Characterization of morphological, reproductive, and productive performances of Mugellese breed: an update of knowledge

Federica Mannelli ,*,[1] Alessandro Franzoni,† Ilaria Galigani,* Virginia Nistri,* Matteo Daghio,* Federica Scicutella,* Margherita Marzoni,‡ Sara Minieri,‡ Sonia Salvucci,‡ Silvia Cerolini,§ Nicolaia Iaffaldano,# Achille Schiavone,‖ Martino Cassandro,¶ Cesare Castellini ,** and Arianna Buccioni*,††

*Dipartimento di Scienze e Tecnologie Agrarie, Alimentari, Ambientali e Forestali, Università degli studi di Firenze, 50144 Firenze, Italy; †Centro di Ricerca Politiche e Bioeconomia, Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria, Firenze, Italy; ‡Dipartimento di Scienze Veterinarie, Università di Pisa, 56124, Pisa, Italy; §Dipartimento di Scienze Veterinarie, Università di Milano, 20134 Milano, Italy; #Dipartimento di Agricoltura, Ambiente e Alimenti, Università del Molise, 86100 Campobasso, Italy; ‖Dipartimento di Scienze Veterinarie, Università di Torino,, 10095, Grugliasco, Torino, Italy; ¶Dipartimento di Agronomia, Alimenti, Animali, Risorse Naturali e Ambiente, DAFNAE, Università di Padova, 35020 Legnaro, Padova, Italy; **Dipartimento di Scienze Agrarie, Alimentarie ed Ambientali, Università di Perugia, 06121 Perugia, Italy; and ††Centro Interdipartimentale di Ricerca per la Valorizzazione degli Alimenti, 50134, Firenze, Italy

ABSTRACT The recovery, safeguarding, and valorization of autochthonous poultry breeds may contribute toward the preservation of animal biodiversity and utilization of marginal lands that otherwise offer little agricultural or industrial value. A key strategy in promoting local breeds involves the characterization of morphological traits and productive performances, which are influenced by the breed's genetic make-up as well as its environment. The Mugellese breed is an Italian local poultry breed originating in the Mugello area of north-east Tuscany. It is characterized by frugality, resilience and resistance to disease, cold, and heat stress. Moreover, these birds are particularly suitable for free-range farming. The Mugellese chicken is described as a dwarf breed with a medium neck, broad shoulders, fairly long and horizontal wings, wide, and well-developed breast (especially in the hen). Over the course of a 1-yr observation and data collection period, involving 23 breeders and 405 adult chickens, the Mugellese breed showed the following performances: 1) a hen-day egg production characterized by 2 major peaks: the first in the spring time (March−April, 65.75%), and the second in the late summer period (August−September, 51.86%); 2) high true fertility values (94.35%) throughout the entire breeding season; 3) a weight gain of 732.44 ± 117.06 g and a feed conversion ratio of 3.94 ± 2.42 at an age of 140 d; 4) a slaughter yield of 77.80% (± 3.91); v) a respective protein, fat, and mineral content in the yolk and albumen were: 27.21 ± 4.21 g, 57.77 ± 1.03 g and 3.47 ± 0.40 g per 100 g of yolk; and 82.50 ± 0.57 g, 0.12 ± 0.01 g and 5.43 ± 0.34 g per 100 g of albumen. More data are needed to validate the data obtained in this trial.

Key words: biodiversity, poultry, phenotype, performance, Mugellese

2023 Poultry Science 102:102259
https://doi.org/10.1016/j.psj.2022.102259

INTRODUCTION

Biodiversity is the genetic, specific and ecological variability among living organisms from all environmental sources, and it contributes toward the characterization of all the world's ecosystems (FAO, 2015). Biodiversity plays a key role in increasing agricultural output in a sustainable way, in supporting agricultural systems and food supply chains, in increasing the resilience of marginal areas and protecting against ecological disasters (FAO, 2007). Its maintenance represents one of the fundamental objectives of the European Community policies, and over the last 20 years the notion of biodiversity protection has held particular significance in the planning and support of rural development. Autochthonous breeds show distinct fitness qualities and aptitudes that could provide valid alternatives in extensive systems.

Received July 11, 2022.
Accepted October 12, 2022.

[1]Corresponding author: federica.mannelli@unifi.it

In fact, certain breeds can be reared in free range systems, even in marginal lands, and fed with sustainable feeding strategies according to their lower requirements compared with those of modern hybrid breeds traditionally used in intensive systems, while maintaining good egg production and weight gain (**WG**) (Rocchi et al., 2019; Cartoni Mancinelli et al., 2020).

The Mugellese chicken is a dwarf poultry breed that originated from the Mugello area of north-east Tuscany. The breed was widespread in this region of Italy due to its excellent aptitude for brooding; indeed, it was traditionally used as a putative hen for the eggs of other chicken breeds and other poultry species. Nevertheless, despite its important role for the subsistence of sharecropper farmers, this characteristic has not made it a "breed of income", and it is presently close to extinction.

The progressive disappearance of the Mugellese breed can be attributed to its low importance in terms of productivity for both eggs and meat. The breed's aptitude for brooding, the little egg size and meat productivity were incompatible with the genetic selection criteria involved in the breeding for highly productive meat breeds and laying hens. Moreover, the introduction of incubators for domestic use contributed to rendering the brooding "work" of the Mugellese hens dispensable.

The role played by the Mugellese breed in the sphere of animal biodiversity is, however, quite different. Its small size, ability to brood, robustness, and lively temperament make it an important example of genetic variability among the poultry breeds of Italian genetic heritage. For this reason, it must be safeguarded and its numbers increased to more acceptable levels in order to oppose the threat of extinction.

The goal of this study was to characterize the Mugellese phenotype (i.e., its morphological traits, reproductive, and productive performances), which has not yet been parameterized. This work is part of a larger project aimed at preserving biodiversity within the poultry sector.

