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# The effect of organic *vs*. conventional rearing system on performance, carcass traits and meat quality of fast and slow growing rabbits*

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**The effect of different housing systems was evaluated on productive performances and carcass and meat quality of a "local grey" population of rabbits (G). To compare data obtained from G, commercial hybrid rabbits (H) were reared and fed under standard practice. Rabbits were reared as follows: 96 G in outdoor colony cages (O) and fed organic feed based on pelleted feed (oP) and alfalfa hay (H) - group GOoPH; 80 G in conventional indoor colony cages (I) and fed the same organic diet (GoPH) - group GIoPH; 96 G in I and fed conventional pelleted diet (cP) - group GIcP; 88 H in I and fed conventional pelleted diet (cP) - group HIcP. Fifteen rabbits of each group were slaughtered at live weight of 2500 g (100 days of age for G and 87 days of age for H), carcass and meat quality parameters were assessed. HIcP showed the highest average daily gain (33.5 g/day; P<0.05) and GOoPH the poorest total feed conversion (5.6; P<0.05). G showed the highest slaughter yield (P<0.05). GOoPH showed higher loin proportion and the lowest LL pH at 45 min *post mortem* (P<0.05). HIcP produced LL and BF meat with the less intense colour and rich in ash. LL meat of GOoPH was the richest in protein. GOoPH and GIoPH LL meat showed higher amount of C14:0 and 18:1 n-9. GOoPH showed the lowest value of 18:2 n-6, and HIcP showed the highest value of 20:4 n-6 and the lowest amount of 16:1 n-7. The G yielded meat with higher nutritive value, and the best results were obtained when animals received both pellets and hay and were reared outdoor.**

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The conservation of native gene pools is a subject of a great interest. The attention of researchers is strongly focusing on the conservation of biodiversity of larger species, included farm animals, while still a small number of studies have been conducted on the conservation of local rabbit populations [Bolet *et al.* 2000]. In this regard since many years the Department of Veterinary Science of the University of Pisa (Italy) has undertaken a conservation project of a local population of grey coloured rabbits (agouti or wild-type), which was traditionally reared in the countryside of Tuscany (middle-west Italy) [Paci *et al.* 2004ab, Lambertini *et al.* 2006, D'Agata *et al.* 2009].

The hybrid rabbit, commonly used in the intensive commercial farming, is not allowed in organic farming, whereas the use of local rabbit breeds is encouraged [AIAB 2012]. Enhancing species and genetic diversification of the agroecosystem in time and space is one of the pillars of agroecology, a novel scientific approach that would address the production by a biodiverse agroecosystem. According to the agroecology vision, the natural resource management strategy must be applicable under the highly heterogeneous and diverse conditions of marginal areas, in which smallholders live, and it must be environmentally sustainable and based on the use of local resources and indigenous knowledge [Altieri 2002]. Organic rabbit production systems meet most agroecological principles. This system is strongly based on local resources [Dalle Zotte and Paci 2013a] and is not dependent from chemical antibiotics to manage animal health. Owing to low structural costs and high sale prices, it enables one person to live from organic rabbit production, despite low animals performance [Dumont *et al.* 2013].

Studies until now conducted on the qualitative meat traits of commercial hybrid rabbits and of local rabbit populations, the latter reared on alternative farming systems (organic, outdoor, open-air pens, etc.), often report conflicting results in relation to genetic variability and farming systems adopted (density, size of the groups, environment, etc.) [Mugnai *et al.* 2001, Paci *et al.* 2004ab, Schiavone *et al.* 2013, Toscano Pagano and Lazzaroni 2004].

In addition, the information on the potential added value of the organic rabbit meat needs to be enriched by nutritional and sensory traits.

This study aimed at investigation on the effect of different housing systems on the productive performance, carcass and meat quality of a "local grey" rabbit population characterized by slow growth. A commercial hybrid was reared and fed under standard practices, and it was used to compare data obtained from the local population.

## Material and methods

### Animals, housing systems and diets

The experiment was carried out at the experimental farm of the Department of Veterinary Science of Pisa (Italy). A total of 360 weaned rabbits of both sexes were used. Three hundred and four rabbits derived from "local grey" population characterized by slow growth rate (G) and weaned at day 37 of age, and 96 commercial hybrid rabbits (H) weaned at day 35 of age, were used. At weaning, rabbits were housed in outdoor (O) or indoor (I) colony cages according to the organic or conventional breeding system.

