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Productive performances and carcase quality of male and female Italian Padovana and Polverara slow-growing chicken breeds

Giulia Tasoniero, Marco Cullera, Gabriele Baldan and Antonella Dalle Zotte

Introduction

In the last decades, the industry needs to achieve high outputs in a short time led to a limited diffusion of local slow-growing breeds. On the contrary, the modern consumer exhibits an emerging interest for poultry products deriving from free-range or organic systems (Fanatico et al. 2007), where the use of local chicken breeds might be encouraged (De Marchi et al. 2005). In the Veneto region (Italy), rustic purebreds Padovana and Polverara are aims of interest for scientists, local institutions and farmers, together with other slow-growing purebreds. This is due to their productive potentiality in alternative production systems and to their strong links to regional traditions. These two fancy breeds could be described as medium-size chickens, reaching sexual maturity at approximately 180 d of age (De Marchi et al. 2005) and consisting of several colour plumage varieties (FIAV 2014). So far, researchers focussed on the genetic characterisation of both breeds (Zanetti, De Marchi, Dalvit, Cassandro 2010). On the contrary, data concerning average daily gain (Rizzi et al. 2013), slaughter yields and meat quality (De Marchi et al. 2005; Zanetti, De Marchi, Dalvit, Molette, et al. 2010; Cassandro et al. 2015), and muscle fibres characterisation (Verdiglione and Cassandro 2013) are available to date only for the Padovana breed. In addition, in vivo performances such as feed intake, feed conversion ratio and mortality were not studied neither in Padovana nor in Polverara breeds. Therefore, the present study aimed at comparing productive performances, slaughter performances and some meat quality traits (pH and instrumental colour) of these two chicken breeds, evaluating also a possible gender effect as source of variation for the considered variables. The ultimate goal is to give a contribution in creating economic interest around these local productions to ensure their survival.

Materials and methods

Birds were handled according to the principles stated in EC Directive 86/609/EEC regarding the protection of
animals used for experimental and other scientific purposes.

Birds management

At the hatchery, 81 Padovana golden (PAD) and 76 Polverara black (POL) 1-d-old chicks breeds of both sexes were vaccinated for Newcastle and Marek’s diseases, infectious bronchitis and fowl poxvirus. Birds were individually tagged and weighed; then, they were housed by genotype until 6 months of age (end of April–beginning of October 2015) in two floor pens of 20 m² each (at a stocking density of 4.1 and 3.8 birds/m² for Padovana and Polverara, respectively) in a broiler unit at the Agricultural Professional High School “Duca degli Abruzzi” (Padova). The rearing period was divided into three feeding phases: first period (0–28 d of age), second period (29–71 d of age) and third period (72–183 d of age). During each period, the two pens received daily fresh water and the same standard crumbled organic vegetable diets (Progeo, Reggio Emilia, Italy) for ad libitum consumption. Ingredients were maize flour, toasted soybean meal, maize gluten meal, soybean oil, added vitamins and mineral, without animal products, antibiotics or coccidiostat. Each pen was equipped with two 120 cm-circumference feeders (to ensure 4.4 cm of front space), two 40 cm-diameter automatic bell drinkers, one perch and straw-bedded floor. Starting from 2 months of age, birds had free access to a grass paddock during the day. Photoperiod and ventilation were natural and environmental conditions were recorded daily by measuring the minimum and maximum temperatures inside the pens at ground level and in the central hallway, where relative humidity was also measured. Animals were monitored daily throughout the whole study to assess availability of feed and water, mortality, and any potential conditions of morbidity. In order to neutralise a coccidiosis infestation, Baycox 2.5% (Bayer AG, Leverkusen, Germany) was administered twice during the second feeding period, at a concentration of 25 ppm toltrazuril/L of drinking water over the 24 h, following the recommendations of the producer. At the end of every feed change (at 28 and 71 d of birds age) and at the end of the study (at 183 d of age), birds were individually weighed, as well as the feed residuals of each pen. Individual average daily weight gain (ADG), feed intake (FI), feed conversion ratio (FCR = kg of feed consumed/kg of weight gain) and mortality rate (no. of deads/overall no. of chickens × 100) were calculated on pen basis at each feeding phase and at the end of the rearing period. Diets were sampled and finely ground; their proximate composition was predicted through NIRS analysis whose results’ quality is guaranteed by an extensive database and the instruments are regularly calibrated and subjected to periodical internal and external validations (r²: 0.89 > 0.99) Measurements of NIR spectra were performed by a FOSS-NIR Systems model 5000 (Foss, Hillerød, Denmark) with small ring cup cells, setting the instrument in a reflectance mode between 1100 and 2498 nm with a step of 2 nm. Each sample was scanned twice and the two spectra were averaged. The resulting spectra were stored as log(1/R) on WINISI II version 1.02 software (InfraSoft International, Port Matilda, PA). Gross energy (GE) values were calculated on the basis of equations in the European Tables (Janssen 1989).