MATERIALS AND METHODS

Animal Rearing and Welfare

Animal handling was carried out in accordance with Italian Government guidelines (D.lgs 26/2014). Male and female birds were employed in the trials to evaluate the productive performances (e.g., meat and eggs). The subjects were reared in outdoor enclosures with spontaneous vegetation. The space available for each animal was approx. 6 m^2 (with a covered space in the handling box designed for feeders, drinkers and, where needed, nests). To prevent the entry of predators and to guarantee excellent ventilation, lighting, and visibility, all the enclosures had metal grid walls and were covered with a flexible non-woven fabric roof. Animals had free access to water supplied in automatic drinking troughs, and were fed ad libitum with commercial feeds according to the growing period. The chemical and nutritional profile of each formula is reported in Table 1.

Table 1. Chemical and nutritional profile of feed formulas provided according to the growth period.

	Growing birds (male and female)			
	0–3 months	3–6 months	Over 6 months	Laying hens
Item[1]	g/100 g of fresh feed			
DM	87.5	87.5	87.5	87.5
	g/100 g of DM			
CP	21.0	22.0	17.5	17.0
EE	5.1	6.0	3.7	3.4
CF	3.2	3.0	4.8	4.7
Ash	7.5	7.0	7.5	12.9
Ca	1.5	1.5	1.5	4.1
P	0.6	0.6	0.6	0.6
Na	0.3	0.3	0.3	0.3
Methionine	0.08	0.08	0.08	0.08

[1]Abbreviations: CF, crude fibre; CP, crude protein; DM, dry matter; EE, ether extract.

Breed General Characterization

General characterization of the Mugellese breed followed the Tixier-Boichard et al. (2009) key points:

- Farm census: breed population sizes, management and productive aptitude;
- Morphofunctional characteristics: biometric measures and phenotypical characteristics;
- Reproduction: age at first egg, egg weight and morphology, incubation traits;
- Animal performances: egg production/year, WG, feed intake (**FI**), feed conversion ratio (**FCR**).

The farm census was based on the self-declared data provided by farmers located throughout Italy, whereas the morpho-functional characteristics and the reproduction and production performances were carried out considering a local population reared in the experimental farm belonging to Florence University (Italy).

The natural brooding aptitude was studied by monitoring 2 flocks in a free-range environment (with natural vegetation) with little human intervention.

Farm Census A questionnaire was designed to identify Italian local chicken breed population sizes and common housing and management practices as previously described by Castillo et al. (2021) and Franzoni et al. (2021). The data on the Mugellese breed reported in these 2 papers were extended by adding those from a second year of monitoring; that is, data were collected for 2 consecutive years, from June 2018 to June 2020. Breeders with more than 10 animals of the Mugellese breed who agreed to participate in the survey were visited by researchers and the questionnaire was completed by means of face-to-face interviews.

Animal Characterization For each evaluation (morpho-functional characteristics, production, and reproduction traits), the minimum number of animals required was determined using G*power software (Faul et al., 2007), according to an α value = 0.05, a power (1-β) = 0.8 and a medium effect size = 0.30.

Morphofunctional Characteristics Bird morphofunctional measurements were taken in accordance with the guidelines set out by the Food and Agriculture Organization of the United Nations (FAO, 2012). Fifteen birds, which hatched at the same day, were chosen for the evaluation. The chicks hatched in the incubator (considered d 1) and were then measured twice a week for three months starting from d 7, and thereafter twice a month until the first egg deposition/or until achieving their commercial weight (d 140). Body length, wing span, chest circumference and shank length were measured using a tape measure, and adult body weight was measured using a hanging spring balance.

Reproduction Age at first egg deposition was recorded for all the birds belonging to the University of Florence's experimental farm as well as for a total of 8 flocks of Mugellese chickens belonging to farms located in Tuscany.

To evaluate reproduction characteristics, two different approaches were adopted. First, true fertility (**TF**), hatchability (**H**) and total mortality were assessed to define the embryonic mortality patterns during the first laying cycle. To this end, 20 females and 4 males aged 28 wk were randomly chosen, divided in 2 groups, placed into outdoor pens and fed ad libitum with the commercial breeder diets as reported in Table 1. Second, the brooding capacities of 2 flocks housed in an enclosure that simulated their natural environment were evaluated by ethological observation.

Artificial Incubation Traits A total of 10 successive artificial incubations, spaced by 15-d intervals, were performed during the reproductive season using eggs obtained from chickens aged 39 to 57 wk of age. Eggs were collected twice a day, labeled and stored for a maximum of 7 d in a controlled environment room set to 16°C and 75% relative humidity. At least 25 eggs were randomly chosen for each evaluation and incubated in a semi-commercial incubator (model I9 − Victoria incubator; Victoria srl, Pavia, Italy) operating at 37.7 ± 0.1°C and 50% relative humidity. Eggs were automatically rotated every hour. On d 18 of incubation, eggs were transferred to the hatchery (model H9 − Victoria incubator; Victoria srl, Pavia, Italy), set to 36.8 ± 0.1°C and 70% relative humidity.

On incubation d 7, eggs were candled, and any dead embryos or clear eggs removed. Clear eggs were opened for macroscopic analysis of the germinal disc to distinguish the real infertile eggs from the fertilized ones containing embryos which died at early stages of development. From these observations, TF was assessed. During the same data recording sessions, embryos were macroscopically observed to determine the exact age of death in days in order to calculate the rate of early embryonic mortality (0−4 d of incubation). Early middle, late middle (5−10 and 11−17 d of incubation, respectively) and late mortality (18−21 d of incubation) were evaluated by means of the same procedure on all the removed eggs at candling on d 18 of incubation and on all the unhatched at the end of hatch at d 21. Embryo development staging was performed according to the methods set out in Hamburger and Hamilton (1951).