Each outdoor wire net floor colony cage (100×160×60 cm) housed 8 animals in order to match the maximum stocking density of 5 rabbits/m², according to the

**Table 1**. Ingredients and analytical composition (%) of the pelleted feed and alfalfa hay

| Item | Complete feed | | Complementary feed |
|---|---|---|---|
| | organic pelleted (oP)feed | conventional pelleted (cP) feed | organic alfalfa hay (H) |
| Compound (%) | | | |
| alfalfa hay | 30.0 | 38.0 | 100.0 |
| pelleted ground hay (grass meadows) | - | 12.0 | |
| wheat middlings | 20.0 | - | - |
| barley | 15.0 | - | - |
| oat | 10.0 | - | - |
| pea | 10.0 | - | - |
| corn | 8.0 | 27.0 | - |
| soybean seed meal | - | 15.0 | |
| faba bean | 5.0 | | - |
| soybean oil | - | 4.0 | |
| calcium diphosphate | 1.2 | 1.8 | - |
| limestone | 0.5 | - | - |
| sodium chloride | 0.3 | 0.3 | - |
| DL-methionine | - | 0.05 | - |
| vitamin-mineral premix* | - | 1.85 | - |
| Analytical data (%) | | | |
| dry matter | 90.7 | 91.1 | 90.4 |
| crude protein | 13.2 | 17.8 | 12.7 |
| ether extract | 3.0 | 3.4 | 1.6 |
| crude fibre (Wendee) | 12.6 | 15.5 | 35.9 |
| NDF | 21.8 | 31.0 | 38.0 |
| ADF | 13.4 | 18.5 | 28.6 |
| ADL | 3.1 | 6.1 | 7.6 |
| nitrogen free extract | 53.6 | 55.4 | 32.7 |
| ash | 8.2 | 9.0 | 7.4 |
| digestible energy (MJ/kg)** | 11.5 | 12.5 | 10.4 |
| Fatty acid profile (% of total FAME) | | | |
| C14:0 | 0.5 | 0.5 | 1.0 |
| C16:0 | 18.9 | 15.4 | 25.6 |
| C18:0 | 2.7 | 3.1 | 4.6 |
| ΣSFA | 22.7 | 19.7 | 32.3 |
| C16:1 n-7 | 0.7 | 0.7 | 1.4 |
| C18:1 n-9 | 21.9 | 19.6 | 9.0 |
| ΣMUFA | 23.2 | 21.0 | 11.4 |
| C18:2 n-6 | 44.2 | 45.1 | 19.3 |
| C18:3 n-3 | 9.9 | 14.2 | 37.0 |
| ΣPUFA | 54.1 | 59.3 | 56.3 |
| Σn-6 | 44.2 | 45.1 | 19.3 |
| Σn-3 | 9.9 | 14.2 | 37.0 |
| n-6/n-3 | 4.5 | 3.2 | 0.5 |

*Per kg complete diet: Vit A 200 IU; alpha-tocopheryl acetate 16 mg; niacin 72 mg; Vit. B6 16 mg; choline 0.48 mg; P 920 mg; K 500 mg, Na 1 g; Mg 60 mg; Mn 1.7 mg; Cu 0.6 mg.
**Estimated according to Fernandez-Carmona *et al*. [1996].

specifications of the Italian Official Certification Organization [AIAB 2012]. Cages were placed in an outdoor pen built to protect animals from predators and shelter from sun. The trial was carried out during spring-summer.

The indoor colony cages (65×40×32 cm), located in the experimental rabbitry (temperature 18±3°C, relative humidity 60-65%, photoperiod of 16 hour light phase), housed 4 animals each and the stocking density was 15-16 rabbits/$m^2$.

The rabbits fed *ad libitum* an organic (pelleted feed + alfalfa hay) or conventional (pelleted feed) diet, until the slaughter weight, usually required by the market (around 2.5 kg), was achieved. Since the two genotypes were characterized by different growth rates, they reached the same slaughter weight at different ages. The composition 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 [1995].