Birds slaughter and further processing

At 183 d of age, birds were sexed and 59 Padovana Golden (37 males and 22 females) and 61 Polverara Black (31 males and 30 females) chickens were selected (maintaining the mean live weight and the standard deviation of each pen), subjected to a 9 h feed withdrawal and individually weighed before transportation to an authorised commercial slaughterhouse. Birds were electrically stunned (120 V, 200 Hz), bled, soft-scaled (53 °C for 2 min), plucked and eviscerated to obtain commercial carcases, which included head, neck, shanks and giblets (heart, liver and gizzard). Carcasses were then air-chilled (precooling at 5 °C for 60 min, followed by chilling at 0 °C for 90 min), stored at 4 °C and transported at the Department of Animal Medicine, Production and Health (MAPS) laboratory for further analyses.

Physical measurements

Four experimental groups were formed: Padovana golden males (PAD M), Padovana golden females (PAD F), Polverara black males (POL M) and Polverara black females (POL F). For each group, commercial carcases were weighed; then, head + neck, wings, shanks and giblets were removed and their weight was recorded, as well as that of the resulting net carcases. Thus, commercial carcase and net carcase yields were computed, as well as the incidences of the individual slaughter wastes. Breast and legs were then excised and their yields were calculated as percentages on slaughter weight and on commercial carcase weight. At 24-h post mortem, pH and colour measurements were performed on left breasts and left legs. On cranial and caudal ends of Pectoralis major and on Iliotibialis lateralis muscles, ultimate pH was measured.
with a Mettler Toledo FE20 pH-meter, and \( L^a a^b \) colour values (CIE 1976) were obtained with RM200QC colorimeter (X-Rite, Co, Neu-Isenburg, Germany). Measuring area: 8 mm; measuring geometrics: 45/0 image capture; illuminant/observer: D65(10) colorimeter. Left legs were deboned; skin was removed and weighed, as well as meat and bones, to calculate skin percentage and meat/bones ratio, respectively. Femurs were calculated as percentage on leg weight; femur length was measured, as well as its diameter at the level of minor thickness at the mid-diaphysis using a digital calliper (±0.02 mm; JUWEL Digital-Schieblehre Rostfrei H4215/5X A12). Then, femurs were analysed for Warner–Bratzler Fracture Toughness (WBFT) by using a three-point flexure test by a dynamometer TA-HDi Texture Analyzer (Stable Macro System, London, UK) at a load rate of 5 mm/min. WBFT was calculated at the average bone length point (corresponding to the mid-diaphysis), placing bones with their natural convex shape downwards on a specific flexure fixture and setting the distance between the two supporting fulcra points at 4 mm.

**Statistical analysis**

Data were analysed using a SAS 9.3 statistical software package for Windows (SAS, 2004). Individual live weight (LW), average daily gain (ADG), carcase yields, meat pH, colour and femur traits data were evaluated by a two-ways ANOVA that considered breed (B) and gender (G) as a fixed effects (PROC GLM). B × G interaction was also analysed. The experimental unit was the single animal. The feed intake (FI) and the feed conversion ratio (FCR) data were not statistically analysed due to the lack of replicates. Z-test was performed to evaluate mortality percentages. Post-hoc pairwise contrasts were evaluated by Bonferroni adjustments and \( p < .05, p < .01, p < .001 \) and \( p < .0001 \) were considered as significance levels. \( p < .1 \) was considered as tendency.