TF (%) was calculated as:

$$(\text{Number of fertile eggs}/\text{Number of incubated eggs}) \times 100$$

H (%) was recorded at the end of each incubation and its value was calculated according to the following formula (Damaziak et al., 2018):

$$(\text{Number of hatched chicks }/\text{Number of incubated eggs}) \times 100$$

Total, early, early middle, late middle, and late mortality during hatching (%) were calculated with the following formula:

$$(\text{Number of death embryos}/\text{Number of fertile eggs}) \times 100.$$

Brooding To evaluate the brooding capacity an observational evaluation was adopted as follow. Two flocks (one rooster with 3 hens per flock) were assembled and located in 2 separate enclosures containing vegetation and natural shelters to recreate a natural-like environment where animals could carry out their natural brooding behavior. The two flocks were monitored for 1 yr in order to assess if birds exploited a natural behavior in egg deposition, brooding aptitude, and parental care toward chicks. In particular mating, laying, brooding capacity, and parental care of both hens and rooster were evaluated. The scores were: 0 = no capacity, 1 = scarce capacity; 2 = regular capacity; 3 = excellent capacity. Moreover, days of brooding and how many chicks were hatched and reached the adult age was registered. The birds' nutrition was integrated daily with commercial feed according to the formulas reported in Table 1, which respected the requirements of the laying hens and the growing chicks.

Animal Performances

Egg production. Each day, for one year, 20 hens were monitored for the egg laying and an egg production curve was generated. The hen-day egg production percentage (HDEP%) was evaluated according to the following formula:

$$(\text{Number of eggs produced on a daily basis}/\text{Number of birds in the flock on that day}) \times 100$$

- Egg morphology. Egg morphology and egg weight were recorded for all the eggs (350) laid between March and May (increasing photoperiod). Egg weight was assessed using a digital balance, and egg length and width were measured using a calliper (FAO, 2012). The egg shape index (**ESI**) was calculated using the following formula:

Egg width/Egg ength.

Finally, 25 eggs were randomly collected for the evaluation of shell, yolk, and albumen weights (Suk and Park, 2001; Englmaierová et al., 2014).

- Weight Gain, Feed Intake and Feed Conversion Ratio. Fifteen Mugellese 1-day-old chicks were used for growth curve evaluation. Chicks born in the artificial incubator were weighed twice a week for the first 3 mo and twice a month until first egg deposition/or until they achieved the commercial weight for the purpose of monitoring growth performances (FAO, 2012). The WG was calculated as the difference between subsequent weights. Chicks were raised in a controlled environment room for the first 3 mo, and then transferred to outdoor pens until the end of the trial.

The individual FI was recorded for each group every weighing day and calculated by dividing the total amount consumed by the number of animals. The FCR was calculated as the ratio of the individual FI/individual WG registered within each group.

Egg Quality and Carcass Traits Twenty-five eggs were evaluated for their chemical and nutritional profile according to AOAC protocols for chemical characteristics (method cod number: 976.06; 920.39; 962.09; 942.05) (van Soest et al., 1991; AOAC International, 1995).

Twenty-five birds aged 140 d were sacrificed in an authorized slaughterhouse in compliance with Italian Government guidelines (D.Lgs.vo 4 March 2014, n. 26). Twenty-four hours after slaughter, the dressing out percentages were evaluated for all birds as the ratio between the eviscerated warm carcass and live weight. Moreover, the weight of selected traits (breast and legs) of all the carcasses were evaluated (Barbut, 2017).

Statistical Analysis

The survey data were entered into a purpose-made Microsoft Office Excel spreadsheet, using manual double entry and data entries checked for errors. The Chi-squared test, followed by the Fisher's test, was used to determine significant differences in the distribution of variables (SAS Institute, 2008). P-values less than 0.05 were considered as statistically significant. Results are presented as the number and percentage of farmers for each categorical variable.

Descriptive statistics was performed to describe animal performances, morphofunctional characteristics, egg morphology and quality, and carcass traits (Mean ± SD; minimum and maximum values; SAS Institute, 2008).

For the data relating to body characteristics, WG, FCR and HDEP%, a regression curve was made up with respect to time (expressed in days) and reported according to the highest R^2 (first degree for WG, sixth degree for HDEP%, and second degree for all others; SAS Institute, 2008).

To evaluate seasonal effect and differences in the distribution of mortality during the 4 incubation periods, the incubation traits (TF, H, and embryo mortality) were analyzed using the Chi-squared test followed by the Fisher test using the statistical analysis software JMP 9.0.1 (SAS Institute, 2008). Results are presented as mean values. Differences showing $P < 0.05$ were considered significant for all the analyzed traits.

RESULTS

Farm Census

A total of 23 farmers raising the Mugellese chicken breed were identified across the Italian territory during the conduction of the survey. Twenty-one farms were recorded in the region of Tuscany, one in Lazio and one in Piedmont (Table S1). The main distribution in Tuscany was observed in the province of Florence (57.14%, $P < 0.01$), followed by the provinces of Arezzo (19.05%) and Siena (9.25%). Only 4.76% of the surveyed Tuscan breeders resided in the provinces of Livorno, Massa-Carrara, and Pistoia. A population size of 405 adult chickens was recorded for the Mugellese breed. This breed was mainly reared in combination with other chicken breeds and/or with other poultry species (47.83% and 26.09%, respectively, $P < 0.05$; Table S2); only 13.04% of the surveyed breeders reported to rear Mugellese chickens only.

Birds were mainly reared in outdoor pens (69.57%, $P < 0.01$; Tab Survey 3) furnished with buckets or bowls as drinkers (73.91% $P < 0.01$; Table S3) and feed hoppers (69.57%, $P < 0.01$; Table S3). No preference was observed among breeders for individual or group nests, whereas open nest boxes (60.87%) or closed nests (34.78%) with litter or wire floors were the main nest solutions ($P < 0.01$; Table S4). Mugellese chickens were mainly fed with milled or crumbed forms of commercial diets (Tab Survey5), and no preference was recorded over pasture access. The majority of the breeders reported that they did not slaughter animals belonging to this breed (78.26%, $P < 0.01$; Table S5). The remaining 21.74% of the breeders reported to slaughter and consume the meat of Mugellese chickens aged between 6 and 12 mo of age (80%, $P < 0.05$; Table S5).