Animals were divided into 4 experimental groups, according to the rearing system (outdoor or indoor), diet (organic or commercial pelleted feed) and rabbit genetic origin ("local grey" population or commercial hybrid): GOoPH group: 96 rabbits belonging to the "local grey" population (G), reared according the organic system in outdoor colony cage (O) and fed organic pelleted (oP) feed and organic alfalfa hay (H); GIoPH group: 80 rabbits belonging to the local "grey population" (G), reared in conventional indoor colony cage (I) and fed the oP and H diet; GIcP group: 96 rabbits belonging to the "local grey" population (G), reared in conventional indoor colony cage (I) and fed the conventional pelleted diet (cP); HIcP group: 88 commercial hybrids (H), reared in conventional indoor colony cage (I) and fed the conventional pelleted diet (cP).

Commercial hybrids were reared under conventional standard procedure, as the use of this kind of genotype is not allowed in organic rabbit breeding systems [AIAB 2012], furthermore in our previous study we demonstrated the difficult of this genotype to fill to the organic feeding and system [Schiavone *et al.* 2013].

The health status of the rabbits was monitored daily. The live weight (LW) and feed intake (FI) of the rabbits were recorded weekly and used to calculate the average daily gain (ADG) and the feed conversion ratio (FCR) on total feed intake basis.

#### Slaughter procedures and sample collection

When animals reached the average weight of 2500 g ±283 (corresponding to 100 and 87 days of age for GOoPH, GIoPH, GIcP and HIcP, respectively) 15 rabbits per group were slaughtered without fasting. Rabbits were electrically stunned and immediately bled. Slaughter and carcass dissection procedures followed the World Rabbit Science Association recommendations [Blasco and Ouhayoun 1996]. Then, skin, genitals, urinary bladder, gastrointestinal tract and the distal part of legs were removed. Hot carcasses (HC, with head, thoracic cage organs, liver, kidneys, perirenal and scapular fat) were weighed, then chilled at +4°C for 24 hour in a ventilated room. The chilled carcasses (CC) were weighed and the head, thymus, trachea, oesophagus, heart, lungs, liver and kidneys were removed from each carcass to obtain the reference carcass (RC). The slaughter yield (CC as percentage of slaughter weight –SW-) and the ratio of the organs and carcass parts to either the CC or to the RC were calculated. The RC was divided into joints: left and right hind legs (HL), and loin region (between the first and the seventh lumbar vertebra) according to Pla and Dalle Zotte [2000] recommendations. The left HL was deboned and the meat-to-bones ratio calculated [Blasco and Ouhayoun 1996], whereas both sides of the *Longissimus lumborum* (LL) muscle were used to determine meat quality analysis. The left LL muscle was divided into two parts. The fore part was used to measure pH and colour whereas the hind part was *vacuum*-packed, frozen and stored at -20°C to determine the thiobarbituric-acid reactive substances (TBARS). The right LL was *vacuum*-packed, frozen, freeze-dried and stored at -20°C until proximate composition and fatty acid (FA) profile analysis.

#### pH measurement

At min. 45 (pH45) and hour 24 *post mortem* (pHu) pH was measured at LL and *Biceps femoris* (BF) muscles by 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 measured on the freshly cut surface of the LL at the 7th lumbar vertebra level and on the surface of the BF muscle at room temperature (20°C) using a MINOLTA CR-331C Minolta Colorimeter (Æ 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 [CIE 1976]. The colour values were obtained considering the average of three readings per meat sample.

#### Lipid oxidation

Lipid oxidation was determined on the LL muscle after 0, 30, 60 and 120 minutes using modified thiobarbituric acid analysis according to the TBARS procedure described by Sárraga *et al.* [2006]. The absorbance was read at 532 nm. Liquid malonaldialdehyde (MDA) (Aldrich Chemical Co. Ltd., Dorset, UK) was used as standard to determine the linear standard response and recovery. The TBARS values were expressed as mg of MDA per kg of muscle tissue.