**Results**

**Experimental diets**

Chemical composition of the commercial diets is reported in Table 1. The two experimental groups received the same diet during each of the three feeding periods. The three administered diets differed to satisfy nutrients and energy requirements of the birds during their growth. Diet of the first period (0–28 d) was characterised by the highest organic matter (OM; 849 g/kg), crude protein (CP; 196 g/kg) and ether extract (EE; 37.3 g/kg) levels. Consequently, first period diet was the most energetic one (4013 kcal/kg), whereas the diet administered during the third period was characterised by the highest dry matter (DM; 906 g/kg), crude fibre (CF; 29.5 g/kg), neutral

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**Table 1. Chemical composition of the diets.**

| Analysed composition, g/kg (as-fed)* | Period 1 (0–28 d) | Period 2 (29–71 d) | Period 3 (72–183 d) |
|-----------------------------------|------------------|------------------|------------------|
| Dry matter (DM)                   | 898              | 882              | 906              |
| Ash                               | 49.7             | 74.4             | 60.5             |
| Organic matter (OM)*              | 849              | 807              | 845              |
| Crude protein (CP)                | 196              | 194              | 174              |
| Ether extract (EE)                | 37.3             | 18.4             | 30.9             |
| Crude fibre (CF)                  | 27.4             | 14.9             | 29.5             |
| NDF                               | 117              | 113              | 119              |
| Starch                            | 367              | 365              | 393              |
| Non-nitrogenous extractsd         | 588              | 580              | 610              |
| NNCe                              | 536              | 500              | 552              |
| Ca                                | 10.5             | 10.8             | 10.3             |
| P                                 | 8.00             | 7.80             | 7.20             |
| Na                                | 13.1             | 13.8             | 14.3             |
| Gross energy (GE), kcal/kgf*      | 4013             | 3726             | 3917             |

*Supplied (per kilogram of diet): E672 Vitamin A, 11,000 U; E671 Vitamin D3: 3000 U (diets 1, 2), 4500 U (diet 3); 3a700 Vitamin E (rac-alfa – tocopheryl acetate): 100 mg (diet 1), 90 mg (diet 2), 80.0 mg (diet 3); Vitamin K, 4.00 mg; Vitamin B1, 2.50 mg; Vitamin B2, 10.0 mg; Vitamin B6, 1.00 mg; Vitamin B12, 0.025 mg; pantothenic acid: 15.0 mg (diet 1); 3a842 D-panthenol: 15.0 mg (diets 2, 3); biotin, 0.20 mg; folic acid, 0.50 mg; nicotinic acid, 20.0 mg.

*bSupplied (per kilogram of diet): Fe, 62.1 mg (diets 1, 2), 319 mg (diet 3) as E1 ferrous carbonate (diets 1, 2 and 3) and ferric oxide (diet 3); I, 1.31 mg as E2 potassium iodide; Cu, 9.83 mg as E4 cupric sulphate pentahydrate; Mn, 193.5 mg as E5 manganese oxide; Zn, 74.4 mg as E6 zinc oxide.

*cOrganic matter content = DM − Ash.

*dNon-nitrogenous extracts content = 100 − (Ash + CP + EE + CF).

*eN NCe: non-nitrogenous cellular content = OM − (CP + NDF).

*fEstimated according to Janssen (1998).
Table 2. Live weight and average daily gain of Padovana (PAD) and Polverara (POL) chickens from hatching until slaughter (0–183 d of age).

| Item                  | Breed (B) | Gender (G) | p Value |
|-----------------------|-----------|------------|---------|
|                       | PAD POL   | M F SE     | B G B × G |
| Number of birds       | 67 70     | 76 61      |         |
| Live weight (LW), g   |           |            |         |
| 0 d                   | 33.8 33.7 | 33.8 33.7  | 0.4     |
| 28 d                  | 248 240   | 255<sub>a</sub> 233<sub>b</sub> | 4       |
| 71 d                  | 786 809   | 871<sub>a</sub> 724<sub>b</sub> | 18      |
| 183 d                 | 2114 2070 | 2437<sub>a</sub> 1747<sub>b</sub> | 22      |
| Average daily gain (ADG), g/d | | |
| Period 1 (0–28 d)     | 7.65 7.35 | 7.88<sub>a</sub> 7.12<sub>a</sub> | 0.15    |
| Period 2 (29–71 d)    | 12.8 13.6 | 14.7<sub>a</sub> 11.7<sub>b</sub> | 0.4     |
| Period 3 (72–183 d)   | 12.0<sup>a</sup> 11.4<sup>b</sup> 14.1<sub>a</sub> 9.22<sub>b</sub> | 0.19    |
| Overall period (0–183 d) | 11.4 11.1 | 13.1<sub>a</sub> 9.36<sub>b</sub> | 0.12    |

<sup>a,b</sup>Means within the same row followed by different lowercase superscript letters differ <i>p</i> ≤ 0.05.
<sup>A,B</sup>Means within the same row followed by different uppercase superscript letters differ <i>p</i> ≤ 0.01; <i>p</i> ≤ 0.001.