Morphofunctional Characteristics

The evaluation of the morphofunctional characteristics of chicks was carried out after the first week of life. Seven-day-old chicks had an average body length of 10.13 ± 0.77 cm, an average wing span of 12.60 ± 0.97 cm, an average chest circumference of 9.37 ± 0.90 cm and a shank length < 0.50 cm. At the end of the first monitoring period (0−30 d of life), the average morpho-functional trait values were: body length, 18.13 ± 1.04 cm; wing span, 21.33 ± 1.13 cm; chest circumference, 15.07 ± 0.86 cm; shank length, 1.50 ± 0.00 cm. The growth rates for these biometric traits were 78.95, 69.31, and 60.85%, respectively. At the end of the second monitoring period (31−60 d of life), the average morphofunctional trait values were: body length, 27.40 ± 1.65 cm; wing span, 30.03 ± 0.93 cm; chest circumference, 19.50 ± 0.29 cm; shank length, 2.13 ± 0.23 cm. The growth rates were 51.10, 40.78, 29.42, and 42.22%, respectively. Finally, in the last monitoring period (61−140 d of life), the average morphofunctional trait values for the birds were as follows: body length, 32.43 ± 1.45 cm; wing span, 36.67 ± 2.74 cm; chest circumference, 25.40 ± 1.80 cm; shank length, 3.27 ± 0.26 cm. The growth rates for this period were 18.37, 22.09, 30.26, and 53.13%, respectively.

The regression curves for morphofunctional characteristics of chicks are reported in Figure 1.

Reproduction

- Age at first egg. Hens laid the first egg at the age of 178 ± 2 d.
- Incubation traits. Hatching occurred at 480 ±12 h. TF, H and true mortality (**TM**) values, recorded throughout the reproductive period, are presented in Figure 2. No statistically significant differences were observed between the 10 batches of incubated eggs for any the trait recorded. The Mugellese breed showed high TF values throughout the entire breeding season; the overall mean TF was 94.35% (Figure 2); high values of H were also recorded.

The mean TM value was 25.20%, and it was mainly attributed to the first 4 d of incubation. The early embryonic mortality mean value was 17.30%, which was higher than the values obtained for early middle, late middle, or late mortality (Figure 3; $P < 0.01$).

- Brooding. The animals of both flocks mated and laid eggs regularly. After 468 ±12 h of brooding, the eggs hatched, and the chicks were followed under the parental care of the hen and in part by the rooster. Over the course of the 1-yr period in which brooding aptitude was analysed, the average number of chicks produced by each hen that reached adulthood was 6.5 (39 chicks in total).

Animal Performances

- Egg production. The trend in HDEP% (Figure 4) showed 2 major peaks: the first in the springtime (March−April), which represented the maximum laying period (65.75%), and the second in the summer period (July−September, 51.86%).
- Egg morphology. Egg morphology was characterized by an average weight of 31.93 ± 4.49 g and an ESI of 0.74 ± 0.09 (average width, 35.07 ± 4.47 cm; average length, 47.53 ± 4.13 cm). Shell, albumen and yolk showed a weight of 3.40 ± 0.61 g, 11.17 ± 1.09 g and 16.00 ± 1.65 g, respectively.
- Weight gain. The average chick weight on the day of hatching was 28.89 ± 3.06 g. On d 30, the average WG was 147.84 ± 24.70 g, with a mean bird weight of 181.80 g ± 26.66 g. Then, for the following 30-d period, the average WG was 198.87 ± 41.47 g, corresponding to an average body weight of 380.67 ±

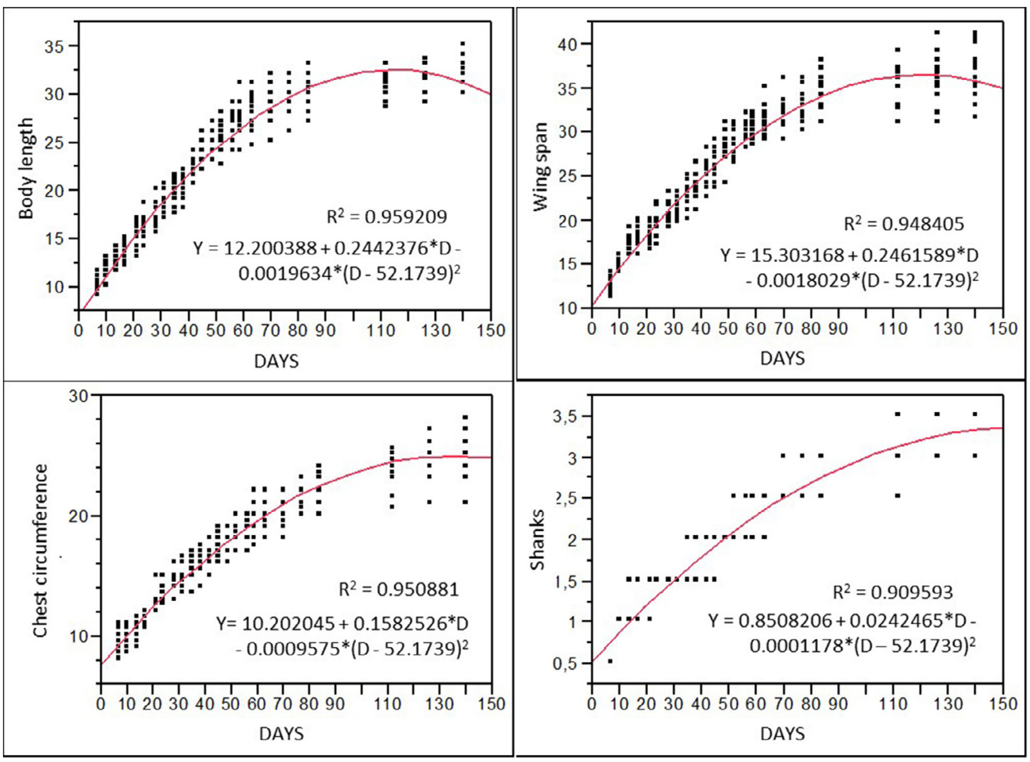

Figure 1. Regression curves of chick morpho-functional characteristics.

