Harmonization of criteria and terminology in rabbit meat research. Revised proposal. World Rabbit Sci. 4:93–99.

Cameron, N. D., G. R. Nute, S. N. Brown, M. Enser, and J. D. Wood. 1999. Meat quality of Large White pig genotypes selected for components of efficient lean growth rate. Anim. Sci. 68:115–127.

Cantier, J., A. Vezinhet, R. Rouvier, and L. Dauzier. 1969. Allometrie de croissance chez le lapin. I. Principaux organes et tissues. Ann. Biol. Anim. Biochem. Biophys. 9:5–39.

Cavani, C., M. Bianchi, C. Lazzaroni, F. Luzi, G. Minelli, and M. Petracci. 2000. Influence of type of rearing, slaughtering age and sex on fattening rabbit: II. Meat quality. Pages 567–572 in Proc. 7th World Rabbit Cong., Valencia, Spain.

Clutter, A. C., and E. W. Brascamp. 1998. Genetics of performance traits. Pages 427–462 in The Genetics of the Pig. M. F. Rothschild and A. Ruvinsky, ed. CAB Int., New York.

Colin, M., and F. Lebas. 1996. Rabbit meat production in the world. A proposal for every country. Pages 323–330 in Proc. 6th World Rabbit Cong., Toulouse, France.

Crawford, R. D. 1990. Poultry Breeding and Genetics. Elsevier, Amsterdam, The Netherlands.

Dalle Zotte, A., and J. Ouhayoun. 1995. Post-weaning evolution of muscle energy metabolism and related physico-chemical traits in the rabbit. Meat Sci. 39:395–401.

Dalle Zotte, A., J. Ouhayoun, R. Parigi Bini, and G. Xiccato. 1996. Effect of age, diet and sex on muscle energy metabolism and on related physicochemical traits in the rabbit. Meat Sci. 43:15–24.

Deltoro, J., and A. M. López. 1985. Allometric changes during growth in rabbits. J. Agric. Sci. 105:339–346.

Deltoro, J., and A. M. López. 1986. Development of commercial characteristics of rabbit carcasses during growth. Livest. Prod. Sci. 15:271–283.

Estany, J., J. Camacho, M. Baselga, and A. Blasco. 1992. Selection response of growth rate in rabbits for meat production. Genet. Sel. Evol. 24:527–537.

Gondret, F., J. Mourot, and M. Bonneau. 1998a. Comparison of intramuscular adipose tissue cellularity in muscles differing in their lipid content and fiber type composition during rabbit growth. Livest. Prod. Sci. 54:1–10.

Gondret, F., H. Juin, J. Mourot, and M. Bonneau. 1998b. Effect of age at slaughter on chemical traits and sensory quality of *Longissimus lumborum* muscle in rabbit. Meat Sci. 48:181–187.

Hernández, P., M. Pla, and A. Blasco. 1996. Prediction of carcass composition in the rabbit. Meat Sci. 44:75–83.

Hernández, P., M. Pla, and A. Blasco. 1998. Carcass characteristics and meat quality of rabbit lines selected for different objectives: Relationships between meat characteristics. Livest. Prod. Sci. 54:125–131.

Larzul, C., F. Gondret, S. Combes, and H. Rochambeau. 2003. Analyse d'une expérience de sélection sur le poids à 63 jours: II—Déterminisme génétique de la composition corporelle. Pages 149–152 in Proc.10th Journ. Rech. Cunicole, Paris, France.

Lebas, F., P. Coudert, H. Rochambeau, and R. G. Thébault. 1996. Le Lapin. Elevage et Pathologie. FAO, Rome, Italy.

Lebas, F., B. Retailleau, and J. Hurtaud. 2001. Évolution de quelques caractéristiques bouchères et de la composition corporelle de 2 lignées de lapins, entre 6 et 20 semaines d'âge. Pages 55–58 in Proc. 9th Journ. Rech. Cunicole, Paris, France.

Lukefahr, S. D., H. B. Odi, and J. K. A. Atakora. 1996. Mass selection for 70-day body weight in rabbits. J. Anim. Sci. 74:1481–1489.

McCarthy, J. 1980. Morphological and physiological effects of selection for growth rate in animals. Pages 100–109 in Selection Experiments in Laboratory and Domestic Animals. A. Robertson, ed. CAB, London, U.K.

Oksbjerg, N., J. S. Petersen, I. L. Sorensen, P. Henckel, M. Vestergaard, P. Eetbjerg, A. J. Moller, C. Bejerholm, and S. Stoier. 2000. Long-term changes in performance and meat quality of Danish Landrace pigs: A study on a current compared with an improved genotype. Anim. Sci. 71:81–92.

Ouhayoun, J., D. Delmas, and B. Poujardieu. 1983. Variability in the myoglobine content of rabbit muscle. Relationships with energy metabolism. Pages 1–6 in Proc. 2nd Int. Colloquy "The Rabbit as a Model Animal and Breeding Object," Rostock, Germany.

Parigi-Bini, R., G. Xiccato, M. Cinetto, and A. Dalle Zotte. 1992. Effect of slaughter age and weight on carcass and meat quality of the commercial rabbit. J. Appl. Rabbit Res. 15:819–826.

Piles, M., A. Blasco, and M. Pla. 2000. The effect of selection for growth rate on carcass composition and meat characteristics of rabbits. Meat Sci. 54:347–355.

Pla, M., and R. Apolinar. 2000. The filter-paper press as method for measuring water holding capacity of rabbit meat. Pages 659–662 in Proc. 7th World Rabbit Cong., Valencia, Spain.

Pla, M., M. Pascual, and B. Ariño. 2003. Estimación de la composición química de la carne de conejo por espectroscopia NIR. ITEA Vol. Extra. 24:250–252.

Sellier, P. 1998. Genetic of meat and carcass traits. Pages 463–510 in The Genetics of the Pig. M. F. Rothschild, and A. Ruvinsky, ed. CAB Int., New York.

Taylor, C. S. 1985. Use of genetic size-scaling in evaluation of animal growth. J. Anim. Sci. 61:118–143.

Vicente, J. S., M. P. Viudes-de-Castro, and M. L. García. 1999. In vivo survival rate of rabbit morulae after vitrification in a medium without serum protein. Reprod. Nutr. Dev. 39:657–662.

Whittmore, C. T. 1986. An approach to pig growth modeling. J. Anim. Sci. 63:615–621.