Live performances

At 28, 71 and 183 d of age, male were heavier than female birds (255 versus 233 g, 871 versus 724 g, and 2437 versus 1747 g, respectively; <i>p</i> < 0.001); on the contrary, breed did not influence animal weight in any of the considered ages (Table 2). Differences in birds weight reflected the trend observed in their ADG: males always displayed greater values than females during the three feeding periods (7.88 versus 7.12 g/d, 14.7 versus 11.7 g/d and 14.1 versus 9.22 g/d, respectively; <i>p</i> < 0.001) and consequently during the overall rearing period (13.1 versus 9.36 g/d, respectively; <i>p</i> < 0.0001) (Table 2). Breed affected only ADG, which was greater for Padovana (PAD) respect to Polverara (POL) during the third period (12.0 versus 11.4 g/d, <i>p</i> < 0.05) (Table 2).

The FI and FCR of these uncommon breeds were calculated on pen basis during the three feeding phases and on the overall rearing period. During the first period (0–28 d of age), PAD ingested numerically less feed (15.7 versus 21.9 g/d) and exhibited better FCR (2.08 versus 3.07), whereas, during the second period (29–71 d of age), both FI and FCR were numerically similar between PAD and POL (FI: 50.9 versus 54.0 g/d, respectively; FCR: 4.19 versus 4.03, respectively). In the third feeding phase (72–183 d of age), PAD displayed a more favourable FCR (5.90 versus 6.57) and a numerically greater ADG than POL, despite recording similar FI (72.7 and 72.0 g/d, respectively). Considering the overall rearing period (0–183 d of age), data revealed similar FI (55.1 and 58.2 g/d for PAD and POL, respectively), that resulted in similar FCR (5.13 and 5.51 for PAD and POL, respectively).

Table 3. Mortality rate of Padovana (PAD) and Polverara (POL) breeds.

| Mortality, % | PAD | POL | p Value |
|--------------|-----|-----|---------|
| 0–28 d       | 3.7 | 0.0 | .118    |
| 29–71 d      | 12.8| 5.3 | .124    |
| 72–183 d     | 0.0 | 1.4 | .131    |
| 0–183 d      | 16.5| 6.7 | .060    |

Table 3 describes mortality rates computed for each phase and for the overall rearing period. As chickens were sexed at the end of the trial, it was not possible to detect gender differences in mortality rate, and so results refer to the breed effect only. Even if there were no statistical differences, PAD was characterised by a greater mortality rate during the first two periods compared with POL (3.7 versus 0.0% and 12.8 versus 5.3%, for PAD and POL, respectively), that lead to an overall tendentially higher mortality rate (16.7 versus 6.7% for PAD versus POL, respectively; <i>p</i> = .060).

Slaughter yields

Slaughter weight (SW), commercial carcase weight (CCW) and net carcase weight (NCW) were affected only by gender and resulted to be heavier in males than females (2425 versus 1747 g; 2008 versus 1432 g; 1431 versus 1026 g, respectively; <i>p</i> < .0001). Differently, commercial carcase yield (expressed as % SW) was influenced by both breed (5% versus .0.0%) and gender (<i>p</i> < .05) and resulted to be greater in POL than in PAD breed (82.9 versus 81.8%; <i>p</i> < .05) and in male than in female birds (82.8 versus 81.9%; <i>p</i> < .05) (Table 4). Net carcase yield was not affected by breed and gender. Despite males had heavier NCW, its incidence was the same of that of females. Probably this is due to greater incidence of heart (0.62 versus 0.51%; <i>p</i> < .0001), neck + head (9.14 versus 8.19%; <i>p</i> < .0001).
Table 4. Slaughter yields of Padovana (PAD) and Polverara (POL) breeds.

| Breed (B) | Gender (G) | p Value |
|----------|------------|---------|
| PAD | POL | M | F | SE | B | G | B × G |
| Number of birds | 59 | 60 | 67 | 52 | | | |
| Slaughter weight (SW), g | 2111 | 2061 | 2425 | 1747 | 25 | .1542 | <.0001 | .2119 |
| Commercial carcass weight (CCW), g<sup>1</sup> | 1729 | 1711 | 2008<sup>a</sup> | 1432<sup>b</sup> | 22 | .5703 | <.0001 | .6502 |
| Commercial carcass yield, % SW | 81.8<sup>b</sup> | 82.8<sup>a</sup> | 82.8<sup>b</sup> | 81.9<sup>a</sup> | 0.2 | .0025 | .0124 | .0075 |