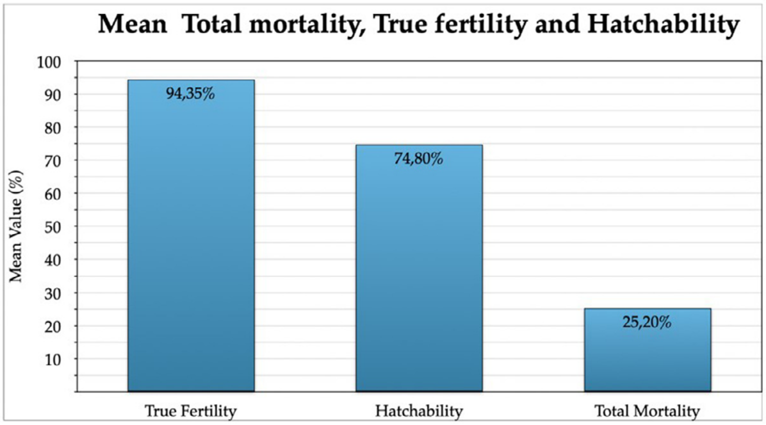

Figure 2. Egg incubation traits.

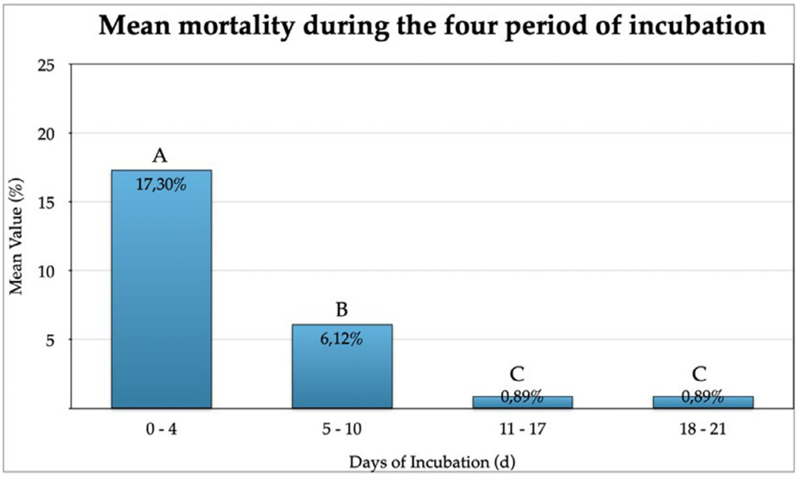

Figure 3. Egg mortality during incubation periods.

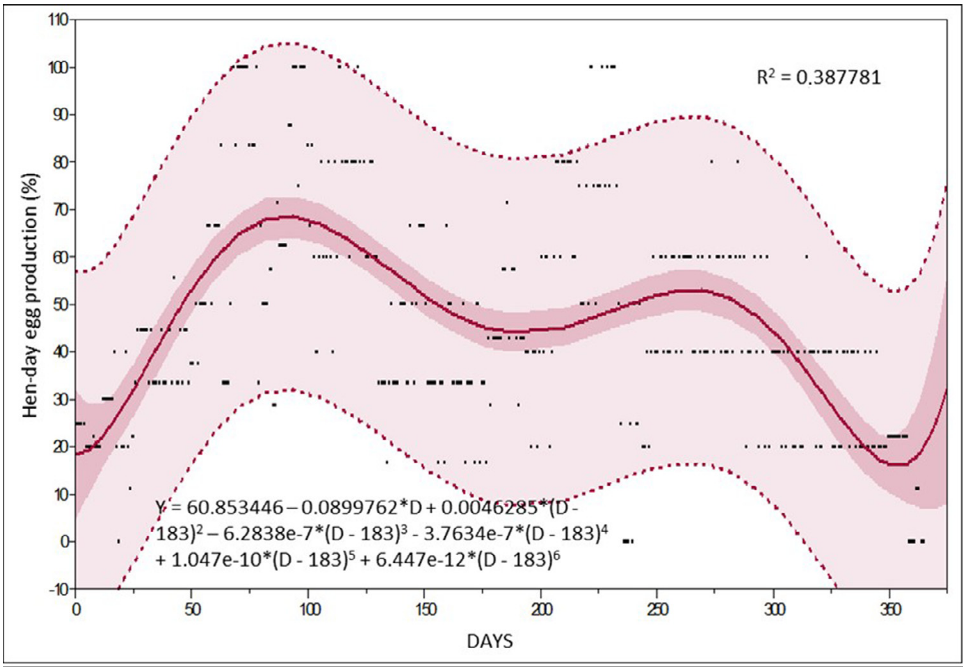

Figure 4. Annual egg production curve.

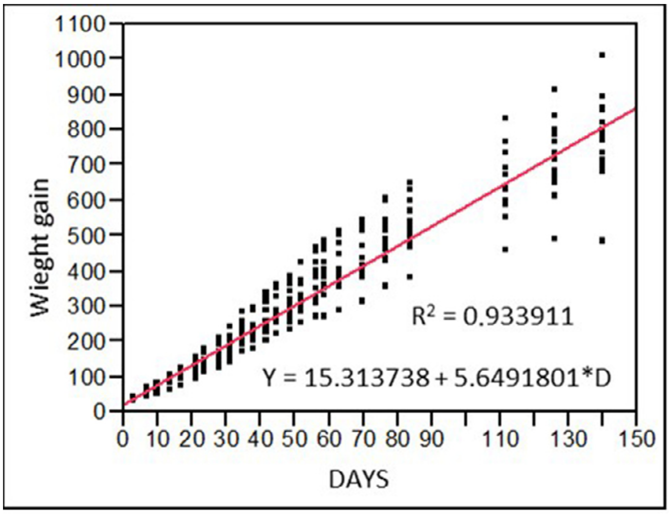

Figure 5. Bird growth regression curve.

55.83 g. Finally, at the end of the monitoring period (d 140) birds weighed 766.40 ± 118.66 g, corresponding to a WG of 414.40 ± 76.56 g for the final 80-d period. Considering the whole period (0−140 d of life), birds showed a total WG of 732.44 ± 117.06 g.

