Plumage colour in Padovana chicken breed: growth performance and carcass quality

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ABSTRACT
Padovana female chickens of two plumage varieties, chamois (PC) and silver (PS) and their cross (PC male × PS female) were reared from 1 d until 200 d of age, when they were slaughtered. PC has light brown feathers with white edge (chamois), PS has white feathers with black edge (silver); PC×PS has silver plumage (cross-S) or completely white plumage (cross-W) at a ratio, at hatching, of 1:2 as cross-S:cross-W. The chickens were kept in a breeder house from May until December. In a population of Padovana chickens, it seems to be a relationship between the colour plumage and body weight until the sexual maturity: from 2 weeks until 6 weeks of age the PC females exhibited a higher daily growth ($p < .001$) than PS, as well as body weight ($p < .01$) at 28 weeks. At 200 d, PC showed higher carcase ($p < .05$) and thigh ($p < .05$) weight than PS, but similar ready-to-cook carcase conformation and pH, colour, water losses and shear force of breast muscle; no difference was checked between the other groups. Under the environmental conditions of the trial, heterosis had a positive effect ($p < .05$) on the daily growth until 70 d of age for cross-S. The results shows a sexual dimorphism for body dimensions increasing until the pubertal age for all the groups; therefore, the females should be slaughtered about 8 weeks later than the males for achieving similar body weight and slaughtering performance and carcase quality.

Introduction
Padovana breed has to be cited among the oldest Italian purebreds still existing, reared in Northern Italy since 1500 (Aldrovandi 1599). Actually, it is diffused and known all over the world as an ornamental breed given its particular head morphology consisting of a cranial hernia and long feathers that partially cover the eyes. This breed shows a comb, when present, little developed and with an irregular shape, the skin and feet are grey and the egg has a white shell. Different plumage varieties exist: white, black, golden, silver and chamois. Other than its ornamental use, this breed can be used also for productive purposes, egg and meat (Verdiglione and Cassandro 2013). The daily growth is slow, less than 20 g/d on average, so the adult body weight is reached after 28 weeks of age (Rizzi et al. 2013). A trial was carried out to study the productive and slaughtering performance, the carcase and meat quality on Padovana chickens with chamois and silver plumage and on the offspring obtained from the cross between them.

Materials and methods

Animals and environmental conditions
The project was approved by the Ethical Committee for the Care and Use of Experimental Animals. The trial was carried out on Padovana chickens of two plumage varieties, chamois (Padovana camosciata, PC, on average 40 birds per each gender) and silver (Padovana argentata, PS, on average 30 birds per each gender), and their cross (PC male × PS female); they were reared from 1 d until 200 d of age. PC plumage consists of light brown feathers with white edge, PS plumage consists of white feathers with black edge; PC×PS showed white feathers with black edge (cross-S, silver phenotype) or completely white feathers (cross-W, white phenotype). The birds came from a centre of breed conservation located in Padova (Progetto COVA, Veneto Agricoltura 2004) and they were reared at a breeder house. The same environmental conditions and profilaxis procedures (Newcastle disease, Marek and Infectious bronchitis vaccines) were applied to the animals throughout the trial.
Sexing (by cloacal inspection) was performed on day-old chicks of each strain; the chickens were reared separately on wooden litter from the start (May) until the end (December) of the trial. During the first 4 weeks of life the chicks were kept under infra-red lamps and the temperature under them was gradually lowered from 33 to 24°C.

The chicks were fed ad libitum the same feed based mainly on corn (48%), soybean (23%), minerals and supplement (vitamins and Cu); formulation and composition (Table 1) did not change throughout the trial, but only the feed form, that was crumbled for the first 8 weeks of trial and then pelleted. Environmental conditions inside the house were checked throughout the experimental period (Table 1); the photoperiod was natural and it decreased during the trial according to the season.

The birds were weighed at 1 d, then every 2 weeks until 70 d of age and then every month.

**Slaughtering procedures**

At two ages, at 126 d for the males, and at 200 d for the females, 8–10 chickens for each group were weighed and brought to the slaughter-house. Feed was withdrawn 12 h before slaughter; the birds, previously weighed, were electronically stunned, killed by exsanguination, plucked, and eviscerated (intestines; perivisceral, perineal and abdominal fat; gall bladder; oesophagus; full crop; proventriculus; and spleen) following the procedure of WPSA (1984). Cold carcass weight (after 24 h at 4°C) were recorded. From the refrigerated carcasses, the head and neck, feet and edible viscera (heart, liver and gizzard) were removed to obtain the ready-to-cook carcass. Successively, the head and neck and the feet were weighed and, then, the breasts, thighs, drumsticks and wings.

