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Egg and meat production performances of two varieties of the local Ardennaise poultry breed: silver black and golden black

N. Moula, C. Michaux, F.X. Philippe, N. Antoine-Moussiaux and P. Leroy
Department of Animal production, Division of Genetics, Biostatistics and Rural Economics, Faculty of Veterinary Medicine, University of Liege, Liege, Belgium

Summary
The Ardennaise breed is emblematic of the Belgian poultry diversity. We compared two varieties of the breed, the golden black and the silver black. The comparison encompassed: (i) the morphology of adult birds, (ii) the growth, carcass characteristics and meat quality of broilers 22 weeks old, (iii) the laying rate during 52 weeks and the egg quality. Significant differences were observed in the size of mature males and females: body weight, diameter and length of the tarsus, size of the comb and wattles. The two varieties did not differ concerning the carcass and meat quality traits. The golden black has a higher laying rate and a higher yolk / albumen ratio, but lays lighter eggs. It could be interesting to complete this study by molecular markers analysis to evaluate the degree of genetic diversity between the two varieties.

Keywords: *Ardennaise breed, poultry diversity, morphology, breeding, broiler and laying performances*

Résumé
La poule Ardennaise est une race emblématique de la biodiversité avicole belge. Cette étude est consacrée à la comparaison de deux variétés de la race Ardennaise (Noire dorée et Noire Argentée). La comparaison est réalisée par le biais de trois études: (1) caractérisation morpho-biométrique des deux variétés; (2) caractérisation de la croissance et de la qualité de la carcasse et de la viande; (3) suivi du taux de ponte pendant 52 semaines et étude de la qualité des œufs à 30, 45, 60 et 75 semaines d’âge. Des différences significatives ont été enregistrées entre les deux variétés au niveau des poids corporels, du grand diamètre du tarse, de la longueur du tarse et de la taille de la crête. La variété de la poule Ardennaise n’influence significativement aucun des caractères quantitatif et qualitatif de production de viande (rendement, poids après abattage, pH, couleur de la viande). Cependant, elle influence significativement le poids de l’œuf entier, le poids du blanc, le pourcentage du blanc, le pourcentage du jaune, le rapport jaune/blanc et le pH du blanc ($p < 0.05$). Il serait intéressant de compléter cette étude par une analyse moléculaire permettant de préciser le degré de similitude génétique entre les deux variétés et éventuellement avec les autres variétés de la race.

Mots-clés: *race Ardennaise, diversité aviaire, morphologie, sélection, poulet de chair et performances de ponte*

Resumen
La raza Ardenesa es una raza emblemática dentro de la diversidad avícola belga. Se han comparado dos variedades de la raza, la negra dorada y la negra plateada. La comparación comprendió (i) la morfología de aves adultas, (ii) el crecimiento, características de la canal y calidad de la carne de pollos broiler de 22 semanas de edad, (iii) la tasa de puesta durante 52 semanas y la calidad del huevo. Se observaron diferencias significativas en el tamaño de machos y hembras maduros: peso corporal, diámetro y longitud de los tarsos, tamaño de la cresta y de las barbillas. Las dos variedades no difirieron en lo que respecta a parámetros de la canal o de calidad de carne. La variedad negra dorada presenta una mayor tasa de puesta y un mayor ratio yema/albumen, pero pone huevos de menor peso. Podría resultar interesante completar este estudio con un análisis de marcadores moleculares para evaluar el grado de diversidad genética entre las dos variedades.

Palabras clave: *raza Ardenesa, diversidad avícola, morfología, mejora, rendimientos cárnicos y de puesta*

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Correspondence to: Dr N. Moula and Professor P. Leroy. Moula, Department of Animal production, Division of Genetics, Biostatistics and Rural Economics, Faculty of Veterinary Medicine, University of Liege, Liege, Belgium. emails: Nassim.Moula@ulg.ac.be; pascal.leroy@ulg.ac.be

Introduction

All through the industrialization process of western countries in the nineteenth and twentieth centuries, modern poultry production has turned to a true landless, input and capital intensive production system, exclusively based on highly productive and specialized hybrid strains. Sustained by the rapid genetic progress allowed by the short life-cycle of the poultry as well as by the economies of scale (increasing returns), a highly concentrated economic sector has emerged, where the global production hardly relies on a few major genetic types (Lariviere and Leroy, 2008). Nowadays, a rapid demand-driven expansion of the livestock sector in developing countries is taking place (Delgado *et al.*, 1999). In this so-called Livestock Revolution, the intensive peri-urban poultry sector did more than its fair share in the satisfaction of the rising demand for animal products in developing urban centres. However, this industrialization process of egg and chicken production constitutes a serious threat to the genetic diversity of poultry around the world. This trend could be particularly damaging to backyard small-scale poultry rearing that emerged these last few years as a powerful tool in poverty alleviation, in which the need for wide genetic resources cannot be overvalued, as a result of the wide array of environmental conditions to be considered. In developed countries also, a major evolution of consumption habits is converting the animal production sector to more qualitative concerns, for which valorization of local breeds should be of prime interest.