#### Proximate composition and fatty acid profile

The right LL samples, previously minced and freeze-dried, were scanned in duplicate by NIR spectroscopy according to the procedure described by Riovanto *et al.* [2009] to estimate the proximate composition and the fatty acid profile, based on robust calibration equations obtained by several hundreds of rabbit meat samples previously chemically analysed and scanned by NIR spectroscopy at the Department of Animal Medicine, Production and Health, University of Padova (Italy).

#### Statistical

Live performances and meat quality traits were analyzed by ANOVA [SAS 2009] considering the group as the main categorical factor. Slaughter traits were analyzed as weight and expressed as percentage. The differences were tested using Tukey's multiple range test. A statistical trend was considered for P values below 10%.

## Results and discussion

During the experimental period, no mortality was observed. The growth performance of rabbits reared under the considered rearing system is reported in Table 2. The "local grey" and the hybrid rabbits showed very different precocities, as indicated by the differences in the slaughter age at the fixed live weight. As expected, "local grey" rabbits, characterised by a slow-growth, needed about 100 days to reach the final body weight whereas hybrids reached the same weight in 87 days.

**Table 2.** Effects of rearing system on productive performance of rabbits

| Group | GOoPH | GIoPH | GIcP | HIcP | SEM[1] |
|---|---|---|---|---|---|
| Genotype | local grey rabbit | local grey rabbit | local grey rabbit | hybrids | |
| Housing system | outdoor | indoor | indoor | indoor | |
| Diet | organic pelleted + hay | organic pelleted + hay | conventional pelleted | conventional pelleted | |
| Number of rabbits | 96 | 80 | 96 | 88 | - |
| Weaning age (d) | 37 | 37 | 37 | 35 | - |
| Weaning LW (g) | 771 | 790 | 767 | 808 | 9.5 |
| Slaughter age (days) | 100 | 100 | 100 | 87 | - |
| Slaughter weight (g) | 2530 | 2587 | 2534 | 2551 | 18.5 |
| ADG (g) | 27.9$^{b}$ | 28.5$^{b}$ | 27.2$^{b}$ | 33.5$^{a}$ | 0.32 |
| Cages (n) | 12 | 20 | 24 | 22 | |
| pellets FI (g) | 127.3 | 110.3 | 112.8 | 121.3 | 2.79 |
| Hay FI (g) | 28.4 | 25.0 | - | - | 0.03 |
| Total FI (g) | 155.6$^{a}$ | 135.3$^{b}$ | 112.8$^{c}$ | 121.3$^{bc}$ | 2.83 |
| FCR | 5.6$^{a}$ | 4.8$^{b}$ | 4.1$^{c}$ | 3.6$^{d}$ | 0.09 |

$^{ab...}$Within row means bearing different superscripts differ significantly at P<0.05.
[1] Standard error of the least squares means.

As reported earlier [Schiavone *et al.* 2013] it was not possible to compare the productive performance of hybrids reared under organic system with those of the other groups since the rearing system and the organic diet are not able to satisfy the requirements of rabbits selected for fast growth. In fact, commercial hybrid rabbits [Schiavone *et al.* 2013] were affected by a reduction of their growth potential and digestive disorders, probably due to the use of the organic diet that cannot be supplemented and medicated like the commercial pelleted diet.

As expected, hybrid rabbits reared under conventional system and fed a commercial pelleted diet (HIcP group) showed the highest daily gain (33.5 g/day), whereas the "local grey" rabbits differently reared (GOoPH, GIoPH and GIcP) all showed the lowest growth rate (27.9, 28.5 and 27.2 g/days, respectively) and the difference was statistically significant (Tab. 2; P<0.05). The productive performances of commercial hybrids are the result of selection program at which they underwent to obtain very fast growth at highly controlled housing conditions, whereas those of "local grey" are the result of selection that aimed to cope with the limited (diet) or uncontrolled (environment) conditions; thus, even though "local grey" animals were reared under conventional conditions their growth rate was unaffected.

Experimental groups showed also significant differences for total FI and total FCR (P<0.05). The poorest FCR (5.6) of GOoPH rabbits, compared to those of GIoPH and GcIP groups, depended on their highest FI (155.6 g/d) combined with a lower or similar ADG. Different factors might explain these results: the higher fibre ingestion which increased intestinal flow, the higher space availability which allowed animal physical activity that, coupled to the outdoor rearing condition, increases energy expenditure.