Organs incidences, % CCW

| Gender | | |
|--------|------------|---------|
| Gizzard | 2.51 | 2.50 | 2.32<sup>e</sup> | 2.69<sup>d</sup> | 0.05 | .9024 | <.0001 | .0564 |
| Liver | 1.76 | 1.75 | 1.66 | 1.76 | 0.04 | .1157 | .0772 | .0066 |
| Heart | 0.57 | 0.56 | 0.60<sup>a</sup> | 0.51<sup>b</sup> | 0.01 | .3839 | <.0001 | .5731 |
| Neck + head | 8.87<sup>a</sup> | 8.46<sup>b</sup> | 9.14<sup>d</sup> | 8.19<sup>e</sup> | 0.13 | .0333 | <.0001 | .5866 |
| Wings | 7.20 | 7.32 | 7.33 | 7.19 | 0.01 | .3804 | .3080 | .5558 |
| Shanks | 3.82<sup>b</sup> | 4.45<sup>a</sup> | 4.46<sup>a</sup> | 3.81<sup>b</sup> | 0.06 | <.0001 | <.0001 | .0584 |

Net carcass weight (NCW), g<sup>2</sup>

| Gender | | |
|--------|------------|---------|
| 1236 | 1220 | 1431<sup>A</sup> | 1026<sup>B</sup> | 18 | .5271 | <.0001 | .7073 |
| Net carcass yield, % SW | 58.5 | 59.1 | 59.0 | 58.7 | 0.3 | .1125 | .4342 | .0454 |
| Whole breast weight, g | 227 | 236 | 255<sup>a</sup> | 208<sup>b</sup> | 5 | .2410 | <.0001 | .0442 |
| Breast yield, % CCW | 10.9<sup>b</sup> | 11.5<sup>a</sup> | 10.5<sup>b</sup> | 11.9<sup>a</sup> | 0.2 | .0253 | <.0001 | .0011 |
| Breast yield, % SW | 13.3 | 13.9 | 12.7<sup>b</sup> | 14.5<sup>a</sup> | 0.2 | .0719 | <.0001 | .0033 |
| Legs weight, g | 439 | 442 | 533<sup>a</sup> | 348<sup>b</sup> | 6 | .7596 | <.0001 | .2286 |
| Legs yield, % SW | 20.7<sup>b</sup> | 21.3<sup>a</sup> | 22.0<sup>a</sup> | 20.0<sup>b</sup> | 0.2 | .0155 | <.0001 | <.0001 |
| Legs yield, % CCW | 25.3 | 25.6 | 26.6<sup>b</sup> | 24.4<sup>a</sup> | 0.2 | .2029 | <.0001 | .0030 |
| Leg meat/bones ratio<sup>3</sup> | 6.07 | 5.93 | 5.82<sup>b</sup> | 6.19<sup>a</sup> | 0.21 | .6366 | 2133 | .5090 |
| Leg skin incidence, % leg weight<sup>3</sup> | 11.1 | 11.2 | 10.2<sup>e</sup> | 12.2<sup>d</sup> | 0.4 | .7254 | <.0001 | 1495 |
| Femur weight, g<sup>3</sup> | 13.1 | 13.9 | 16.5<sup>a</sup> | 10.5<sup>b</sup> | 0.4 | .119 | <.0001 | .4517 |
| Femur length, mm<sup>3</sup> | 93.3<sup>a</sup> | 90.4<sup>b</sup> | 96.7<sup>a</sup> | 87.0<sup>b</sup> | 0.9 | .0176 | <.0001 | .966 |
| Femur diameter, mm<sup>3</sup> | 8.04<sup>b</sup> | 8.37<sup>a</sup> | 8.61<sup>a</sup> | 7.80<sup>b</sup> | 0.10 | .014 | <.0001 | .9246 |
| Femur WBFT, N<sup>4</sup> | 373<sup>b</sup> | 404<sup>a</sup> | 459<sup>a</sup> | 317<sup>b</sup> | 11 | .0403 | <.0001 | .0456 |

<sup>a</sup>M = Means within the same row followed by different lowercase superscript letters differ p < .05.

<sup>2</sup>N = Means within the same row followed by different uppercase superscript letters differ P < .01; p < .001.<n
<sup>1</sup>C = Commercial carcasse: slaughtered bird after removal of blood, feathers and viscera, with stomach, gizzard, liver, heart, and head, neck and shanks attached.

