on performance, carcass characteristics and meat quality of slow growing rabbits

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SUMMARY

Introduction - The conservation of local rabbit breeds, characterized by slow growth, is very important for organic farming, because in most cases production regulations prohibit the use of commercial hybrids.

Aim - The aim of this study was to investigate the effect of two different housing systems on the productive performance, carcass characteristics and meat quality of the local grey coloured rabbit population of Tuscany (middle-west Italy) compared to commercial hybrids.

Material and methods - 88 rabbits of local populations were housed in colony cages, in open air (GO) organic rearing system; 84 rabbits of the same autochthonous populations (GI) and 80 hybrids (HI) were housed in colony cages in conventional rearing system. An organic diet, composed by pelleted feed and alfalfa hay, was given *ad libitum*. Thirty animals of each group were slaughtered at 103 days (autochthonous) and 90 days of age (hybrids), and carcass and meat quality parameters were assessed.

Results and discussion - The HI group showed the lowest live weight at slaughtering age, the poorest productive performance and the highest mortality. GI group showed the highest live weight and more favorable feed conversion ratio compared with GO group. GO and GI groups showed higher hot carcass and dressing out percentage and lower incidence of full gastrointestinal tract percentage than group HI. Hind leg meat-to-bone ratio was significantly higher in HI group than in GO and GI groups (4.7% *vs*. 4.0% and 3.8%, respectively; P<0.05). The lowest muscular acidification was found in group GO (pHu=5.79 *vs*. 5.59 and 5.63, for group GO, GI and HI, respectively; P<0.05). The muscles of GO group showed lower lightness (L*) than the other groups (GO = 54.4 *vs*. GI = 59.1 *vs*. HI = 63.4; P<0.05). The GO and GI groups showed higher redness and yellowness than HI group. Chemical composition and lipid oxidation did not show differences due to genotype or housing system. As far as fatty acid content concerns, differences were found only for miristic and vaccenic acid between GO and HI groups.

Conclusions - The local rabbits yielded more coloured meat, which could add value for potential consumers, independently of the rearing system used in the study.

KEY WORDS

Rabbit, rearing system, organic, productive performance, fatty acid.

INTRODUCTION

The conservation of local rabbit breeds, characterized by slow growth, is very important for alternative (particularly organic) rearing system, because in most cases production regulations prohibit the use of commercial hybrids selected for intensive rearing system[1]. In addition, organic farming contributes to the development of marginal and rural areas, which are not adapted to intensive rearing system. Recent years have seen a sharp rise in the demand for organic animal products because consumers perceive that this food is safer; also, there is the added value of an "animal-friendly" rearing system, which is more and more appreciated by consumers. Some research has been carried out to study the effect of outdoor alternative rearing system on the productive performance and meat quality of commercial hybrid rabbits and local rabbit populations. However, conflicting results in relation to genetic variability and the rearing technologies adopted (density, size of groups, environment, etc.) are often reported[13].

According to the organic farming rules, a slow-growing rabbit must be used in alternative production[1]. Organic Agriculture[11] suggest avoiding the use of commercial hybrids under organic conditions. The aim of this study was to investigate the effect of different rearing systems and genotype on the productive performance, slaughter traits and meat quality of the local rabbit population characterized by slow growth. A commercial standard hybrid was used to compare data obtained from the local grey population.

MATERIAL AND METHODS

The trial was carried out at the experimental farm of the Department of Veterinary Science of Pisa (Italy). A local grey-coloured population (G) and a commercial hybrids (H) were used. The local population had the following characteri-

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stics: high rusticity, 90% fertility rate, 8.2 ± 2.8 n total born/delivery, 4000 ± 100 g (male) and 3400 ± 200 g (female) adult live weight, 890 ± 155 g (35d) weaning weight, 2500 ± 300 g slaughter weight, and 60% carcass yield[7].

The weaning age was 32 days in hybrids (weaning age usually adopted for commercial hybrids selected for fast growth) and 37 days in local grey population (weaning age adopted for this population characterized by slow growth rate). At weaning, rabbits were housed in outdoor (O) or indoor (I) colony cages according to the organic or conventional rearing systems.