The bird growth regression curve is reported in Figure 5.

The final weight of male birds was 853.00 ± 77.60 g, while that of female birds was 690.63 ± 94.55 g.

- Feed intake and conversion ratio. During the first month of life, birds showed an FI of about 45.36 ± 17.48 g corresponding to an FCR of 2.53 ± 0.81. This value had increased to 98.32 ± 20.30 g by d 60, with a FCR of 3.56 ± 1.35. From d 61 until d 140, the FI was ± 160.29 g and the FE was 7.21 ± 2.68.

The FCR regression curve is reported in Figure 6.

Egg Quality and Carcass Traits

The protein, fat and mineral content of the yolk was: 27.21 ± 4.21 g/100 g DM, 57.77 ± 1.03 g/100 g DM and 3.47 ± 0.40g/100 g DM, respectively; whereas these values for the albumen were: 82.50 g/100 g DM ± 0.57, 0.12 ± 0.01g/100 g DM and 5.43 ± 0.34 g/100 g DM, respectively.

The dressing out of the birds in the slaughterhouse was 77.80% (± 3.91), with an average breast weight of 258.35 ± 42.82 g, and an average leg weight of 96.42± 25.16 g.

The major morphological traits and performance data are summarized in Table 2.

DISCUSSION

The Mugellese is a dwarf chicken breed with a medium neck, well-arched, broad shoulders, fairly long and horizontal wings, and a wide and well-developed breast (especially in the hen); however, no information about the biometric measures of this breed were available in the literature. The head of this breed is small, and it has lively eyes, a simple straight comb (with 5−6 teeth), and medium wattles and mumps. The face, comb and wattles are bright red, while mumps are white or spotted with red. The tail is held at 45° in roosters, but lower in hens. Legs are short but strong, and the shanks are light pink in color. This breed's plumage shows evident sexual dimorphism, and is similar to that of the Red Jungle Fowl (*Gallus gallus*). The rooster's plumage is highly colorful: feathers are mahogany brown on the head, degrading to brilliant brown and gold on the shoulders and tail hanging; the breast and the sides of the body are generally a deep, dark-colured feather that become iridescent in the wings with shades of blue and violet. From the shoulder to the wing extremities, feathers are initially iridescent black, followed by a section of brown and finally black feathers again. The tail is iridescent black with shades of dark green and blue. Two different patterns of plumage color are acknowledged in the hen. One, called "wild type" or "gold neck", is similar to the wild *G. gallus* hen, with gold feathers on the neck, which are black flamed, while the rest of the body is well camouflaged, being an ash gray or ash brown color, except for the breast that is salmon pink. The second plumage variety is completely different: feathers are mahogany brown on the head and neck, and wheaten buff over the rest of the body (TuBAvI Polli italiani Mugellese, 2017).

The majority of the surveyed breeders were located within the province of Florence in Tuscany, where the Mugellese breed first originated and developed. The restricted distribution of other Italian local chicken breeds to their native areas was similarly reported by Cartoni Mancinelli et al. (2020), namely the Livorno and Ancona breeds. The population size of the Mugellese breed during the interval June 2018−June 2019 (Castillo et al., 2021) comprised 277 breeding individuals; whereas a total of 405 breeding individuals was recorded by the end of the survey period (June 2020).

The Mugellese breed is part of Italian poultry heritage and constitutes a typical breed used in sharecropper farms. At present, this breed is in extreme risk of extinction due to the advent of modern breeds characterized by high meat or egg productivities. Based on the present data, the risk status of the Mugellese breed, according to the FAO risk status classification (FAO, 2007), is "at risk" (FAO et al., 2021). However, while the Domestic Animal Diversity Information System of the FAO (DAD-IS) reported a population size for the Mugellese breed of just 81 individuals in 2018, the population size reported here of 405 breeding individuals in June 2020 indicates that an encouraging population growth trend is presently underway.

Modern chicken hybrids can reach a commercial weight of 2 to 3 kg in 35 to 45 d, or 300 eggs laid over the course of a year. The Mugellese chicken is certainly unable to compete with such high performances or endure the intensive management systems that

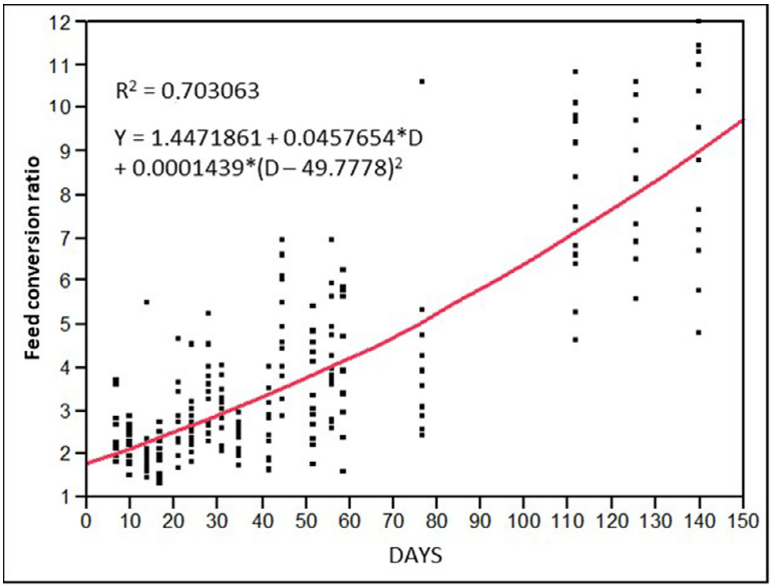

Figure 6. Feed conversion ratio regression curve.

characterize modern poultry livestock farming. Considering the data collected, the Mugellese breed has a long growing period and lays a low number of small-sized eggs. Nevertheless, it shows interesting characteristics that constitute a valuable element of chicken biodiversity.

The Mugellese chicken reaches adulthood at 5 mo of age, and weighs 700 to 900 g. These data, combined with the morphofunctional measures, underscore the dwarf dimensions and the slow growth rate of this breed.

Table 2. Summary of major parameters.