<sup>2</sup>W = Commercial carcasse: slaughtered bird after removal of stomach, gizzard, liver, heart, and head.

<sup>3</sup>D = Determined on the left legs.

<sup>4</sup>B = Warner–Bratzler Fracture Toughness.

and shanks (4.46 versus 3.81%; p < .0001) displayed by males. The percentages of some slaughtering wastes varied also between PAD and POL breeds, with PAD exhibiting greater incidence of neck + head (8.87 versus 8.46%, respectively; p = .0333) and POL displaying a greater incidence of shanks (4.45 versus 3.82%; p < .0001). Breast and legs weights were similar between PAD and POL, whereas they differed between male and female chickens (255 versus 208 g and 533 versus 348 g, for breast and legs, respectively; p < .0001). As for breast and legs yield, differences emerged in favour of Polverara for both breast (11.5 versus 10.9% SW; p < .05) and leg yields (21.3 versus 20.7% SW; p < .05); however, this difference attributable to breed disappeared when the yields were considered on CCW. Breast yield difference was in favour of females, whereas legs yield difference was in favour of males (Table 4).

Leg meat/bone ratio was not affected by breed and gender, whereas leg skin incidence was higher in females than males (12.2 versus 10.2% leg weight; p < .0001). Femur traits revealed that differences exist between the two breeds also considering bones structure. Indeed, being femur weight and its incidence equal in the two breeds, POL chickens exhibited shorter (90.4 versus 93.3 mm; p < .05) but thicker (8.37 versus 8.04 mm; p < .05) femurs compared with PAD chickens, and thus the former needed a higher breaking load (404 versus 373 N; p < .05). As expected, a gender difference had been observed: male femurs were heavier (16.5 versus 10.5 g; p < .0001), longer (96.7 versus 87.0 mm; p < .0001), thicker (8.61 versus 7.80 mm; p < .0001) and tougher (459 versus 317 N; p < .0001) than those of females. Breed and gender (B × G) interaction was observed on yields, revealing the highest commercial carcasse yield (p < .01) and legs yield (% CCW; p < .01) of POL M chickens. On the contrary, PAD M birds showed the lowest breast incidence on CCW (p < .05), and the two female groups exhibited the lowest leg yields (p < .01) (Figure 1(a–c)).

**Meat pH and colour values**

Birds of the two breeds did not differ in the pH value of the *Pectoralis major* muscle, whereas it was significantly higher in males than females (5.90 versus 5.84; p < .001) (Table 5). The significant B × G interaction showed that breast pH of POL F was lower than that...
of POL M (5.81 versus 5.94; \( p < .0001 \)) (Figure 2(a)). Instrumental colour measurement of the breast (Pectoralis major muscle) revealed that PAD birds had lighter (higher \( L^* \) value) breast meat than POL (50.0 versus 48.5; \( p < .01 \)). As a consequence of their lower pH, females breasts resulted in higher \( L^* \) and \( b^* \) values compared with male breasts (50.4 versus 48.9; \( p < .01 \)).

Differently, breast \( a^* \) colour value did not vary neither considering breed nor gender. Interestingly, the B \( \times \) G interaction was significant for \( L^* \) (\( p < .01 \)) and \( b^* \) (\( p < .0001 \)) colour values: POL F showed the yellowiest (\( b^* = 9.08 \)) breasts, whereas POL M the darkest (lowest \( L^* \) value = 47.4) and the least yellow (\( b^* = 4.72 \)) ones.

Table 5. Pectoralis major muscle pH and \( L^*a^*b^* \) colour values of Padovana (PAD) and Polverara (POL) breeds, measured at 48-h post mortem.

| Breed (B) | Gender (G) | \( p \) Value |
|-----------|------------|---------------|
| PAD       | M          | F             | SE       | B        | G        | B \( \times \) G |
| POL       |            |               |          |          |          |               |
| Number of samples | 59       | 60          | 67       | 52       |          |               |
| pH        | 5.87      | 5.87        | 5.90\(^A\) | 5.84\(^B\) | 0.01     | .9385        | .0001         | <.0001 |
| \( L^* \) (lightness) | 50.0\(^A\)  | 48.9\(^B\)    | 48.5\(^A\) | 50.4\(^B\) | 0.3      | .0040        | <.0001        | .0087  |
| \( a^* \) (redness) | -1.41     | -1.03       | -1.25    | -1.20    | 0.14     | .0520        | .8004         | .0915  |
| \( b^* \) (yellowness) | 6.73      | 6.90        | 5.51\(^A\) | 8.13\(^B\) | 0.23     | .5935        | <.0001        | <.0001 |

\( ^{A,B} \) Means within the same row followed by different uppercase superscript letters differ \( p \leq .01 \); \( p \leq .001 \); \( p \leq .0001 \).