Each outdoor (O) wire net floor colony cage (100 x 160 x 60 cm) was equipped with an external pen (100 x 100 cm). Cages were 50 cm elevated from the ground, and connected with the soil by a chute equipped with a gradient of 15%. Each cage housed 8 animals in order to match the maximum density of 5 rabbits/m^2, according to the specifications of the Italian Department of Organic Agriculture and Farming Certification[1]. Cages were placed in an outdoor pen built to provide the animals with protection against predators and shelter from sun. The ambient temperature ranged between 10 and 18°C.

The indoor (I) colony cages (65 x 40 x 32 cm) were located in the experimental rabbitry which was supplied by a forced-ventilation system (temperature 18 ± 3°C, relative humidity 60-65%, photoperiod of 16 h light phase). Each cage housed 4 animals and the density was 15-16 rabbits/m^2.

An organic pelleted diet was given *ad libitum* to all rabbits during the experimental period with the exception of a short period (from 39 to 54 days for the onset of digestive disorders) during which a feed restriction was applied to commercial hybrids (85% of *ad libitum*). The organic diet was composed by pelleted feed and alfalfa hay and was given until the live weight, usually required by the market for the slaughter, was achieved. Since the two genotypes are characterized by different growth rates, they reached similar live weight at different ages (103 days for local population and 90 for hybrids). The characteristics of the pelleted feed and alfalfa hay is reported in Table 1. Diet samples were analysed in duplicate according to the methods of the AOAC[2].

Animals were divided in the following 3 experimental groups, according to the rearing technology and genetic origin of rabbits ("local grey population" or commercial hybrid). GO group: 88 rabbits belonging to the local grey population (G), reared according the organic system in outdoor colony cage (O); GI group: 84 rabbits belonging to the local grey population (G), reared in conventional indoor colony cage (I); HI group: 80 commercial hybrids (H), reared in conventional indoor colony cage (I). Commercial hybrids were not reared under full organic procedure, as the use of this kind of genotype is not allowed in organic rabbit breeding systems[1].

All animals received vaccinations against Myxomatosis and Viral Hemorrhagic Disease.

The health status of the rabbits was monitored daily and mortality rate was recorded. The animals were considered ill when they showed signs of diarrhoea. The live weight and feed intake were recorded every week. Collected data were used to calculate the average daily gain and the feed conversion ratio on total feed intake basis.

Table 1 - Composition of the organic diet.

	Complete feed	Complementary feed
	Pelletted feed	Alfalfa hay
Ingredients (g/kg diet)		
Alfalfa hay	300	–
Wheat middlings	200	–
Barley	150	–
Oats	100	–
Peas	100	–
Corn	80	–
Faba bean	50	–
Calcium diphosphate	12	–
Limestone	5	–
Sodium chloride	3	–
Analytical data (%)		
Dry matter	90.7	90.4
Crude protein	13.2	12.7
Ether extract	3.0	1.6
Crude fibre	12.6	35.9
NDF	21.8	38.0
ADF	13.4	28.6
ADL	3.1	7.6
Nitrogen free extract	53.6	32.7
Ash	8.2	7.4
Digestible Energy (MJ/kg DM)	11.5	10.4

[#] Estimated according to Fernández-Carmona et al.[9]

Slaughter procedures and sample collection

At the end of the experimental period, 30 female rabbits of similar live weight from each group were weighed (slaughter weight, SW) and slaughtered without fasting. Rabbits were electrically stunned and immediately bled to death. Since the two genotypes are characterized by different growth rates, they reached the same slaughter weight at different ages and the slaughtering age was 103 days for the local grey population (GO and GI groups) and 90 days for commercial hybrids (HI group), respectively. The slaughtering and carcass dissection procedures followed the World Rabbit Science Association described by Blasco and Ouhayoun[3].