As reported by other authors the organic rearing system as well as other extensive housing systems in which rabbits are reared in collective cages with low stocking density and large living space, promoting thus an increase of animal locomotory activity, reduce the productive performance [Dalle Zotte and Paci 2013b, Paci *et al.* 2013, Szendrő and Dalle Zotte 2011]. This is the result of the difference in FCR found between GOoPH and GIoPH groups. As expected, rabbits of HIcP group exhibited the best FCR (3.6).

The slaughter age and weight are important factors of variation for carcass and meat quality. The comparison between unselected local population and hybrids is difficult, because they reach the same weight at different ages. For this reason, in our study the carcass and meat traits of the two genotypes were compared at similar slaughter weight (around 2500 g), the latter chosen to satisfy the requirements of the local market. For the hybrids this weight corresponds at about 60% of their adult weight (adult weight 4300 g), while for the "local grey" at about 70% of their adult weight (adult weight 3600 g); for this reason the present study will take into account not only the effect of the age but also the different degree of maturity of two genotypes.

Slaughter traits and carcass yields are presented in Table 3. "Local grey" rabbits showed the highest slaughter yield irrespective of the housing or feeding systems, if compared to hybrid rabbits (P<0.05). The highest values of slaughter yield found in GOoPH, GIoPH and GIcP groups were mainly attributable to the difference in full gastrointestinal tract between "local grey" population and hybrids. The percentage of the full gastrointestinal tract was then lower in the "local grey" population than in hybrids, and it was irrespective to the rearing system. Considered that rabbits were compared at the same SW but at different stages of maturity (100 days for "local grey" population and 87 days for commercial hybrids), the lower proportion of full gastrointestinal tracts might be explained by allometry of growth [Dalle Zotte 2002, Dalle Zotte and Paci 2013b]. In fact, when the slaughter age is postponed, higher slaughter yields are generally observed [Cantier *et al.* 1969, Dalle Zotte 2002]. The CC weight and the RC weight and yield showed a similar trend.

**Table 3**. Effect of rearing system on slaughter traits of rabbits

| Group | GOoPH | GIoPH | GIcP | HIcP | SEM[1] |
|---|---|---|---|---|---|
| Genotype | local grey rabbit | local grey rabbit | local grey rabbit | hybrids | |
| Housing system | outdoor | indoor | indoor | indoor | |
| Diet | organic pelleted + hay | organic pelleted + hay | conventional pelleted | conventional pelleted | |
| Number of rabbits | 15 | 15 | 15 | 15 | - |
| Slaughter age (days) | 100 | 100 | 100 | 87 | - |
| Slaughter weight (SW) (g) | 2583 | 2618 | 2523 | 2530 | 36.5 |
| Chilled carcass (CC) (g) | 1532[a] | 1560[a] | 1492[a] | 1406[b] | 24.1 |
| Reference carcass (RC) (g) | 1250[a] | 1269[a] | 1225[a] | 1133[b] | 20.3 |
| % SW | | | | | |
| skin and paws | 17.5 | 16.9 | 16.9 | 17.3 | 0.14 |
| full gastrointestinal tract | 18.5[b] | 17.7[b] | 18.6[b] | 21.5[a] | 0.25 |
| slaughter yield | 59.3[a] | 59.6[a] | 59.1[a] | 55.56[b] | 0.25 |
| RC yield | 48.4[a] | 48.5[a] | 48.6[a] | 44.8[b] | 0.26 |
| % RC | | | | | |
| perirenal fat | 2.4[a] | 2.4[a] | 1.4[b] | 1.5[b] | 0.15 |
| loin | 22.5[a] | 21.4[b] | 22.2[ab] | 22.0[ab] | 0.14 |
| hind legs | 35.1 | 34.3 | 35.2 | 35.3 | 0.19 |
| Hind leg meat to bones ratio | 3.8[b] | 3.8[b] | 3.9[b] | 4.3[a] | 0.06 |

[ab...]Within row means bearing different superscripts differ significantly at P<0.05.
[1] Standard error of the least squares means.