**Table 1.** Chemical composition of the feed and environmental conditions.

| Chemical compositiona | Environmental conditions |
|------------------------|--------------------------|
| %                      | Temperature °C | RH, % |
| Dry matter             | 87.5           | Ageb  |
| Crude protein          | 21.0           | II    |
| Crude fat              | 5.14           | III   |
| Crude fibre            | 4.35           | IV    |
| Ash                    | 7.24           | V     |
| Calcium                | 1.65           | VI    |
| Phosphorus             | 1.81           | VII   |
| Lysine                 | .92            | VIII  |
| Methionine             | .42            | IX    |
| ME (kcal/kg)           | 2847           |       |

ME: metabolisable energy; RH: relative humidity.

Integration per kilogram of feed: A vitamin, 15,000 U; D3 vitamin, 3000 U; E vitamin (x-tocopherol 91%), 30 mg; B2 vitamin, 35 mg; Cu (Cu sulphate) 10 mg.

Age of the animals: II (27 d), III (42 d), IV (55 d), V (70 d), VI (97 d), VII (124 d), VIII (152 d), IX (186 d).

**pH and physical traits of breast meat**

On the right breast muscle, *Pectoralis major*, at 48-h post-mortem, the ultimate pH was recorded by a Delta Ohm HI-8314 pHmeter (Delta Ohm, Padova, Italy) and Crison electrode (Crison, Barcelona, Spain). Colour was recorded on breast skin and muscle by a Minolta Chroma metre CR-300 tristimulus analyser (Minolta Corp., Ramsey, NJ) (CIELAB colour space model, Commission International de l’Eclairage, 1978). The CIELAB colour space model was chosen to numerically describe the colour parameters. Lightness (L*) is the amount of incident light that a surface reflects; −a* values represent green and +a* values represent red colour; −b* values represent blue and +b* values represent yellow colour.

The skinless breasts were weighed and frozen at −20°C for further analyses. After 2 weeks, they were removed from the freezer, placed on trays and thawed in a commercial refrigerator at 3–4°C for 24 h. The breast muscles were blotted dry and then cooked in water at 75°C for 60 min inside sealed bags. After 15 min of cooling under running water, the fillets were dried with paper.

Each breast fillet was weighed before and after thawing and cooking to evaluate the thawing losses [(frozen weight − thawed weight)/(frozen weight) × 100] and cooking losses [(uncooked weight − cooked weight)/(uncooked weight) × 100]. Then, on the cooked sample, shear force was performed on three cylindrical cores (1.13 cm of diameter) by using a TA-HDi Texture Analyzer (Stable Macro System, London, UK) with a Warner-Bratzler shear attachment (10 N load cell, crosshead speed of 2 mm/s). The average peak shear force from the three replicates was taken as the final shear force value.

**Chemical composition of diet and meat**

The feed and raw meat of the left breasts were homogenised in a homogeniser (Grindomix GM200, Retsch GmbH), stored at −20°C and after 12 d chemically analysed for dry matter (method 950.46, AOAC 2000), protein (method 981.10, AOAC 2000), lipid (method 991.36, AOAC 2000) and ash (method 920.153, AOAC 2000); for the meat samples, total lipids were extracted according to the method of Folch et al. (1957).

**Statistical analysis**

All the data on the females and males were evaluated by ANOVA and processed by using a general linear model (SAS, version 9.3, Inst. Inc., Cary, NC) that
considered genotype (for daily growth, final body weight, slaughtering and carcase and meat quality data) as main effect; to evaluate the presence of dimorphism for each strain, the body weight data of different ages were submitted to ANOVA using a model with gender as main effect. Post hoc pairwise contrasts were evaluated by Bonferroni adjustments at a significance level of $p \leq 0.05$. Furthermore, for females, contrast estimates between each cross and the average of PC and PS allowed to identify if each crossbred significantly deviated from the average of the two parental genotypes.

Results and discussion

Sexual dimorphism and growth

Before discussing the results on the growth performance, it is well remembering that at the hatching the offspring from the crossing PC males with PS females showed a different plumage colour and the ratio white plumage:silver plumage (Figure 1) was 2:1 for the females (cross-W=67%, white plumage and cross-S=33%, silver plumage) and 3:1 for the males (cross-W=76%, white plumage and cross-S=24%, silver plumage).

Actually the factors determining this ratio are unknown and more investigations are needed to understand whether this ratio origins from the layed eggs or the hatched eggs as genetic factors and environmental conditions of incubation could be involved (Collins and Wentworth 1958; Conway and Martin 2000; Yilmaz et al. 2011).