After the slaughtered rabbits were bled, the skin, genitals, urinary bladder, gastrointestinal tract and the distal part of legs were removed. Carcasses (with head, thoracic cage organs, liver, kidneys, perirenal and scapular fat) were weighed (hot carcass), then chilled at +4°C for 24 h in a ventilated room. The chilled carcass weight (CCW) was then recorded. The head, thymus, trachea, esophagus, heart, lungs, liver and kidneys were removed from each carcass to obtain the reference carcass weight (RCW). The incidence of the skin (as percentage of SW), of gastrointestinal tract (as percentage of SW), the dressing out (CCW as percentage of SW) and the ratio of the organs and carcass parts to either CCW or to RCW were calculated. The RCW was divided into joints: left and right hind legs, and loin region (between the first and the seventh lumbar vertebrae) according to Pla and Dalle Zotte[16] recommendations. The left hind leg was carefully deboned and the meat-to-bone ratio calculated[3], whereas both sides of the *longissimus lumborum* muscle were used for meat quality determinations. The left *longissimus lumborum* muscle was divided into two parts. The fore part was used to

measure pH and colour. The hind part of the left *longissimus lumborum* was vacuum-packed, frozen and stored at -20°C to determine the thiobarbituric-acid reactive substances (TBARS). The right *longissimus lumborum* was vacuum-packed, frozen, freeze-dried and stored at -20°C until determination of chemical and fatty acid (FA) composition.

pH measurement

The *longissimus lumborum* muscle pH was measured immediately after slaughtering and after 24 h by means of pH-meter (model HI8417, Hanna Instruments Inc., Woonsocket, USA) provided with a Hamilton Biotrode pH electrode (Hamilton, Bonaduz AG, Switzerland).

Colour measurements

Meat colour was assessed on the freshly cut surface of the loin at the 7th lumbar vertebra level and on the surface of the muscle at room temperature (20°C) using a Minolta CR-331C Minolta Colorimeter (∅ 25 mm measuring area, 45° circumferential illumination/0° viewing angle geometry) with the D65 illuminant and 2° standard observer. The results were expressed in terms of lightness (L*), redness (a*) and yellowness (b*) in the CIELAB colour space model[6]. The colour values were obtained considering the average of three readings per meat sample. Three readings were taken on the fresh surface over the level of the second segment, and averaged.

Chemical analyses

Meat chemical composition was assessed in duplicate on freeze-dried samples of the right *longissimus lumborum* muscle and expressed on a fresh basis[2].

Lipid oxidation

Lipid oxidation was determined on the *longissimus lumborum* muscle after 0, 30, 60 and 120 minutes using modified thiobarbituric acid analysis according to the TBARS procedure described by Sárraga et al.[19]. The absorbance was read at 532 nm. Liquid malonaldehyde bis diethyl acetal (MDA) (Aldrich Chemical Co. Ltd., Dorset, UK) was used as the standard to determine the linear standard response and recovery. The TBARS values were expressed as nmol of MDA per kilogram of muscle tissue.

Fatty acid determination

The lipid extraction of the right *longissimus lumborum* muscle freeze-dried samples was performed according to Peiretti and Meineri[15]; the extract was expressed as crude fat and used for the trans-methylation of the FAs. FA methyl esters in hexane were then injected into a gas chromatograph (Dani Instruments S.P.A. GC 1000 DPC; Cologno Monzese, Italy) equipped with a flame ionization detector and a PTV injection port used in the split mode, with a split vent flow of 100 mL/min and a split ratio of 1:25. The injector and detector ports were set at 245°C and 270°C, respectively. The oven temperature program was initially set at 50°C for the first minute, then increased at a rate of 15°C/min to 200°C, where it remained for 20 minutes, and then increased at a rate of 5°C/min to 230°C, where it remained for the last 23 minutes. Helium was used as carrier gas. The separation of FA methyl esters was performed with a Supelcowax-10 fused silica capillary column [60 m x 0.32 mm (i.d.), 0.25 μm]. The peak area was measured using a Dani Data Station DDS 1000. Each peak was identified by pure methyl ester standards (Supelco and Restek Corporation, Bellefonte, PA) and the data were expressed as relative values.

Statistical analysis

The occurrence of mortality was analysed by chi-square tests. Data were analyzed by ANOVA considering the rearing system with genotype as the main categorical factors. The cage was the replicate for growth performance. The animal was the replicate for slaughter performance and meat quality parameters. The differences were tested using Tukey's multiple range test.

RESULTS AND DISCUSSION

Table 2 reports *in vivo* performance of rabbits reared under three different experimental conditions. The hybrids showed the highest live weight at weaning than the other groups (HI = 947 g *vs*. GO = 742 g and GI = 803 g; P<0.05), which confirms the characteristics of this genotype which derives from an intensive selection for fast growth rate with high live weight at weaning.