Adult birds morphological traits (cm)	
Body length	32.43 ± 1.45
Wing span	36.67 ± 2.74
Chest circumference	25.40 ± 1.80
Shank lenght	3.27 ± 0.26
Natural brooding	
Age at first egg	5 months
Incubation length	468 ±12 h
Reproduction parameters	
Incubation length	480 ±12 h
TF%[1]	94.35
TM%[2]	25.20
Performances	
Total WG[3] (g)	732.44 ± 117.06
Average FCR[4]	3.94 ± 2.42
Egg production	
Major production peak	March-April
HDEP%[5] at major peak	65.75
Egg parametres	
ESI[6]	0.74 ± 0.09
Shell weight (g)	3.40 ± 0.61
Albumen weight (g)	11.17 ± 1.09
Yolk weight (g)	16.00 ± 1.65

[1]TF, true fertility.
[2]TM, true mortality.
[3]WG, weight gain.
[4]FCR, feed conversion ratio.
[5]HDEP% hen-day egg production percentage.
[6]ESI, egg shape index.

In fact, the morphological data reported here for this breed are typical of mesomorphic subjects (the coefficients for wingspan and body length are the same), being typical characteristics of egg-type chickens and not of those used in meat production. These observations are also reinforced by the fact that 78% of the surveyed breeders did not use this breed for meat consumption.

Nonetheless, the growth performances for the Mugellese breed were supported by a FCR value of 4 on average. This high value was probably due to the high level of growth variability among the birds. Since the Mugellese breed did not undergo to a strong selective pressure, nowadays, the subjects show a wide range of phenotypic variability. Comparing the FCR for this breed with that of commercial hybrid broilers (which ranges from about 1.2–1.5; Benyi et al., 2015), it cannot compete with the latter, but considering the lower growth rate of commercial breeds (such as the Kabir chicken and of other unselected poultry species such as duck; Attia et al., 2013; Buccioni et al., 2020), the Mugellese chicken exhibited comparable performances.

It should also be noted that in "natural" environments, the food intake of Mugellese chickens is under-estimated since these scavenger chickens also eat grass, earthworms, insects, arthropods, etc. which probably improved the feed/weight gain ratio (Sossidou et al., 2019).

The Mugellese breed showed valuable incubation traits throughout the period considered. Similar high fertility values were reported by Iqbal et al. (2016)) for the Hubbard Classic broiler strain. Moreover, the same authors reported this characteristic to vary over time: they reported a lower fertility value for the Hubbard Classic at 60 wk of age (83.87%). In the present study, no statically significant variation in TF was observed between the ten incubations. Lower fertility and H values were reported by Cerolini et al. (2010) for another Italian dwarf chicken breed, the "Mericanel della Brianza" breed: the authors reported a mean fertility and H value of 81.6 and 49.6%, respectively, both of which were associated with significant levels of variation over the reproduction period examined (here you could state what that period was, e.g., March-September). Embryo mortality in Mericanel della Brianza chickens mainly occurred between 3 and 7 or 19 and 20 d of incubation, or at the moment of hatching. A similar distribution of embryo mortality in the early stage of development was observed in the present study for the Mugellese breed. However, embryo mortality in the late stage was very low (0.89%).

Cendron et al. (2020) and Soglia et al. (2021) considered the Mugellese and another 22 Italian local breeds in a neighbour-joining tree model based on Reynold's genetic distances. The representation suggests that the Mugellese breed diverged from the other breeds of the study early on, forming a highly distinct isolated branch. These findings highlight the completely different genetic history of Mugellese chicken, which was selected over centuries not for its production qualities but for the provision of a "brooding service".

From an ethological standpoint, the Mugellese chicken is characterized by its lively temperament, and wild traits. The observation of wild brooding has shown that Mugellese hens are more likely to share the nest and collectively brood a higher number of eggs, thus providing better defence against danger. This observation was confirmed by the surveyed breeders; in fact, no preferences were recorded by the breeders for individual vs. group nests for the Mugellese breed. It was observed that Mugellese hens actively defend the nest and their chicks when humans enter the enclosures. Such behavior is not reported in relation to productive breeds. Mugellese flocks reared in wild-like environments with only strictly necessary human intervention permitted exhibit a low nest abandonment rate (observational data).

Eggs laid in early November (short photoperiod) reliably hatched, and chicks reached adult maturity without demonstrating health problems, even with temperatures around 0°C. The egg production curve clearly highlights that this ancient breed (i.e., which was not subjected to artificial selection) shows lower levels of seasonality and less broodiness. The egg production losses that accompany broodiness are responsible for the waveform of this annual egg laying curve. The second peak in the curve was probably due to the resumption of ovarian activity in the hens whose prolactin levels had dropped. This hormone initiates incubation activities and keeps the hen in a broody state for several weeks after the chicks' hatch (Buntin, 1996).

CONCLUSIONS

In summary, comparing the data collected in this trial with those pertaining to other local chicken breeds, the Mugellese breed shows high frugality and fitness, confirming its laying and brooding capacity. This breed has a very long history in Tuscany, but it has risked extinction several times during modern times. That said, its characteristics make it a suitable breed to reintroduce into extensive farming systems. The Mugellese breed should be considered an indispensable tool for small farms in marginal lands and for sustainable chicken management. However, more data are needed to validate its growth traits and laying performances.

DISCLOSURES

The authors declare that they have no competing interests.

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.psj.2022.102259.

REFERENCES

AOAC International. 1995. Official Methods of Analysis of AOAC International. 16th ed. The Association, Washington DC.

Attia, Y. A., A. E. Abd Al-Hamid, H. S. Zeweil, E. M. Qota, F. Bovera, G. Monastra, and M. D. Sahledom. 2013. Effect of dietary amounts of inorganic and organic zinc on productive and physiological traits of White Pekin ducks. Animal 7:895–900.

Barbut, S. 2017. Ingredient Addition and Impacts on Quality, Health, and Consumer Acceptance. Elsevier Ltd, Guelph, Canada.