In Belgium, where 95 percent of local poultry breeds are greatly endangered (Larivière and Leroy, 2005), a local breed named Ardennaise is considered as promising in the context of quality terroir production (Moula *et al.*, 2009a, 2009b), the flavour of its flesh being largely renowned. By its remarkable robustness and its resistance to humid climates, this breed has also been proposed for amelioration projects of village chicken production in Sub-Saharan Africa (Youssao *et al.*, 2009). The Ardennaise breed is actually composed of 12 recognized varieties, of which the white one is sometimes considered as a different breed, named the Famennoise (Moula *et al.*, 2009a, 2009b, 2009c; Moula *et al.*, 2012). As the selection process that gave birth to those varieties has been realized on the basis of non-productive phenotypic traits (plumage and eye colour and morpho-biometric characteristics), the question of the relevance of their differentiation regarding production objectives must be considered. In this context, the present study aims at evaluation of egg and meat production abilities of the two major Ardennaise varieties, namely, the silver black feathered and the golden black feathered Ardennaise.

Material and methods

This study was implemented from January 2008 till December 2009 and involved three phases. The first phase consisted in the morpho-biometric characterization of Ardennaise individuals from both silver and golden varieties available at the Animal Production Department of the Faculty of Veterinary Medicine of the University of Liege (Belgium). In the second phase, the meat production performances were recorded through the follow-up of live weight for a growth period of 22 weeks and the assessment of meat quality at slaughter. Quantitative and qualitative egg production performances were then studied during a third phase for a 52-weeks laying period.

Morpho-biometry

Adult birds (over 10 months of age) of the silver black and the golden black varieties from breeding flocks were used for the morpho-biometric characterization. The different body measurements were recorded in accordance with the FAO recommendations (FAO, 1981), by means of a digital balance (precision 1 g), an electronic sliding caliper (precision 0.01 mm) and a tape measure.

The collected data were thus the sex and age of the bird, the comb's length and height, wattles height, the length and diameter of the tarsus and the beak.

Growth and carcass and meat quality

A total of 304 eggs, among which 130 of the silver black Ardennaise and 174 of the golden black Ardennaise, were incubated. All the eggs were less than 10 days old and originated from the flock of the Veterinary Faculty. The number of chicks obtained was 90 for the silver black and 124 for the golden black variety. All the chicks were vaccinated against Marek's disease at day 1.

All the chicks were floor-bred on a sawdust litter in the same ventilated building, both varieties being separated by netting. The chicks were first put under a heating lamp and the room temperature was regulated manually according to the chicks' behaviour. Continuous light program was adopted for the whole experiment period. The chicks were fed *ad libitum* with a starter mix until the age of 14 days (energy: 2 870 kcal/kg, density: 0.732 kg/l) and a traditional poultry mix (energy: 2 950 kcal/kg, density: 0.723 kg/l) from day 14 to slaughter. Between days 14 and 21, both feed types were mixed to provide an adaptation period. Both mixes contained wheat, corn, soyabean, soyabean oil, methionine, lysine, vitamins and BHT ethoxyquine anti-oxidant. Their compositions are listed in Table 1.

Each bird was identified individually, first by a numbered plastic ring at the leg then by metallic ones after week 5. Sexing was achieved visually at week 9 by comb inspection. The birds were weighed individually once a week from week 1 till week 16 with an electronic balance (accuracy 0.01 g). The birds were weighed once again, at week 22, before slaughter. An overall feed conversion index was calculated for each variety from the total feed intake and the total gain.

Mortality was recorded during the growing period.

Four birds of each sex were randomly chosen among each variety ($n = 16$) and were slaughtered at week 22, which is the regular slaughter age for slow-growing local breeds

Table 1. Feed mix composition for starting, growth and laying.

Ingredients	Broiler Starter mix	Broiler mix	Layer hens
Soyabean oil cake	32.00	30.00	20.00
Wheat	37.00	31.00	11.00
Corn	25.00	33.00	50.00
Soyabean oil	2.30	2.00	3.00
Calcium phosphate	1.50	1.80	1.00
Minerals (vitamins, micronutrients)[1]	1.10	1.00	1.00
Calcium carbonate	1.08	1.20	7.50
Methionine	0.02	0.20	0.10
Alfalfa	–	–	2.40
Beets molasse	–	–	1.50
Wheat middlings	–	–	2.50
Composition			
Metabolizable energy (kcal/kg)	2870.00	2950.00	3060.40
Fat content (g/kg)	55.13	52.18	54.53
Lysine (g/kg)	12.45	8.46	11.28
Methionine (g/kg)	5.39	3.45	4.36
Calcium (g/kg)	9.50	38.00	10.00
Phosphorus (g/kg)	6.03	5.62	5.68
Dry matter (g/kg)	612.90	749.60	561.26
Crude protein (g/kg)	220.00	170.00	189.00

[1]Vitamin A 13 500 UI/kg, vitamin D3 3.000 UI/kg, vitamin E 25 mg/kg and copper sulphate 15 mg/kg.

such as the Ardennaise. The birds were deprived of feed for 15 h before last live weight record and slaughter. They were bled, plucked under warm water, weighed again and eviscerated. The legs were sectioned at the tibiotarsus–metatarsus joint and the head was cut at the skull–atlas joint. The warm carcass was then weighed. The dressing out percentage was then calculated as the ratio between warm carcass weight and live weight at slaughter.

The carcass was then cut and the wings, legs and drumsticks were sampled and weighed after being skinned. The left pectoral muscles (*Pectoralis major* and *Pectoralis profondus*) were sampled about 8 h post-slaughter, weighed and packed in plastic bags for conservation at 4 °C for 24 h. Water loss was calculated as the difference between muscles' weight at sampling and after 24 h of draining on absorbent paper.

pH was measured with a Portamess 751 pH-meter (Knick GmbH&Co, Berlin, Germany) combined with a Mettler-Toledo electrode (LoT406-DXKS7/25; Mettler-Toledo International Inc., Urdorf, Switzerland). Meat colour of the left pectoral muscles was determined on three different parts of each sample after exposition to air, with a spectrocolourimeter Hunterlab Lab-Scan II (Hunter Associates Laboratory, Reston, USA). Colour was expressed in CIE units: L* a* b* with L* being a value indicating the darkness (lightness), high values of a* indicating an intense red colour of meat (redness) and high values of b* indicating an intense yellow colour of the meat (yellowness).