The perirenal fat of GIcP and HIcP rabbits (1.4 and 1.5%, respectively) was significantly (P<0.05) lower if compared to that of GOoPH and GIoPH animals (2.4%). For HIcP the result might be related to the different slaughter age [Ouhayoun 1998], for GIcP it might be due to the more balanced diet, that oriented the metabolism towards a muscle growth instead of a lipid depot.

The loin proportion was higher in rabbits reared in outdoor conditions, likely due to their greater locomotor activity promoted by lower stocking density [Dal Bosco *et al.* 2000, Dal Bosco *et al.* 2002, Pla 2008]. Meat to bone ratio values were similar to those observed in our earlier study [Paci *et al.* 2012] and significantly higher (P<0.05) in commercial hybrids than in "Local grey" rabbit confirming the fast growth of commercial hybrids and the effect of the selection programmes for improving the meat content of carcass.

The $pH_{45}$ value of LL muscle of GOoPH rabbits was significantly lower than that observed in GIoPH and HIcP groups (P<0.05; Tab. 4), with intermediate value for GIcP group. GOoPH rabbits could have suffered the pre-slaughter stress more than the other groups, likely because they were used to live in semi-extensive conditions, and so less exposed to human manipulation. However both the pHu of LL and the $pH_{45}$ and pHu of BF were unaffected by the experimental groups.

The LL and BF meat of the HIP group showed less intense colour with lower a* (2.74 and 2.82, respectively) and b* (2.56 and 2.53, respectively) values, than the average of the values found in the other groups of "local grey" rabbits. A trend

**Table 4**. Effect of rearing system on pH and colour of Longissimus lumborum and Biceps femoris muscles (n = 60) of rabbits

| Group | GOoPH | GIoPH | GIcP | HIcP | SEM[1] |
|---|---|---|---|---|---|
| Genotype | local grey rabbit | local grey rabbit | local grey rabbit | hybrids | |
| Housing system | outdoor | indoor | indoor | indoor | |
| Diet | organic pelleted + hay | organic pelleted + hay | conventional pelleted | conventional pelleted | |
| *Longissimus lumborum* muscle | | | | | |
| $pH_{45}$ | $6.3^{b}$ | $6.5^{a}$ | $6.4^{ab}$ | $6.60^{a}$ | 0.03 |
| pHu | 5.6 | 5.7 | 5.7 | 5.7 | 0.02 |
| L* | 53.5 | 58.8 | 57.2 | 56.7 | 0.79 |
| a* | $3.77^{a}$ | $3.68^{ab}$ | $2.79^{bc}$ | $2.74^{c}$ | 0.12 |
| b* | $3.23^{ab}$ | $4.42^{a}$ | $3.2^{ab}$ | $2.56^{b}$ | 0.18 |
| *Biceps femoris* muscle | | | | | |
| $pH_{45}$ | 6.4 | 6.3 | 6.4 | 6.5 | 0.04 |
| pHu | 5.7 | 5.7 | 5.8 | 5.8 | 0.02 |
| L* | 53.9 | 53.3 | 54.1 | 53.6 | 0.24 |
| a* | $4.18^{ab}$ | $5.02^{a}$ | $3.48^{ab}$ | $2.82^{b}$ | 0.24 |
| b* | $4.23^{a}$ | $4.81^{a}$ | $4.34^{a}$ | $2.53^{b}$ | 0.21 |

[ab...] Within row means bearing different superscripts differ significantly at P<0.05.
[1] Standard error of the least squares means.

**Table 5**. Effect of rearing system on chemical composition (% on fresh matter basis) and TBARS (mg MDA/kg meat) of Longissimus lumborum muscle (n = 60 for proximate composition; n = 32 for TBARS)