During the experimental period no drugs or feed additives were administered to animals and the hybrid group presented digestive disorders (diarrhoea, constipation, weight loss, decreased feed intake). In particular, they showed the highest mortality rate if compared with other groups (GO = 12.5%, GI = 13.8%, HI = 20.7%; P<0.05). The onset of digestive disorders and the difference for the mortality rate between genotypes is probably due to the fact that the hybrids are not able to fit organic diet. Moreover the feed restriction applied for a short period during rearing, used to control the digestive disorders, was unsatisfactory for hybrids that are usually fed with medicated diets.

Comparing the productive performance of the three groups, the HI showed the lowest live weight at slaughtering age, and the poorest productive performance. This could be explained by the difficulty to overcome the digestive disorders and by the use of an organic diet which is not supplemented like the commercial standard pelleted diet (i.e. with synthetic amino

Table 2 - Productive performance of slow-growing and fast-growing rabbit (mean ± s.d.).

Group code	GO	GI	HI
Breed	Local rabbit	Local rabbit	Hybrids
Housing system	Outdoor	Indoor	Indoor
Animal number	88	84	80
Cages number	10	21	20
Weaning age (d)	37	37	32
Live weight at weaning (g)	742±21.1^{b}	803±26.5^{b}	947±26.3^{a}
Slaughtering age (d)	103	103	90
Final live weight (g)	2450±26.5^{b}	2539±24.5^{a}	2366±29.9^{c}
Daily weight gain (g)	25.9±0.47^{a}	26.3±0.60^{a}	24.5±0.82^{b}
Pelletted feed intake (g)	122.5±6.44^{a}	100.2±4.94^{b}	86.3±4.80^{c}
Alfalfa feed intake (g)	28.7±2.35	25.1±1.93	25.4±2.37
Total feed intake (g)	151.2±2.48^{a}	125.3±2.74^{b}	111.7±3.5^{c}
Total feed conversion ratio	5.8±0.18^{a}	4.8±0.14^{b}	4.5±0.13^{b}
Mortality rate (%)	12.5^{b}	13.8^{b}	20.7^{a}

^{a,b,c} Means with unlike superscripts within row differ (P<0.05).

acids, vitamins and minerals), which is normally formulated to satisfy the high nutritional requirements of the rabbits selected for fast growth. As concern the final live weight of the local population, independently by the rearing system, it was reached only at the age of 103 days due to the slow growing that characterized the local rabbit[7].

Comparing the growth performance of local genotype reared under different rearing system, the local rabbit showed lower live weight, higher feed intake and worse feed conversion when reared outdoor. The findings of GO group might be linked to space availability and to the variable environmental condition. In accordance to the Italian guidelines of the organic production[1] the rabbits were reared at lower density and higher group size than those reared under conventional system. Regarding to the effect of stocking density recent literature reports that when stocking density is lower than 15-17 rabbits/m^2, only random effects are observed on rabbit growth performance[20]. As regards as the group size, high group size is known to lead to a decline of some productive traits[20]. In this study the lower density, which allowed a greater space availability, combined with the higher group size probably allowed a greater animal physical activity and consequently a worsening of performance. Moreover the less controlled environmental condition of the outdoor rearing system and the fiber-rich diet fed, partly as hay, might have affected the feed consumption and feed to gain ratio[14].

The slaughter age and the live body weight are important factors of variability for carcass and meat quality. The comparison between unselected local population and selected hybrids is difficult, because they reach the same weight at different age. In this trial the two genotypes were compared at the similar slaughter weight, chosen to satisfy the requirements of the market (around 2500 g).

In Table 3 the slaughter traits of rabbits reared under two different housing conditions are summarized. The GO and GI groups provided higher hot carcass and dressing out percentage and lower incidence of gastrointestinal tract than HI group (respectively 60.7% and 60.7% *vs*. 58.1%, P<0.05; 59.1% and 59.4% *vs*. 56.8%, P<0.05; 19.5% and 18.5% *vs*. 22.1, P<0.05). These results were mainly due to the difference of gastrointestinal tract percentage between local population and hybrids in spite of skin percentage incidence that was numerically higher (but not statistically significant) in GO and GI groups than HI group.