Egg production and quality

Egg laying rate was assessed in 40 silver black and 30 golden black. The hens were first housed under natural light conditions. At week 24, the hens began to produce small eggs and were transferred at week 28 in a building under artificial lighting where a 16 h light/8 h dark programme was applied. The hens were fed with a mix for layers, containing 10 g/kg calcium (see Table 1 for composition). Laying was followed-up for 52 weeks. The eggs were collected every day and conserved at 6 °C except abnormal eggs (cracked and broken) which were eliminated. Quality analysis was implemented the day after egg collection and conducted at different hens' ages: 30, 45, 60 and 80 weeks. Total weight was measured (electronic balance, accuracy 0.01 g) and average egg weight was obtained by dividing total eggs weight by eggs number. Then, their length and width were measured by means of an electronic sliding caliper (precision 0.01 mm), so that an egg shape index could be calculated as the ratio between length and width multiplied by 100 (Monira, Salahuddin and Miah, 2003; Parmar *et al.*, 2006). The yolks were carefully separated from the albumen. The shells including the membranes and yolks were weighed separately (accuracy of 0.01 g). Albumen weight was determined by subtracting yolk and shell weights from the total egg weight. The shell thickness was measured at three different random points in the equatorial shell zone using an electronic micrometer (precision 0.01 mm) and average calculated. Tyler and Geake (1964) indeed reported the eggshell thickness to be slightly thinner but more stable in the equatorial shell zone compared with the other shell zones. Yolk and albumen pH was then measured with a pH-meter (ORION, model 290A, 1990 Orion Research Inc. Boston, MA 02129, USA).

Statistical analyses

The analysis of data was conducted by using the SAS package (procedure GLM, SAS, 2001) and least square means (LSM) and standard errors were calculated, allowing ranking of variety and sexes according to Duncan's procedure.

The following models were used.

$$Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + e_{ijk}$$

where Y_{ijk} are the mature body weight and measurements and meat quality traits in 22-week-old chicks, μ is the overall mean, A_i is the fixed effect of the ith variety (golden black and silver black variety), B_j is the fixed effect of the jth gender (male, female) and e_{ijk} is the random residual effect.

$$Y_{ijkl} = \mu + A_i + B_j + C_k + (AB)_{ij} + (AC)_{ik} + (BC)_{jk} + (ABC)_{ijk} + e_{ijkl}$$

where Y_{ijkl} is the body weight, μ is the overall mean; A_i is the fixed effect of the ith variety (golden black and silver black variety), B_j is the fixed effect of the jth gender (male, female), C_k is the fixed effect of the kth age (1 to 22 weeks), and e_{ijkl} is the random residual effect.

$$Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + e_{ijk}$$

where Y_{ijk} is the egg quality traits, μ is the overall mean, A_i is the fixed effect of the ith variety (golden black and silver black variety), B_j is the fixed effect of the age (30, 45, 60 and 80 weeks) and e_{ijk} is the random residual effect.

The Gompertz equation was used to model the growth of the chickens (Porter *et al.*, 2010). This equation has the form: $Y = \alpha e^{-\beta e^{-\gamma t}}$

where Y is the weight of the chicken in grams, α is the asymptotic weight, β is constant, γ is growth speed factor (maturation factor), and t is the age in days.

The growth curve parameters of the Gompertz equation were estimated (proc NLIN, SAS, 2001). The age at inflexion when the growth rate is maximum was calculated using the following formula (Porter *et al.*, 2010): $t_i = (1/\gamma) \times \ln|\beta|$

To compare the egg-laying rate, hatching rate and mortality rate between the silver black and the golden black varieties, the Chi squared test was used.

Results

Morpho-biometric characteristics

The least squares means of the live weight and body measurements of mature animals are given in table 2 along with the significance of the fixed effects of sex and variety.

The sex effect is highly significant ($P < 0.001$) on all studied traits. The effects of variety and interaction variety × sex were significant ($P < 0.05$) on body weight, large diameter and length of the tarsus and on the comb length. The males of the golden black variety were significantly ($P < 0.05$) heavier (2 674 g) than the males of the silver golden black variety (2 290 g) but the live weight was not significantly different between the hens of the two varieties.

Golden black males had body measurements (length of the tarsal, the length and height of the comb and the length of the wattles) greater ($P < 0.05$) than the silvery black variety. In females, there was no significant difference in comb height and wattles length between the two varieties (Table 2).

Growth

Figure 1 shows the live weight growth of the birds from 1 day old (36 g for all sex and varieties) up to 22 weeks

Table 2. Body weight (g) and measurements (mm) of adult Ardennaise chicken according to variety (V) and sex (S), least squares means and standard error and significance level of the effects of variety, sex and their interaction (V × S).