Sexual dimorphism lead to significant differences in pH and colour values of the iliotibialis lateralis muscle: females had higher pH (6.19 versus 6.11; \( p < .001 \)), \( L^* \) (49.4 versus 47.7; \( p < .0001 \)) and \( b^* \) (4.96 versus 3.10; \( p < .0001 \)) colour values than males, whereas males exhibited significantly higher \( a^* \) value (2.27 versus −0.36; \( p < .0001 \)). The statistically significant B \( \times \) G interaction highlighted differences between PAD F and POL M.

![Figure 1](image1.png)

Figure 1. Effect of B \( \times \) G interaction on slaughter yields, referred to (a) commercial carcase yield; (b) breast yield; (c) legs yield.

![Figure 2](image2.png)

Figure 2. Effect of B \( \times \) G interaction on (a) Pectoralis major muscle pH; (b) iliotibialis lateralis muscle pH.
groups, reflecting the sexual dimorphism trends (Figures 2(b) and 4(a–c)).

**Discussion**

The obtained live weights were in accordance to those provided by the standards included into the “Registry of Italian Indigenous Chicken Breeds” (D.M. No. 19536 of 01.10.2014), indicating live weights of about 2 kg and 1.8 kg for adult PAD and POL breeds, respectively. Up until now, the selection for these slow-growing breeds mainly aimed at the conservation of morphological traits and to assure their survival, even though some efforts were made also to increase chicken live weight (LW) throughout the last decade. However, observing the average LW of PAD breed at 180 d of age, during the last 12 years, this selection effort has been partially achieved. In fact, in 2005 PAD chickens weighed on average 1674 g (De Marchi et al. 2005) in 2015 they reached 2571 g of LW (Cassandro et al. 2015), but in the present study, their LW was only 2114 g. Uneven live performances among different experiments could also be explained by the natural environmental rearing conditions; variations in indoor temperatures and photoperiod throughout the study can make target market weights difficult to obtain (Fanatico et al. 2005).

Overall average daily gain (ADG) in the present study was lower than that calculated by Rizzi et al. (2013) (11.4 g/d versus 15.0 g/d, respectively), despite the two trials were conducted under similar environmental conditions (natural photoperiod and ventilation, indoor temperatures and relative humidity). Probably, these discrepancies could be explained by the lack of standardisation in the productive performances of these animals. In fact, the primary goals pursued so far by

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**Table 6.** Iliotibialis lateralis muscle pH and \( L^*a^*b^* \) colour values of Padovana (PAD) and Polverara (POL) breeds, measured at 48-h post mortem.

| Breed (B) | Gender (G) | \( p \) Value |
|-----------|------------|---------------|
|           |            |               |
| PAD       | POL        |               |
| Number of samples | 59 | 60 | 67 | 52 | 0.01 | <.0001 | <.0001 | <.0001 |
| pH        | 6.20, A | 6.11, B | 6.11, B | 6.19, A | 0.01 | <.0001 | <.001 | <.0001 |
| \( L^* \) (lightness) | 49.4, A | 47.9, B | 47.7, B | 49.6, A | 0.3 | .0002 | <.0001 | <.0001 |
| \( a^* \) (redness) | -0.01, B | 1.92, A | 2.27, A | -0.36, B | 0.20 | <.0001 | <.0001 | .320 |
| \( b^* \) (yellowness) | 4.30, B | 3.75, B | 3.10, B | 4.96, A | 0.20 | .0564 | <.0001 | .010 |