The ratio of full gastrointestinal tract weight to live weight decreases with age[4]: in our study the animals were slaughtered at the similar body weight but at different age for this reason the lower proportion of full gastrointestinal tract of GO and GI might be explained by the value of allometric coefficient of digestive tract which decreases with growth[4]. Some Authors reported that selection for faster growth in commercial hybrids was linked to the increase of intestinal content and the decrease of dressing out percentage[10]. Consequently the different growth rate and the lower incidence of full gastro intestinal tract might explain the higher dressing out percentage of GO and GI.

The loin incidence was lower in both genotypes reared under conventional system (GO = 22.6%, GI = 21.5% and HI = 21.0%; P<0.05). The greater development of loin observed in rabbits reared under outdoor system may be a result of the greater locomotor activity promoted by a greater availability of space due to lower stocking density[8].

Table 3 - Slaughter traits of slow-growing and fast-growing rabbit (mean ± s.d).

Group code	GO	GI	HI
Breed	Local rabbit	Local rabbit	Hybrids
Housing system	Outdoor	Indoor	Indoor
Slaughtering age (d)	103	103	90
Animal number	30	30	30
Slaughter weight (SW, g)	2425±52	2519±62	2344±55
Skin (% SW)	16.3±0.2	16.0±0.3	15.4±0.3
Full gastrointestinal tract (% SW)	19.5±0.4^b	18.5±0.5^b	22.1±0.4^a
Hot carcass (g)	1469±9.1^a	1470±10.9^a	1411±9.6^b
Hot carcass (% SW)	60.7±0.4^a	60.7±0.4^a	58.1±0.4^b
Dressing out (%)	59.1±0.4^a	59.4±0.4^a	56.8±0.0^b
Reference carcass weight (RCW, g)	1159±4.1	1160±4.9	1148±4.4
Loin (% RCW)	22.6±0.2^a	21.5±0.2^b	21.0±0.2^b
Hind leg (% RCW)	33.6±0.6	34.4±0.8	34.5±0.7
Meat/bone ratio	4.0±0.1^b	3.8±0.1^b	4.7±0.1^a

^{a,b} Means with unlike superscripts within a row differ (P<0.05).

Hind leg meat-to-bone ratio was significantly higher in HI group than GO and GI groups (4.7% *vs*. 4.0% and 3.8% respectively; P<0.05) (Table 3) confirming the fast growth of HI group and the effect of the selection programs for improving the meat content of carcass[10].

Table 4 reports the meat quality parameters. The pH of *longissimus lumborum* muscle at 24 hours of GO group (5.79) was significantly higher than those of GI (5.59) and HI (5.63) groups (P<0.01). This result is in agreement with previous observations in the same population reared in outdoor cages[7] and could be related to the stress produced by capture for slaughter of the animals reared outdoor.

With respect to meat colour, GO group showed lower value of L* than the other groups (GO = 54.4 *vs*. GI = 59.1 and HI = 63.4; P<0.01) (Table 4). In the same muscle, commercial hybrids meat presented less intense colour as showed by the a* and b* values compared to data of grey rabbits (HI = 1.9 *vs*. GO = 3.9 and GI = 3.3; HI = 2.8 *vs*. GO = 4.0 and GI = 3.8; P<0.01 and P<0.05, respectively). The lowest value of L* observed in GO group could be explained by the relative highest value of pHu, which decreases the light scattering compared to GI and HI groups. The other colour variations seem to be genotype-related, such that independently of the rearing system, there was always more coloured meat as observed in our previous experience[7]. The loin chemical composition and lipid peroxidation were similar among groups, irrespective of the genotype and/or housing conditions (Table 4).

The loin FA composition was similar between the three groups (Table 4). As far as fatty acid content concerns, differences were found only for miristic (C14:0) and vaccenic (C18:1 n-7) acid between GO and HI groups. This result could be partly due to the different percentage of the two ingested feed (mixed feed and alfalfa hay). However the FA profile of the muscle in the rabbits fed organic diet was similar to those reported in the literature[17]. Some experiments have shown that housing conditions can modify FA profile. D'Agata et al.[7] reported that meat derived from the outdoor systems had a lower fraction of saturated FA (SFA) and a hi-

Table 4 - Loin (*longissimus lumborum*) meat quality of slow-growing and fast-growing rabbit (n = 6) (mean ± s.d).