	Golden black		Silver black		Level of significance			R^2
	n	**LSM ± SE**	***n***	**LSM ± SE**	**V**	**S**	**V × S**	
Body weight (g)					**	***	**	0.28
Male	10	2 674 ± 95[a]	26	2 290 ± 59[b]				
Female	52	1 956 ± 42	97	1 972 ± 30				
Small diameter of tarsus					NS	***	NS	0.37
Male	10	11.98 ± 0.30	26	11.41 ± 0.19				
Female	52	9.64 ± 0.13	97	9.79 ± 0.10				
Large diameter of tarsus					*	***	*	0.18
Male	10	15.62 ± 0.43[a]	26	14.43 ± 0.27[b]				
Female	52	13.24 ± 0.19	97	13.28 ± 0.14				
Length of tarsus					*	***	**	0.21
Male	10	94.53 ± 2.60[a]	26	85.90 ± 1.61[b]				
Female	52	77.88 ± 1.14	97	79.53 ± 0.83				
Beak length					NS	***	NS	0.22
Male	10	36.84 ± 0.87	26	35.35 ± 0.54				
Female	52	32.22 ± 0.38	97	32.17 ± 0.28				
Comb length					*	***	*	0.34
Male	10	122.39 ± 8.41[a]	26	96.02 ± 5.21[b]				
Female	52	58.73 ± 3.69	97	57.22 ± 2.70				
Comb height					NS	***	NS	0.55
Male	10	74.78 ± 5.00	26	63.69 ± 3.10				
Female	52	22.41 ± 2.19	97	23.57 ± 1.61				
Wattles length					NS	***	*	0.56
Male	10	61.01 ± 3.93[a]	26	50.11 ± 2.44[b]				
Female	52	16.95 ± 1.72	97	19.26 ± 1.26				

***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; NS: $P > 0.05$. LSM ± SE: Least squares means ± SE; a, b: different superscripts indicate significant differences ($P < 0.05$).

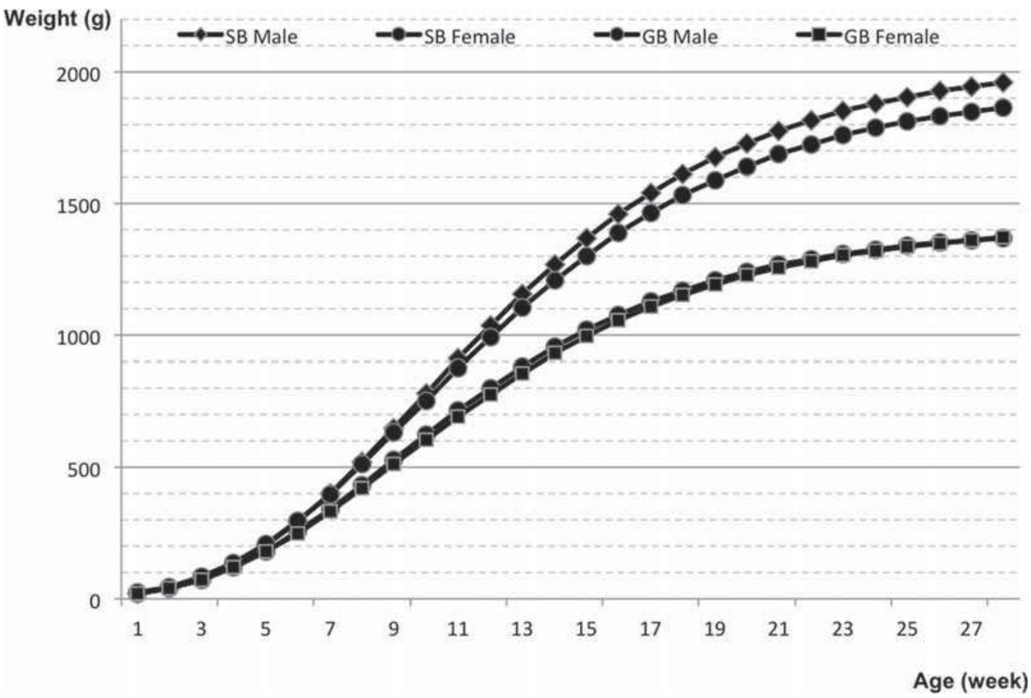

Figure 1. Gompertz growth curve parameters of Ardennaise broilers by varieties (SB, Silver black; GB, Golden black) and sex.

of age. Mean weight at 22 weeks of age was 1 550 and 1 513 g in golden and silver varieties, respectively. The body weight was significantly ($P < 0.01$) influenced by the fixed effects of the variety, the sex, the age and the interaction between sex and age (Table 3).

The parameters of the Gompertz curve, the average daily gain (ADG) and the feed conversion ratio (FCR) of the two Ardennaise varieties and sexes are shown in Table 4. Asymptotic weights were 2 042 and 1 946 g in males and 1 411 and 1 420 g in females for the silver

Table 3. Body weight of Ardennaise broilers by variety (V), sex (S) and age (A). LSM ± SE and significance level of the effects of variety, sex and age and their interactions.

	Golden black			Silver black				Level of significance						
	Male (41)	Female (39)	Total (90)	Male (55)	Female (69)	Total (124)		V	S	A	V × S	V × A	S × A	V × A × S
Day 1	35.8	35.6	35.6	36.5	35.4	35.9	}	**	***	***	NS	NS	***	NS
Week 8	609	501	555	618	494	556								
Week 12	1 139	870	1 007	1 111	848	977								
Week 16	1 518	1 147	1 338	1 446	1 126	1 282								
Week 22	1 814	1 258	1 550	1 752	1 266	1 513								

(), number of specimens; V, varieties; S, sex; A, age. ***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; NS, $P > 0.05$.

Table 4. Gompertz growth curve parameters, average daily gain (ADG) and feed conversion ratio (FCR) of Ardennaise broilers by variety and sex.