| Group | GOoPH | GIoPH | GIcP | HIcP | SEM[1] |
|---|---|---|---|---|---|
| Genotype | local grey rabbit | local grey rabbit | local grey rabbit | hybrids | |
| Housing system | outdoor | indoor | indoor | indoor | |
| Diet | organic pelleted + hay | organic pelleted + hay | conventional pelleted | conventional pelleted | |
| Proximate composition (%) | | | | | |
| water | 75.6 | 75.9 | 76.6 | 76.6 | 0.13 |
| protein | $21.8^{a}$ | $21.1^{ab}$ | $21.3^{ab}$ | $20.5^{b}$ | 0.14 |
| lipids | 1.3 | 1.4 | 1.0 | 0.8 | 0.08 |
| ash | $1.3^{b}$ | $1.6^{ab}$ | $1.1^{b}$ | $2.1^{a}$ | 0.10 |
| Iron-induced TBARS (mg MDA/kg meat) | | | | | |
| 0 min | 2.13 | 2.56 | 2.19 | 2.76 | 0.18 |
| 30 min | 8.39 | 7.79 | 6.25 | 8.59 | 0.59 |
| 60 min | 7.96 | 7.81 | 6.65 | 8.10 | 0.47 |
| 120 min | 7.64 | 7.28 | 6.30 | 7.92 | 0.48 |

[ab...] Within row means bearing different superscripts differ significantly at P<0.05.
[1] Standard error of the least squares means.

reduction of a* was observed for both LL and BF in GIP group, probably due to reduced physical activity and diet.

The proximate composition of LL meat (Tab. 5) suggests a possible mixed effect of genotype, breeding system and slaughter age. The protein level resulted higher in GOoPH group than HIcP group (P<0.05), and GIoPH and GIcP showed intermediate results. This suggests a possible genetic influence on meat proximate composition as the "local grey" rabbits displayed a trend improvement, irrespective from the housing system, and the influence of functional movement, as in outdoor conditions the rabbits disposed low density. The LL meat of HIcP rabbits exhibited the highest ash content, likely related to genetic differences and slaughter age, however between HIcP and GIoPH group no statistical differences were found.

No differences were found in lipid oxidation of LL meat evaluated by TBARS-iron induced technique (Tab. 5).

Fatty acid profile of LL meat is shown in Table 6. The influence of diet on fatty acid profile of rabbit meat have been widely investigated [Fraga *et al.* 1983, Ouhayoun *et al.* 1987, Ouhayoun 1998]. Animals fed the organic pellet plus hay (GOoPH and GIoPH groups) showed higher level of C 14:0 and 18:1 n-9 compared to animals fed the conventional pelleted diet without hay supplementation (GIcP and HIcP). The improved oleic acid amount (18:1 n-9) is relevant from a nutritional point of view as it is beneficial for cell membranes [Lee and Ahn 1977, Enser *et al.* 1996, Dalle Zotte 2002]. Animals fed and reared under full organic procedure (GOoPH group) showed the lowest value of linoleic acid (18:2 n-6). The reduction of linoleic acid is pursued as it is the precursor of the pro-inflammatory arachidonic acid (20:4 n-6). The commercial hybrids (HIcP group) showed a higher value of arachidonic acid (20:4 n-6) than the other groups, thus its reduction is pursued [Simopoulos 2000].