Group code	GO	GI	HI
Breed	Local rabbit	Local rabbit	Hybrids
Housing system	Outdoor	Indoor	Indoor
pH_{24h}	5.79±0.04^{A}	5.59±0.05^{B}	5.63±0.04^{B}
L*	54.4±0.97^{C}	59.1±1.13^{B}	63.4±1.26^{A}
a*	3.9±0.25^{A}	3.3±0.29^{A}	1.9±0.33^{B}
b*	4.0±0.65^{a}	3.8±0.76^{a}	2.8±0.85^{b}
Chemical composition (% on fresh matter basis)			
Water	74.92±0.94	74.98±0.37	74.84±0.70
Protein	21.76± 0.61	21.88±0.37	21.08±0.74
Lipids	2.26±0.68	2.34±0.51	2.78±0.70
Ash	2.10±0.43	1.47±0.14	1.59±0.80
Iron-induced TBARS (nmol MDA/kg meat)			
0 minutes	0.8±0.50	0.7±0.3	0.7±0.4
30 minutes	6.1±2.15	5.9±1.5	6.5±1.6
60 minutes	11.1±2.6	10.6±1.7	11.5±2.3
120 minutes	16.9±2.8	15.5±2.6	17.4±2.8
Fatty acid composition (% of total FA)			
C12:0	0.17±0.05	0.093±0.10	0.17±0.03
C14:0	3.63±0.38^{a}	3.40±0.32^{ab}	3.12±0.17^{b}
C15:0	0.55±0.08	0.65±0.14	0.68±0.04
C16:0	32.64±2.18	32.09±1.44	31.55±0.93
C16:1 n-7	3.72±1.96	2.74±1.44	2.52±0.52
C17:0	0.66±0.15	1.03±0.71	0.70±0.05
C18:0	5.96±0.83	7.42±1.23	6.28±0.71
C18:1 n-9	28.15±1.45	27.71±2.43	27.67±1.92
C18:1 n-7	1.09±0.12^{a}	0.99±0.05^{ab}	0.93±0.04^{b}
C18:2 n-6	20.62±2.36	20.37±1.97	22.84±2.05
C18:3 n-3	1.39±0.34	1.87±0.52	1.58±0.22
C20:1 n-9	n.d.$^{\#}$	n.d.	0.26±0.21
C20:4 n-6	0.36±0.12	0.58±0.42	0.42±0.06
Others	1.08±0.28	1.05±0.33	1.29±0.22
SFA	43.61±1.68	44.69±2.83	42.50±1.08
MUFA	32.96±1.23	31.44±3.71	31.37±2.05
PUFA	22.36±2.68	22.82±2.17	24.84±2.21

^{A,B,C} Means with unlike superscripts within a row differ (P<0.01).
$^{a, b}$ Means with unlike superscripts within a row differ (P<0.05).
$^{\#}$ Not detected.

gher fraction of monounsaturated FA (MUFA) than that of indoor systems. Furthermore, these Authors observed differences in some polyunsaturated FA (PUFA), with higher value in meat from indoor than outdoor systems. This is probably due to the lower amount of intramuscular fat and hence to the greater percentage of phospholipids as reported by Dal Bosco et al.[8]. Cavani et al.[5] found that rabbits reared outdoor had higher SFA, lower MUFA and higher PUFA hind leg meat than indoor rabbits. Partially opposing results were published by Preziuso et al.[18] when comparing rabbits reared indoor or outdoor. The hind leg meat of outdoor rabbits was higher in SFA and MUFA, while no differences were observed for PUFA. However, the diet is considered the main factor affecting FA profile of rabbit meat[12].

Conclusions

In general the feeding strategies combined with the systems used in organic production seem to determine a positive effect on productive performance of the local population. This is due to the more natural rearing conditions, that favor physical activity and consequently the development of the muscle mass. Moreover local rabbits showed consistently favorable slaughtering traits independently of the rearing system. Local population seems to fit well to the feeding strategies used with organic production and when the diet was combined with organic rearing system the productive performance are slightly reduced. Regarding the meat quality, it is interesting to observe that local rabbits yielded more coloured meat, which could add value for potential consumers, independently of the rearing system utilized in the study.

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