Variety	Sex	*N*	Parameters of the Gompertz growth curve				ADG by age (g/j)				Global FCR by age (g/g)			
			α (g)	β	γ (j^{-1})	t (j)	0–8 weeks	0–12 weeks	0–16 weeks	0–22 weeks	0–8 weeks	0–12 weeks	0–16 weeks	0–22 weeks
Silver black	Males	41	2042.3	4.66	0.1725	62.45	10.23	13.13	13.23	11.55				
	Females	39	1410.6	4.279	0.1841	55.27	8.31	9.93	9.92	7.94				
	Total	90	1760.3	4.48	0.1752	59.65	9.27	11.56	11.63	9.83	3.03	4.01	4.49	6.71
Golden black	Males	55	1945.7	4.454	0.1718	60.86	10.40	12.80	12.59	11.14				
	Females	69	1419.9	4.203	0.1766	56.91	8.19	9.67	9.74	7.99				
	Total	124	1691.3	4.308	0.1714	59.92	9.28	11.20	11.12	9.59	2.98	3.99	4.60	6.19

α is the asymptotic weight; β is constant; γ is the growth rate parameter (maturing factor); t is age in days.

black and the golden black, respectively. The age of inflexion was near 60 days for the silver and golden varieties.

The overall FCR was similar for the two varieties during the first 16 weeks and slightly higher in silver black thereafter. The birds of the silver black and golden black variety

Table 5. Carcass and meat quality traits of Ardennaise broilers by variety and sex. LSM ± SE and significance level of the effects of sex.

	Silver black variety		Golden black variety		Level of significance
	n	**LSM ± SE**	***n***	**LSM ± SE**	**Sex**
Slaughter body weight (g)					***
Male	4	1 856 ± 28	5	1 803 ± 25	
Female	4	1 441 ± 28	5	1 399 ± 25	
Carcass weight (g)					***
Male	4	1 249 ± 27	5	1 237 ± 24	
Female	4	931 ± 27	5	913 ± 24	
Yield (%)					**
Male	4	67.30 ± 0.95	5	68.56 ± 0.85	
Female	4	64.59 ± 0.95	5	65.29 ± 0.85	
Head weight (g)					***
Male	4	62.38 ± 1.06	5	58.82 ± 0.95	
Female	4	35.33 ± 1.06	5	35.76 ± 0.95	
Legs weight (g)					**
Male	4	67.05 ± 1.00	5	69.41 ± 0.89	
Female	4	38.60 ± 1.00	5	36.91 ± 0.89	
Abdominal fat weight (g)					**
Male	4	63.51 ± 2.30	5	69.59 ± 2.06	
Female	4	76.16 ± 2.30	5	72.90 ± 2.06	
Drumsticks + thighs weight (g)					***
Male	4	418.14 ± 16.82	5	417.86 ± 15.04	
Female	4	329.70 ± 30.55	5	293.00 ± 15.04	
Drumsticks and thighs weight without skin (g)					***
Male	4	392.85 ± 15.50	5	385.73 ± 13.86	
Female	4	305.54 ± 15.50	5	272.01 ± 13.86	
Wings weight (g)					***
Male	4	169.33 ± 1.38	5	165.98 ± 1.24	
Female	4	129.88 ± 1.38	5	128.29 ± 1.24	
Pectoral muscle weight (g)					**
Male	4	282.21 ± 10.83	5	287.30 ± 9.69	
Female	4	246.41 ± 10.83	5	239.30 ± 9.69	
Drip loss after 1 day of storage (%)					NS
Male	4	0.55 ± 0.13	5	0.80 ± 0.12	
Female	4	0.68 ± 0.13	5	0.62 ± 0.12	
Drip loss after 3 days of storage (%)					NS
Male	4	3.03 ± 0.27	5	2.98 ± 0.24	
Female	4	2.69 ± 0.27	5	2.41 ± 0.24	
Drip loss after cooking (%)					NS
Male	4	18.52 ± 1.43	5	20.72 ± 1.43	
Female	4	22.60 ± 1.43	5	20.71 ± 1.16	
pH ultimate					NS
Male	4	5.68 ± 0.04	5	5.73 ± 0.04	
Female	4	5.70 ± 0.04	5	5.67 ± 0.04	
Temperature (°C)					NS
Male	4	17.67 ± 1.69	5	16.84 ± 1.51	
Female	4	15.80 ± 1.69	5	19.16 ± 1.51	
b*					NS
Male	4	12.41 ± 1.53	5	12.66 ± 1.53	
Female	4	13.19 ± 1.53	5	13.60 ± 1.25	
a*					NS
Male	4	2.88 ± 0.45	5	3.43 ± 0.45	
Female	4	3.02 ± 0.45	5	2.27 ± 0.37	
L*					NS
Male	4	52.46 ± 1.33	5	53.13 ± 1.19	
Female	4	48.35 ± 1.33	5	52.03 ± 1.19	

***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; NS: $P > 0.05$. LSM ± SE: Least squares means ± SE; a, b: different superscripts indicate significant differences ($P < 0.05$).

Note: The variety × sex interaction had no significant effect on any trait.