**Table 6.** Effect of rearing system on *Longissimus lumborum* meat fatty acids (FA) profile (% of total FAME) (n=60)

| Group | GOoPH | GIoPH | GIcP | HIcP | SEM[1] |
|---|---|---|---|---|---|
| Genotype | local grey rabbit | local grey rabbit | local grey rabbit | hybrids | |
| Housing system | outdoor | indoor | indoor | indoor | |
| Diet | organic pelleted + hay | organic pelleted + hay | conventional pelleted | conventional pelleted | |
| C14:0 | $1.63^{A}$ | $1.69^{A}$ | $1.37^{B}$ | $1.36^{B}$ | 0.03 |
| C16:0 | $24.79^{a}$ | $24.30^{ab}$ | $22.75^{b}$ | $23.48^{ab}$ | 0.27 |
| C18:0 | $9.05^{ab}$ | $8.92^{b}$ | $9.36^{ab}$ | $9.43^{a}$ | 0.07 |
| Σ SFA | 37.97 | 37.45 | 36.30 | 36.79 | 0.30 |
| C16:1 n-7 | $1.53^{ab}$ | $1.63^{a}$ | $1.24^{ab}$ | $1.18^{b}$ | 0.06 |
| C18:1 n-9 | $19.95^{a}$ | $20.16^{a}$ | $19.24^{b}$ | $19.34^{b}$ | 0.11 |
| C20:1 n-9 | 0.19 | 0.19 | 0.18 | 0.18 | 0.01 |
| Σ MUFA | 23.65 | 23.96 | 22.88 | 22.73 | 0.16 |
| C18:2 n-6 | $29.81^{b}$ | $30.68^{ab}$ | $32.24^{a}$ | $31.51^{ab}$ | 0.26 |
| C20:4 n-6 | $4.25^{ab}$ | $4.02^{b}$ | $4.58^{ab}$ | $4.69^{a}$ | 0.08 |
| C18:3 n-3 | 1.58 | 1.75 | 1.63 | 1.58 | 0.04 |
| C20:5 n-3 | $0.08^{ab}$ | $0.07^{b}$ | $0.08^{ab}$ | $0.08^{a}$ | 0.01 |
| C22:5 n-3 | $0.63^{ab}$ | $0.60^{b}$ | $0.69^{ab}$ | $0.71^{a}$ | 0.01 |
| C22:6 n.3 | $0.12^{ab}$ | $0.11^{b}$ | $0.13^{a}$ | $0.13^{a}$ | 0.01 |
| Σ PUFA | $39.90^{B}$ | $39.91^{B}$ | $42.30^{A}$ | $41.73^{AB}$ | 0.26 |
| Σ n-6 | $37.15^{BC}$ | $37.01^{C}$ | $39.34^{A}$ | $38.84^{AB}$ | 0.24 |
| Σ n-3 | $2.51^{b}$ | $2.72^{ab}$ | $2.81^{a}$ | $2.71^{ab}$ | 0.04 |
| n-6/n-3 | 13.67 | 13.33 | 13.69 | 13.88 | 0.09 |

[ab...]Within row means bearing different superscripts differ significantly at P<0.05.
[1] Standard error of the least squares means.

In this study the lowest percent of palmitoleic acid (16:1 n-7) was observed in HIcP group and the highest in GIoPH group (1.18 vs 1.63 % total FAME; P<0.05). Experiments in cell culture [Morgan and Dhayal 2010], animal models [Cao *et al.* 2008, Morgan *et al.* 2008, Matthan *et al.* 2009, Yang *et al.* 2011], and humans [Garg *et al.* 2003, Griel *et al.* 2008] have shown that palmitoleic acid (or a diet rich in palmitoleic acid) may favourably affect glucose and lipid metabolism, consequently the trend in the improvement of this acid observed in the "local grey" population is considered positively from a nutritional point of view. The highest amount of PUFA of n-3 and n-6 series was observed in GIcP group and numerically also in HIcP group. These animals fed the conventional pelleted diet without external hay administration, received a diet richer in PUFA, that favoured the endogenous synthesis of long chain n-3 and n-6 fatty acids from linolenic and linoleic acid, respectively.

In conclusion the "local grey" rabbit population showed a wide intra-individual variation which did not allow to obtain homogeneous results. Nevertheless, it exhibited a wide adaptability to different farming conditions and feeding systems, as shown by the similar slaughtering weight and age of the three experimental group of the "local grey" population. The adaptability to different rearing systems is very important for the organic rearing system, which is not standardized. The lowest meat $pH_{45}$ observed in rabbits reared and fed under organic conditions, suggests that caution must be paid to the capturing, transporting and stunning procedures of organic rabbits, in order to avoid fast muscle glycogen depletion early *post mortem*. According to this observation, even though pHu was not affected by treatments, organic rabbits appeared to be more sensitive to stress and some meat technological traits could be negatively affected. From nutritional point of view, the organic rabbit meat obtained with "local grey" animals may appear attractive for consumers because of the enhanced protein content, and a reduced linoleic acid (18:2 n-6) and arachidonic (20:4 n-6) amount. In addition, feeding organic diets seemed to be related to an improvement of the beneficial oleic (18:1 n-9) and palmitoleic (16:1 n-7) acid synthesis. On the contrary, the endogenous synthesis of long chain fatty acid resulted slightly depressed. Organic rabbit production system meets most agroecological principles because it encourages the use of local resources and is independent from chemical antibiotics; furthermore it enables the farmer to obtain good animal products despite reduced animal performance, if compared to commercial hybrid rabbits.

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