Table 2 shows sexual dimorphism in body weight for PS, PC and cross-W and cross-S. The body weight of all the males were constantly higher ($p < 0.001$) than those of the females from 90 until 180 d of life. Sexual dimorphism in poultry is present in almost all the breeds or strains, as the jungle fowl lives in polygamy and the males are quite different from the females for many body traits for constituting their harem for reproduction. One of the main traits that shows differences between males and females is the body weight: analysis of sexual differences for each group showed different values as until 55 d of age dimorphism was less than 10% (data not shown), but in elder birds it raised in a different manner according to the genotype, reaching values, respectively, of 45% and 53% in cross-S and cross-W, and 39% and 32% in PC and PS, at 26 weeks.

Table 3 summarises the daily growth from 10 d until 200 d of life and the body weight at slaughter of the females. The daily growth significantly differed between all the groups, with exception of the comparison between cross-W and cross-S, throughout the first 10 weeks of life, then it was quite similar and reached a maximum of 12–14 g at 97 d of age. PS growth was lower ($p < 0.001$) than PC until 42 d. In the cross genotypes, the heterosis was statistically significant at I age ($p < 0.001$) and VI age ($p < 0.05$) for the cross-W, and for all the first growing period ($p < 0.05$) until 70 d of age for the cross-S. The final body weight at 200 d was significantly higher in PC in comparison

### Figure 1. Incidence (%) of silver and white plumage of offspring chickens from crossing PC males with PS females.

### Table 2. Sexual dimorphism for body weight of four genotypes from 90 until 180 d of life of Padovana breed.

| Age  | PC    | PS     | Cross-W | Cross-S |
|------|-------|--------|---------|---------|
|      | BW, g | M vs. F | p       | RMSE    | BW, g | M vs. F | p       | RMSE    | BW, g | M vs. F | p       | RMSE    | BW, g | M vs. F | p       | RMSE    |
| 90 d | 1170  | 272    | <.001   | 98     | 981   | 159    | <.001   | 142    | 1227  | 329    | <.001   | 89     | 1068  | 274    | <.001   | 68     |
| 130 d| 1505  | 426    | <.001   | 125    | 1300  | 332    | <.001   | 138    | 1470  | 524    | <.001   | 102    | 1410  | 512    | <.001   | 88     |
| 150 d| 1712  | 663    | <.001   | 216    | 1500  | 437    | <.001   | 179    | 1723  | 725    | <.001   | 146    | 1656  | 670    | <.001   | 111    |
| 180 d| 1897  | 644    | <.001   | 143    | 1709  | 485    | <.001   | 225    | 1932  | 838    | <.001   | 172    | 1809  | 689    | <.001   | 152    |

Genotypes and number of observations for males (M) and females (F) – PC: Padovana chamois (90-130 d: 35 M, 43 F; 150-180 d: 22 M, 33 F), PS: Padovana silver (90–130 d: 22 M, 27 F; 150–180 d: 14 M, 19 F), cross-W: cross-white (90–130 d: 26 M, 30 F; 150–180 d: 20 M, 23 F), cross-S: cross-silver (90–130 d: 8 M, 13 F; 150–180 d: 7 M, 10 F).

BW: body weight of males and females.

M versus F: difference (g) of body weight between males and females.

p: statistical significance; RMSE: root mean square error.
to PS ($p < .01$) and cross-S ($p < .05$), whereas no differences were detected between the other groups.

The feathering process may be a factor influencing the growth rate of the birds, so chickens with different plumage colour belonging to the same breed can differ for liveability and growth performance, as stated in the past by Jaap and Grimes (1956) and Collins and Wentworth (1958) that checked a lower growth and a higher mortality in chickens with feathers containing the black colour for the presence of some unknown genes when compared to white plumage birds.

In this trial, a high mortality rate until 17 weeks of age, with many deaths during the first weeks of life, was observed in PS (25%), cross-S (13%) and cross-W (9%), whereas in PC it was 5%.

Our results on body weight and liveability of the animals showing a plumage containing the black colour agree with the results obtained previously (Jaap and Grimes 1956; Collins and Wentworth 1958); nowadays, the model of pigments deposition in birds is still not completely known (Mills and Patterson 2009). The females showed a live body weight adequate for slaughtering at 28 weeks of age, and lower than those of commercial hybrids (Petracci et al. 2015) that are slaughtered 22 weeks earlier. Indications on the adult body weight for PC and chamois plumage (Veneto Agricoltura 2004) and for PS and silver plumage (Rizzi et al. 2013) stated that at 200 d the PC and the PS birds have reached, respectively, more than 90% and 80% adult body weight.