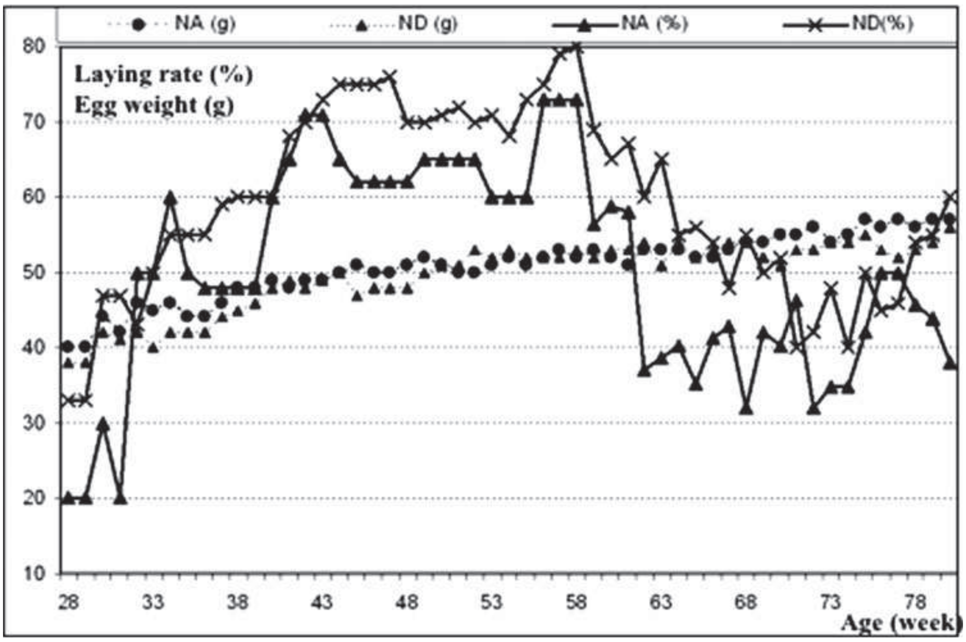

Figure 2. Evolution of laying rate (%) and egg weight (g) during the 80 weeks laying period of the Ardennaise breed by variety (NA: Silver black; ND: Golden black).

had cumulative FCR of 3.03 and 2.98 at 8 weeks of age, 4.01 and 3.99 at 12 weeks of age, 4.49 and 4.60 at 16 weeks of age and 6.71 and 6.19 at the end of the rearing.

Reproductive traits

The hatching rate is not significantly different between the silvery black variety (69.2 percent) and the golden black variety (71.3 percent).

The mortality at 22 weeks of age, was similar ($\chi^2 = 0.094$, $P = 0.7$) for the two varieties and reached 6.92 and 6.32 percent for the silver black and the golden black, respectively.

Carcass characteristics and meat quality

Carcass characteristics and meat quality of the broilers at 22 weeks of age were compared for sex, variety and two factors interaction in Table 5.

The variety and the interaction of variety × sex had no significant effect on these various traits. The male showed significantly higher weights for the body, head, legs, wings, drumsticks and thighs ($P < 0.01$).

None of the various traits of meat quality were affected by any of the three factors studied.

Egg production

From the age of 28 weeks up to 80 weeks, the laying rate varied between 20 and 78 percent for the silver black and between 33 and 80 percent for the golden black (Figure 2). Over the whole laying period, the laying rate was not different between the two varieties ($\chi^2 = 0.57$, $P = 0.32$) neither at 30, 45, 60 and 80 weeks. The golden black produced on average 199 eggs per year and the silver black 183 eggs per year. The changes in egg weight during laying period are shown in Figure 2. The mean of the egg weight during the production period was 54.4 and 49.6 g for the silver black and the golden black, respectively.

Egg quality

Table 6 shows the mean values of the various traits of egg quality per variety and indicates the significance of the effects of variety, age and interaction variety × age. Only the variety has an effect ($P < 0.05$) on the egg and the albumen weights, the albumen percentage, the yolk/albumen ratio and the albumen pH. Age influenced ($P < 0.05$) all traits related to egg quality. The weight of egg, albumen, yolk and shell and the yolk percentage increased with age. The interaction between variety and age was significant ($P < 0.05$) for the egg and yolk weights and the albumen pH.

The two Ardennaises varieties had significant differences in the egg weight at 30 and 45 weeks of age, albumen weight at 30, 45 and 80 weeks, yolk weight at 45 and 60 weeks, albumen percentage at 60 weeks, ratio yolk/albumen at 60 weeks, egg shape at 60 weeks and the albumen pH at 30 weeks.

Discussion

Morpho-biometric characterization

The first visible difference between silver black and golden black is the colour of the plumage. The colour of the hackle is easily observable, white (silver) in the silver variety and red (gold) in the golden black variety.

Table 6. Egg quality of Ardennaise hens by variety and age. LSM ± SE and significance level of the effects of variety, age and interaction.