Benyi, K., T. S. Tshilate, A. J. Netshipale, and K. T. Mahlako. 2015. Effects of genotype and sex on the growth performance and carcass characteristics of broiler chickens. Trop. Anim. Health Prod. 47:1225–1231.

Buccioni, A., G. Brajon, L. Nannucci, V. Ferrulli, F. Mannelli, A. Barone, M. Daghio, G. Secci, S. Rapaccini, D. Gatta, M. Falce, and S. Minieri. 2020. Cardoon meal (Cynara cardunculus var. altilis) as alternative protein source during finishing period in poultry feeding. Sustain 12:5336.

Buntin, J. D. 1996. Neural and hormonal control of parental behavior in birds. Adv. Study Behav. 25:161–213.

Cartoni Mancinelli, A., S. Mattioli, A. D. Bosco, A. Aliberti, M. G. Amato, and C. Castellini. 2020. Performance, behavior, and welfare status of six different organically reared poultry genotypes. Animals 10:1–12.

Castillo, A., M. Gariglio, A. Franzoni, D. Soglia, S. Sartore, A. Buccioni, F. Mannelli, M. Cassandro, F. Cendron, C. Castellini, A. C. Mancinelli, N. Iaffaldano, M. Di Iorio, M. Marzoni, S. Salvucci, S. Cerolini, L. Zaniboni, and A. Schiavone. 2021. Overview of native chicken breeds in Italy: conservation status and rearing systems in use. Animals 11:490.

Cendron, F., F. Perini, S. Mastrangelo, M. Tolone, A. Criscione, S. Bordonaro, N. Iaffaldano, C. Castellini, M. Marzoni, A. Buccioni, D. Soglia, A. Schiavone, S. Cerolini, E. Lasagna, and M. Cassandro. 2020. Genome-wide SNP analysis reveals the population structure and the conservation status of 23 Italian chicken breeds. Animals 10:1441.

Cerolini, S., M. Madeddu, L. Zaniboni, C. Cassinelli, M. G. Mangiagalli, and S. P. Marelli. 2010. Breeding performance in the Italian chicken breed *Mericanel della Brianza*. Ital. J. Anim. Sci. 9:e72.

Damaziak, K., M. Pawęska, D. Gozdowski, and J. Niemiec. 2018. Short periods of incubation, egg turning during storage and broiler breeder hens age for early development of embryos, hatching results, chicks quality and juvenile growth. Poult. Sci. 97:3264–3276.

Englmaierová, M., E. Tůmová, V. Charvátová, and M. Skřivan. 2014. Effects of laying hens housing system on laying performance, egg quality characteristics, and egg microbial contamination. Czech J. Anim. Sci. 59:345–352.

FAO Browse by country and species | Domestic Animal Diversity Information System (DAD-IS) | Food and Agriculture Organization of the United Nations http://www.fao.org/dad-is/browse-by-country-and-species/en/(accessed Mar. 2021).

FAO. 2007. The State of the World's Animal Genetic Resources for Food and Agriculture – in Brief. FAO, Rome.

FAO. 2012. Phenotypic characterization of animal genetic resources. FAO Animal Production and Health Guidelines No. 11. FAO, Rome.

FAO. 2015. The Second Report on the State of the World's Animal Genetic Resources (BD Scherf and D Pilling, Eds.). FAO Commission on Genetic Resources for Food and Agriculture Assessments, Rome, Italy.

FAO, IFAD, UNICEF, WFP, and WHO. 2021. The State of Food Security and Nutrition in the World 2021. Transformi, Rome, Italy.

Faul, F., E. Erdfelder, A.-G. Lang, and A. Buchner. 2007. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav. Res. Methods 2:175–191.

Franzoni, A., M. Gariglio, A. Castillo, D. Soglia, S. Sartore, A. Buccioni, F. Mannelli, M. Cassandro, F. Cendron, C. Castellini, A. C. Mancinelli, S. Cerolini, A. A. Sayed, N. Iaffaldano, M. Di Iorio, M. Marzoni, S. Salvucci, and A. Schiavone. 2021. Overview of native chicken breeds in Italy: small scale production and marketing. Animals 11:629.

Hamburger, V., and H. L. Hamilton. 1951. A series of normal stages in the development of the chick embryo. Develep. Dynam 88:231–272.

Iqbal, J., S. H. Khan, N. Mukhtar, T. Ahmed, and R. A. Pasha. 2016. Effects of egg size (weight) and age on hatching performance and chick quality of broiler breeder. J. Appl. Anim. Res. 44:54–64.

Rocchi, L., L. Paolotti, A. Rosati, A. Boggia, and C. Castellini. 2019. Assessing the sustainability of different poultry production systems: a multicriteria approach. J. Clean. Prod. 211:103–114.

SAS Institute. 2008. Introduction to Analysis of Variance Procedures. SAS Institute, Charlotte, NC.

Soglia, D., S. Sartore, E. Lasagna, C. Castellini, F. Cendron, F. Perini, M. Cassandro, M. Marzoni, N. Iaffaldano, A. Buccioni, S. Dabbou, A. Castillo, S. Maione, C. Bianchi, M. Profiti, P. Sacchi, S. Cerolini, and A. Schiavone. 2021. Genetic diversity of 17 autochthonous Italian chicken breeds and their extinction risk status. Front. Genet. 12:1492.

Sossidou, E. N., A. Dal Bosco, C. Castellini, and M. A. Grashorn. 2019. Effects of pasture management on poultry welfare and meat quality in organic poultry production systems. World Poultry Sci J 71:375–384.

Suk, Y. O., and C. Park. 2001. Effect of breed and age of hens on the yolk to albumen ratio in two different genetic stocks. Poult. Sci. 80:855–858.

Tixier-Boichard, M., A. Bordas, and X. RognoMn. 2009. Characterisation and monitoring of poultry genetic resources. Worlds. Poult. Sci. J. 65:272–285.

van Soest, P. J., J. B. Robertson, and B.a. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583–3597.

TuBAvI Polli italiani Mugellese, 2017. https://www.pollitaliani.it/en/portfolio-articoli/mugellese/ (accessed Sep. 2021).