**Slaughtering performance and carcase and meat quality**

Table 4 shows the slaughtering performance of PC, PS and cross groups. PC showed values of the carcase weight higher ($p < .05$) than PS, a same trend ($p = .06$) for the weight of the breasts, and significant differences for the thighs ($p < .05$). The incidence on body weight of head and neck and feet were similar between the two groups, as well as the ready-to-cook carcase conformation for a similar incidence of breasts, wings and hindlegs. Differences between cross-W and cross-S, and between the crosses and PC and PS were not statically significant.

Table 5 shows some physical and rheological traits of the breast. The colour of the breast skin did not differ as $L^*$, $a^*$ and $b^*$ were similar between the groups. For the breast fillet, $L^*$ did not differ, whereas cross-S was higher ($p < .05$) than PS for $a^*$ and than PC ($p < .01$) for $b^*$. Thawing and cooking losses did not differ between groups as well as the shear force.
### Table 4. Carcase quality of females belonging to four genotypes of Padovana breed.

| Genotypesa | PC   | PS   | Cross-W | Cross-S | p    | RMSE | PC vs. PS | Cross-W vs. cross-S | Cross-W vs. PC | Cross-W vs. PS | Cross-S vs. PC | Cross-S vs. PS |
|------------|------|------|---------|---------|------|------|-----------|---------------------|----------------|----------------|----------------|----------------|
| Carcaseb weight, g | 1341 | 1176 | 1193    | 1224    | <.05 | 107  | <.05      | ns                  | ns              | ns             | ns             | ns             |
| Commercial cuts |      |      |         |         |      |      |           |                     |                 |                |                |                |
| Breasts, g    | 275  | 225  | 233     | 229     | <.05 | 39   | ns        | ns                  | ns              | ns             | ns             | ns             |
| Wings, g      | 156  | 144  | 143     | 149     | ns   | 22   | ns        | ns                  | ns              | ns             | ns             | ns             |
| Thighs, g     | 259  | 215  | 223     | 230     | <.05 | 29   | <.05      | ns                  | ns              | ns             | ns             | ns             |
| Drumsticks, g | 150  | 142  | 137     | 143     | ns   | 10   | ns        | ns                  | ns              | ns             | ns             | ns             |
| Body weight, % : |      |      |         |         |      |      |           |                     |                 |                |                |                |
| -head and neck, feet | 8.63 | 9.15 | 8.44    | 9.07    | ns   | .72  | ns        | ns                  | ns              | ns             | ns             | ns             |
| Ready-to-cook carcasec % |      |      |         |         |      |      |           |                     |                 |                |                |                |
| -breasts      | 23.2 | 21.8 | 22.5    | 22.0    | ns   | 3.3  | ns        | ns                  | ns              | ns             | ns             | ns             |
| -wings        | 13.2 | 13.9 | 13.7    | 14.3    | ns   | 1.7  | ns        | ns                  | ns              | ns             | ns             | ns             |
| -hindlegs     | 34.5 | 34.6 | 34.7    | 32.5    | ns   | 3.2  | ns        | ns                  | ns              | ns             | ns             | ns             |

*aGenotypes and number of observations – PC: Padovana chamois (9), PS: Padovana silver (9), cross-W: cross-white (7), cross-S: cross-silver (7).
bCold carcase weight; ccarcase without head and neck and feet.
ns: not significant; p: statistical significance; RMSE: root mean square error.

### Table 5. Physical and rheological characteristics of breast skin and meat of females belonging to four genotypes of Padovana breed.

| Genotypesa | PC   | PS   | Cross-W | Cross-S | p    | RMSE | PC vs. PS | Cross-W vs. cross-S | Cross-W vs. PC | Cross-W vs. PS | Cross-S vs. PC | Cross-S vs. PS |
|------------|------|------|---------|---------|------|------|-----------|---------------------|----------------|----------------|----------------|----------------|
| Skin       |      |      |         |         |      |      |           |                     |                 |                |                |                |
| L*         | 63.4 | 65.1 | 64.0    | 64.7    | ns   | 5.7  | ns        | ns                  | ns              | ns             | ns             | ns             |
| a*         | −2.15| −1.96| −2.22   | −2.23   | ns   | .62  | ns        | ns                  | ns              | ns             | ns             | ns             |
| b*         | 8.19 | 6.24 | 5.87    | 5.64    | ns   | 3.91 | ns        | ns                  | ns              | ns             | ns             | ns             |
| Muscleb    |      |      |         |         |      |      |           |                     |                 |                |                |                |
| L*         | 44.2 | 44.9 | 44.5    | 44.1    | ns   | 1.7  | ns        | ns                  | ns              | ns             | ns             | ns             |
| a*         | −1.58| −1.90| −1.81   | −1.25   | <.05 | .37  | ns        | ns                  | ns              | ns             | ns             | ns <.05        |
| b*         | 4.73 | 5.52 | 5.42    | 6.07    | <.01 | .71  | ns        | ns                  | ns              | ns             | ns             | ns             |
| Thawing loss, % | 6.68 | 7.46 | 6.82    | 7.21    | ns   | 1.69 | ns        | ns                  | ns              | ns             | ns             | ns             |
| Cooking loss, % | 21.9 | 21.9 | 21.5    | 22.9    | ns   | 1.5  | ns        | ns                  | ns              | ns             | ns             | ns             |
| Shear force, N | 16.3 | 15.6 | 16.6    | 16.3    | ns   | 2.8  | ns        | ns                  | ns              | ns             | ns             | ns             |