	Silver black varieties		Golden black varieties		Level of significance			R^2 (%)
	n	LSM ± SE	*n*	LSM ± SE	Variety	Age	Variety × age	
Egg weight (g)					***	***	**	85.11
At 30 weeks of age	10	45.28 ± 0.60[a]	15	41.93 ± 0.49[b]				
At 45 weeks of age	20	51.34 ± 0.42[a]	30	48.04 ± 0.35[b]				
At 60 weeks of age	15	53.06 ± 0.49	25	53.16 ± 0.38				
At 75 weeks of age	10	57.24 ± 0.60	15	55.89 ± 0.49				
Albumen weight (g)					***	***	NS	69.46
At 30 weeks of age	10	26.65 ± 0.48[a]	15	24.19 ± 0.39[b]				
At 45 weeks of age	20	29.67 ± 0.34[a]	30	27.88 ± 0.28[b]				
At 60 weeks of age	15	30.49 ± 0.39	25	29.53 ± 0.30				
At 75 weeks of age	10	32.61 ± 0.48[a]	15	31.28 ± 0.39[b]				
Yolk weight (g)					NS	***	**	68.80
At 30 weeks of age	10	13.24 ± 0.42	15	12.57 ± 0.34				
At 45 weeks of age	20	15.72 ± 0.30[a]	30	14.50 ± 0.24[b]				
At 60 weeks of age	15	16.34 ± 0.34[a]	25	17.45 ± 0.26[b]				
At 75 weeks of age	10	18.35 ± 0.42	15	18.36 ± 0.34				
Eggshell weight (g)					NS	***	NS	28.35
At 30 weeks of age	10	5.39 ± 0.19	15	5.17 ± 0.16				
At 45 weeks of age	20	5.96 ± 0.14	30	5.67 ± 0.11				
At 60 weeks of age	15	6.23 ± 0.16	25	6.18 ± 0.12				
At 75 weeks of age	10	6.29 ± 0.19	15	6.24 ± 0.16				
Albumen (%)					*	**	NS	18.2
At 30 weeks of age	10	58.85 ± 0.73	15	57.73 ± 0.59				
At 45 weeks of age	20	57.77 ± 0.51	30	58.08 ± 0.42				
At 60 weeks of age	15	57.46 ± 0.59[a]	25	55.55 ± 0.46[b]				
At 75 weeks of age	10	56.94 ± 0.73	15	55.98 ± 0.59				
Yolk (%)					NS	***	NS	25.76
At 30 weeks of age	10	29.23 ± 0.69	15	29.94 ± 0.56				
At 45 weeks of age	20	30.63 ± 0.49	30	30.12 ± 0.40				
At 60 weeks of age	15	30.80 ± 0.56[a]	25	32.83 ± 0.44[b]				
At 75 weeks of age	10	32.05 ± 0.69	15	32.85 ± 0.56				
Eggshell (%)					NS	*	NS	9.10
At 30 weeks of age	10	11.91 ± 0.35	15	12.33 ± 0.28				
At 45 weeks of age	20	11.61 ± 0.25	30	11.79 ± 0.20				
At 60 weeks of age	15	11.74 ± 0.28	25	11.63 ± 0.22				
At 75 weeks of age	10	11.00 ± 0.35	15	11.17 ± 0.28				
Yolk/albumen ratio ($\times 10^{-2}$)					*	***	NS	23.65
At 30 weeks of age	10	49.72 ± 1.90	15	52.03 ± 1.55				
At 45 weeks of age	20	53.18 ± 1.34	30	52.12 ± 1.10				
At 60 weeks of age	15	53.80 ± 1.54[a]	25	59.49 ± 1.20[b]				
At 75 weeks of age	10	56.38 ± 1.90	15	58.85 ± 1.54				
Eggshell thickness (10^{-2} mm)					NS	*	NS	8.29
At 30 weeks of age	10	33.08 ± 0.87	15	32.59 ± 0.71				
At 45 weeks of age	20	31.88 ± 0.62	30	31.40 ± 0.50				
At 60 weeks of age	15	31.18 ± 0.87	25	30.90 ± 0.71				
At 75 weeks of age	10	30.65 ± 0.72	15	30.84 ± 0.55				
Egg shape index					NS	**	NS	15.92
At 30 weeks of age	10	74.93 ± 0.88	15	74.45 ± 0.72				
At 45 weeks of age	20	75.53 ± 0.62	30	75.28 ± 0.51				
At 60 weeks of age	15	77.67 ± 0.72[a]	25	75.12 ± 0.56[b]				
At 75 weeks of age	10	77.39 ± 0.88	15	77.78 ± 0.72				
Albumen pH					**	***	**	43.70
At 30 weeks of age	10	8.62 ± 0.27[a]	15	8.79 ± 0.02[b]				
At 45 weeks of age	20	8.88 ± 0.02	30	8.88 ± 0.01				
At 60 weeks of age	15	8.91 ± 0.02	25	8.90 ± 0.02				
At 75 weeks of age	10	8.85 ± 0.03	15	8.89 ± 0.02				
Yolk pH					NS	*	NS	7.29
At 30 weeks of age	10	6.08 ± 0.05	15	6.13 ± 0.04				
At 45 weeks of age	20	6.22 ± 0.04	30	6.21 ± 0.03				
At 60 weeks of age	15	6.21 ± 0.04	25	6.20 ± 0.03				
At 75 weeks of age	10	6.25 ± 0.05	15	6.23 ± 0.04				

***$P < 0.001$; **$P < 0.01$; *$P < 0.05$; NS: $P > 0.05$. LSM ± SE: Least square means ± SE; a, b: different superscripts indicate significant differences ($P < 0.05$).

The golden black cocks are significantly bigger than the silver black cocks, but the golden black hens tended to be smaller (1 956 versus 1 972 g), increasing the sexual dimorphism in the golden black. Nevertheless, our results for mature body weight (2 674 g and 1 956 g and 2 290 g and 1 972 g, for male and female of the golden and silver varieties, respectively) are well above those reported at the beginning of the last century by Carpiaux (1921) and Voitellier (1925) which barely exceeded 2 and 1.5 kg for male and female, respectively. However, these weights are close to those reported by N'Dri (2006) for the Gauloise breed (2.5 kg for rooster and 1.5–2.0 kg for hen).

Growth

The silver black and golden black Ardennaise performed similar weights at hatching (35.84 versus 36.53 g for males and 35.56 versus 35.42 g for females) and at 22 weeks (1 814 versus 1 752 g for males and 1 258 versus 1 266 g for females).

At 12 weeks of age, the average weight was 1 139 and 1 111 g in males and 870 and 848 g in females, for the golden black and silver black, respectively, lower than the weight at 12 weeks of the white Ardennaise variety, 2 000 and 1 500 g in males and females, respectively (Moula *et al.*, 2009a).