A, B Means within the same row followed by different uppercase superscript letters differ \( p \leq .01 \); \( p \leq .001 \); \( p \leq .0001 \).
scientific community and local Institutions have been the protection of this local breeds and the conservation of their morphological traits. As expected, both pure-breds demonstrated overall good resistance and adaptability to the extensive farming conditions. On the one hand, it is likely that the stress created by a low tolerance toward daily human presence predisposed animals to a coccidiosis onset, responsible of a numerically greater mortality exhibited by the PAD group during the second feeding period. On the other hand, it is worthy to be noticed that PAD recovered the health status and exhibited no mortality together with better ADG and FI compared to POL breed in the latter uncomfortable summer period (July–October). The good resistance of these two slow-growing genotypes is also confirmed by their bones traits. Hormonal differences can account for the differences in the growth and bone strength between males and females (Rath et al. 1999). Globally, femurs of both sexes observed in this trial were longer, thicker and heavier than those belonging to their commercial counterpart (Bruno et al. 2007; Shahnazari et al. 2007; Salaam et al. 2016), with a superior bone strength than that of fast-growing meat-type hybrids (Rath et al. 1999). A higher level of locomotory activity, which is a component of slow-growing behavioural patterns (Mench 1988), was demonstrated to strengthen bones and to reduce deformities (Reiter and Bessei 1998). Then, mature bones can reach their optimum physical and biomechanical properties because they have the time to complete their structural development and the mineralisation processes (Rath et al. 2000). The impressive growth rate and final live weight of heavy strains predispose broiler chickens to bone weakness, deformities, lameness (Julian 1998; Williams et al. 2004; Salaam et al. 2016) and to cortical bone fractures during catching and transportation (Rath et al. 2000); these problems are scarce or absent in slower growing strains (Havenstein et al. 1994). On the one hand, these skeletal abnormalities represent a welfare issue, because they are painful and reduce walking ability (Bradshaw et al. 2002); as a consequence, lame broilers have more breast blisters, scratches, inflammatory processes and muscle atrophy (Julian 1998; Vaillancourt and Martinez 2002) as they spend more time lying in the litter (Oviedo-Rondón et al. 2009). On the other hand, there are economic concerns: mortality on the farm increases, as well as condemnations within processing plant (Rath et al. 1999). In addition, the automatic processing lines are slowed down and the requirement of manual trimming during deboning increases (Oviedo-Rondón 2007). Bone fragility is also correlated with the incidence of bone fragments in deboned meat products and discolouration of meat adjacent to bone due to the leaching of blood (Gregory and Wilkins 1992).

Some differences on carcase traits were noticed between our findings and the mean values observed in the previous studies. In fact, birds of the present study exhibited heavier commercial carcases and heavier legs compared to the values proposed by De Marchi et al. (2005). At the same time, edible portion weight, breast and carcase yields of the present study were inferior to those observed by Cassandro et al. (2015) at the same birds’ age.

Breast meat quality traits differences were also found between our observations and those previously made by other researchers. The breast pH value of PAD breed was higher than that found in the literature (De Marchi et al. 2005; Cassandro et al. 2015), and also higher when compared with that measured in Robusta Maculata, another local chicken breed of the Veneto Region (Castellini, Dal Bosco, et al. 2002). Differently, the breast meat pH of our PAD chickens resulted to be much lower than that observed by Zanetti, De Marchi, Dalvit, Molette, et al. (2010), who reported an aggressive and alert behaviour of animals. It is known that stress conditions could be responsible of a poor glycogen storage (Jaturasitha et al. 2004; Debut et al. 2005); here, according to Castellini, Dal Bosco, et al. (2002), Castellini et al. (2002a), the protective effect of motor activity could have mitigated the negative effect of the stress on breast pH. Regarding POL M, it is not clear which is the prevalent mechanism that led to a low pH value of the iliobialis lateralis muscle. Considering the extremely red colour of the iliobialis lateralis muscle exhibited by POL M, a high pH value was expected for this group. Indeed, because red fibres have a prevalent oxidative metabolism, they are well known to possess less glycogen content, thus limiting the muscle pH post mortem drop. Unfortunately, no previous study had been conducted on Polverara breed, thus, our pH and colour values are not comparable with literature; however, the hypothesis formulated by Castellini, Dal Bosco, et al. (2002), Castellini et al. (2002a) on a protective effect of motor activity against stress outcome could have been confirmed here also for thigh oxidative muscles.

Males exhibited heavier breast characterised by higher pH; this finding could be explained considering the positive correlation \( r = 0.84 \) linking breast weight and pH value, as a consequence of a lowered level of glycogen stored in heavier muscles (Le Bihan-Duval et al. 2008). In addition, according to Le Bihan-Duval et al. (2008), higher \( L^* \) values and the more yellow fillets exhibited by females could be explained by the negative correlation linking pH with \( L^* \) and \( b^* \) traits.
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Conclusions
The present study demonstrated that both Padovana and Polverara chicken breeds present a good adaptation to the extensive rearing conditions. Furthermore, they have a good potential to be used in gastronomic niche market, due to their meat characterised by specific and unique quality traits.

Disclosure statement
Authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article. Any financial interest or benefit arose from the direct applications of the present research.

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