*aGenotypes and number of observations – PC: Padovana chamois (9), PS: Padovana silver (9), cross-W: cross-white (7), cross-S: cross-silver (7).
bPectoralis major muscle.
ns: not significant; p: statistical significance; RMSE: root mean square error.
A comparison with breast fillets of hybrid genotypes indicates that Padovana chickens have a breast meat darker, less greenish and yellowish than that of hybrid chickens (Tasoniero et al. 2016) and a different kind of fibres (Verdiglione and Cassandro 2013).

Table 6 shows some chemical data of the breast fillet. The final pH and the chemical composition of the meat, as protein, total lipids and ash content, were similar for the four groups. Furthermore, the breast muscle of Padovana showed an ultimate pH < 6.0 but higher than 5.8, condition favourable for its microbiological stability (Barbut et al. 2008), avoiding different types of spoilage microorganisms that impair taste, flavour and appearance of meat, and poor water holding capacity (Petracci et al. 2015).

Table 7 summarises some slaughtering performance and carcase and meat quality of the four groups of Padovana chickens according to gender and to plumage colour.

As previously reported in Table 2, dimorphism affected all the groups of Padovana breed, and the slaughtering age highly differs between gender, as 10 weeks (18 vs. 28) separate the age of males and females for reaching a mean body weight of 1.7 kg.

Both male (p < .05) and female (p < .05) birds with white and chamois plumage showed a body weight higher than that of chickens with silver plumage.

The lower body dimensions of birds with silver plumage involved also the ready-to-cook carcase weight, in the females (p < .05) and, as a trend, in the males (p = .08).

Birds with silver plumage showed a higher incidence on body weight of head and neck in males (p < .05), and of feet in males (p < .05) and in females (p < .05).

The female birds with white chamois plumage showed a breast weight higher (p < .05) than that of silver plumage, whereas the incidence of commercial cuts on the ready-to-cook carcase showed similar
values between the two phenotypes, both in females and males.

The breast weight of these genotypes is about 50% the breast weight of commercial hybrids slaughtered at 35 d of age and more similar to the weight of hybrids of 1957 slaughtered at 57 d (280 g) as reported by Petracci et al. (2015).

For the chemical and rheological traits, differences were checked only for the males as thawing losses was higher ($p < .05$) in silver phenotypes that showed a total lipids ($p < .05$) and ash ($p < .05$) content lower than that of the white chamois plumage group. It is well remembering that these traits are highly affected by the age of the animals: the males were notably younger than the females, even if they showed similar carcase weight, and a growing muscle in a younger bird has a water and lipids content different from that of a muscle of a bird that has almost achieved the adult body weight.

Conclusions

The results indicate that in a population of Padovana chickens it seems to be a relationship between the colour plumage and body weight until the sexual maturity: from 2 weeks until 28 weeks of life the birds with light colour feathers exhibited higher body growth and weight than those with dark colour feathers. At 200 d, as far as the slaughtering performance is concerned, PC showed higher carcase weight than PS, but similar ready-to-cook carcase conformation and meat quality. PS chickens showed a higher incidence on body weight of head and neck, and feet.

Crossing PC males to PS females produces females with different plumage colour, silver and white, according to a 1:2 ratio. Under the environmental conditions of the trial, heterosis had a positive effect on the daily growth, especially for the chickens with silver plumage, until 70 d of age. Padovana breed, a slow-growing breed, shows a sexual dimorphism for body dimensions increasing until the pubertal age according to the plumage variety, therefore females should be slaughtered many weeks later than the males, about 8 weeks, for achieving the same slaughtering performance of the males.

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