The ADG is also always higher in males, which explains the higher final weight in cocks compared with females.

The FCR was similar for the two varieties during the first 16 weeks and slightly lower in the golden black over the last 6 weeks.

Carcass characteristics and meat quality

Comparison between the two varieties of the Ardennaise breed of carcass characteristics and meat quality traits of animals slaughtered at 22 weeks of age revealed no significant difference. The results only showed that the weights of different body parts are higher in roosters compared with hens. Similar results were recorded by Youssao *et al.* (2009) in the Coqard chicken, which is a crossbred between traditional Ardennaises cock and hen from a French commercial slow growing strain. However, dressing percentage was better in the Ardennaise than in the French industrial red label, 67 and 65.5 percent, respectively.

After cooking, the average loss in the Ardennaise is about 20 percent which is considerably lower than the recommendations of Sauveur (1997) for the Label Rouge chicken (25 percent). However, the slaughter age of the latter is 12 weeks, while it is 22 weeks for the Ardennaise. The choice of this slaughter age (22 weeks) by the connoisseurs of Ardennaise, can be explained by the improved flavours and taste with age but at the expense of the tenderness (Touraille *et al.*, 1981).

The ultimate pH of the muscles stabilizes to a value between 5.7 and 5.9 in poultry (Sante, Fernandez and Monin, 2001). The values measured in the pectoral muscles of the two varieties of Ardennaises, around 5.7, are very close to this range and with the values found in different genetic groups by Debut *et al.* (2005) and Quentin *et al.* (2003) where ultimate pH ranged from 5.59 to 6.01.

The colour, which represents the first criterion for assessing meat by the consumer and the absence of difference between the varieties of Ardennaise is interesting from the point of view of the uniformity of the commercial product. L* values recorded in the present study (48.35–53.13) are lower than those recorded by Quentin *et al.* (2003) ranging from 54.5 in fast growing strains to 53.5 in slow growing strains including the French red label. The values of a* of Ardennaises, 2.3–3.4, are higher than those recorded in many studies, ranging from −0.8 to 0.28 (Quentin *et al.*, 2003; Debut *et al.*, 2005). These high values of a* indicate that the meat of Ardennaise is redder, in fact these values are closer to those recorded in turkeys (a* of about 5) in the study of Molette *et al.* (2005). The average value of b* (approximately 13) in the Ardennaise is much higher than those recorded (6.89–11.8) by Debut *et al.* (2005) and Quentin *et al.* (2003), therefore, a yellow colour is more pronounced in the Ardennaise.

The laying rate and egg quality

The hens of both varieties begin to lay at the age of 24 weeks, an age identical to that recorded by Hocking *et al.* (2003) on a group of traditional breeds (Barnvelder, White Sussex). However, this age remains well above that of industrial strains such as ISA-Brown (22 weeks of age) (Benabdeljelil *et al.*, 2003). However, they are precocious compared with Indian breeds (Danki, Kalasthi and Ghagus) whose age at first egg varies from 25 to 32 weeks on average (Vij *et al.*, 2006) and the Egyptian Fayoumi breed whose first egg is generally laid at the age of 28 weeks (Zaman, Sorensen and Howlider, 2004).

Even if there is no difference in the laying rate of the two varieties of Ardennaise, golden black hens lay more eggs than silver black hens (199 eggs vs 183 eggs). However, the weight of the latter is slightly higher (50.74 versus 49.53 g). Similar differences were recorded in different varieties of the Gauloise (N'Dri, 2006).

The influence of age on the composition of the egg is already reported by numerous studies (Marion *et al.*, 1964; Akbar *et al.*, 1983; Fletcher *et al.*, 1983; Nys, 1986; Rossi and Pompei, 1995; Hartmann *et al.*, 2000; Dolgokorova, 2006).

The comparison of the two varieties of eggs had revealed some differences for certain traits at given age (Table 6).

The freshness of the egg is represented in this study by the pH. Except at the age of 30 weeks where albumen pH was significantly higher in black golden Ardennaise (8.79

versus 8.62), the pH of the white and the yellow were similar at the other ages. These values are comparable with those recorded by Moula *et al.* (2009a, 2009c).

The soundness of the shell is the second most important economic quality of the eggs (Wells, 1968). The fragility of the shell is the cause of about 6–8 percent of the losses in the egg industry (Washburn, 1982). In this study, the two Ardennaise varieties presented similar thicknesses at all ages (ranging from 30.65 to 33.08×10^{-2} mm), values close to those recorded by Moula *et al.* (2009c) in Ardennaise.

The third important criterion of the egg quality is the yellow-to-white ratio. High proportions of yellow are sought because it has a significant effect on the dry matter of the eggs (Harms and Hussein, 1993; Hartmann *et al.*, 2003) which is an essential criterion in the industry (Flock, Preisinger and Schmutz, 2001). In this study, the Ardennaises golden black yellow/white ratio exceeds that of the silvery black Ardennaise (52.03–59.49 versus 49.72–56.38).

Conclusion

Most of the growth and laying traits as well as most of the quality characteristics of meat and egg did not differ significantly among the golden and silver varieties. These results might indicate that these varieties could be managed as one same population in order to face the problem of small population size.

It could be very interesting to complete this study by molecular markers analysis to evaluate the degree of genetic similarity between the two varieties. A wider study extended to the other ten varieties of Ardennaise would be welcome to fully assess the variability of the breed. This project should need the collaboration between public authorities, academic institutions and local race fans associations.

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