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Laying performance characteristics, egg quality, and integument condition of Saxonian chickens and German Langshan bantams in a free-range system

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Primary Audience: Flock Supervisors, Researchers, Breeders

SUMMARY

Indigenous poultry breeds represent an important animal genetic resource. However, their characteristics in respect of performance, product quality, and integument condition are often poorly investigated. Therefore, the local breeds Saxonian chickens (**SaChi**) and German Langshan bantam chickens (**GLB**) of different plumage colors were characterized. The high-performing hybrid strain of Lohmann brown chickens (**LB**) served as the control group. For each group, 60 hens and 6 roosters were studied in an extensive free-range system from 21 to 80 wk of life. The plumage and foot pad quality were scored on 9 distinct observation dates and the measurements of the egg quality were performed at 7 different time periods.

The number of eggs per hen housed in the first laying year was significantly lower in the SaChi (146.4 ± 30.8) and the GLB chickens (107.8 ± 20.4) when compared to the LB chickens (295.0 ± 16.8) ($P < 0.001$). Regarding laying performance, we detected effects of plumage color within both local breeds ($P < 0.001$). Within 4/7 plumage colors, effects of the breeder were also found ($P \leq 0.037$). The eggs of the local chicken breeds showed lower egg weights ($P < 0.001$), shell breaking strength ($P \leq 0.041$), albumen consistency ($P < 0.001$), and a lower egg shape index ($P < 0.001$), but higher proportions of yolk ($P < 0.001$) when compared to the eggs of the LB chickens. The logistic regression models for the plumage and footpad condition demonstrated that the SaChi and GLB hens underwent less plumage loss and footpad swelling than the LB hens ($P < 0.001$).

Overall, this study shows that the laying performance of the local breeds was significantly lower, but there were noticeable advantages in terms of egg composition and animal welfare indicators when compared to a high-performing hybrid strain. In further studies and the use in extensive production systems, the observed performance differences between plumage colors and breeders should be taken into account.

Key words: indigenous chickens, dual-purpose chickens, genetic resources, product quality, animal welfare

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DESCRIPTION OF PROBLEM

Worldwide, the production of chicken eggs and meat is dominated by the use of commercial hybrid strains, which either possess a very high growth potential and low reproductive potential (broiler hybrids) or a very high laying performance with comparatively weak growth performance. This circumvents the negative genetic correlation between laying performance and growth (Preisinger, 2018). However, the high-yielding, specialized hybrid strains have high demands in respect of husbandry, feeding, and management in order to fully exploit their respective genetic potentials (FAO, 2014). Furthermore, in regard to laying hybrid production, male day-old chickens are killed after hatching for economic reasons. This is due to the fact that they are not suitable for profitable fattening (Damme and Ristic, 2003).

In Germany, since 2022, the killing of male day-old chicks in laying lines has been prohibited by the Animal Welfare Act (BMEL, 2021; TierSchG, 2022). From 2023, France will also abandon the killing of male laying chicks (CNPO, 2023). The main alternatives are now in ovo-sexing approaches, the raising of male laying hybrids for meat production (which is subsidized by the eggs of the sisters), and the use of dual-purpose chickens (Jahn and Tiemann, 2022). Dual-purpose chickens are strains that are selected for both laying and fattening performances. Indeed, they represent a compromise, as the negative genetic correlation between laying and fattening performance means that a high performance among specialized hybrid strains cannot be achieved (Ibrahim et al., 2019; Preisinger, 2021). According to Jahn and Tiemann (2022), the following genotypes can be used as dual-purpose chickens: 1) dual-purpose hybrids (i.e., hybrids of commercial strains); 2) crossbred chickens (i.e., hybrids of local breeds with the parents of commercial strains); and 3) dual-purpose breeds (mostly indigenous, purebred chicken breeds). The latter 2 variants offer a great potential to promote the conservation of old, local breeds. Moreover, these indigenous breeds represent a valuable animal genetic resource, whose breeding is in the hands of private breeders and whose existence is often threatened (Weigend et al., 2014). Due to their independent breeding histories and different selection criteria, indigenous chicken breeds can possess genetic traits that are potentially useful for the purposes of commercial breeding programs (Weigend et al., 2014; Malomane et al., 2019). Furthermore, indigenous chicken breeds are characterized by a high resilience, robustness, and improved integument conditions (Ajayi, 2010; Tiemann et al., 2020).

In Germany, indigenous poultry breeds of particular preservation interest were identified in the National Program for the Conservation and Sustainable Use of Animal Genetic Resources (BLE, 2021). These breeds cover a wide range of the global genetic diversity of domestic chickens (Malomane et al., 2019). Among the 39 chicken breeds, Saxonian chickens (**SaChi**) who began to be bred around 1880 in the Ore Mountains (Saxony, Germany) are classified as extremely endangered, and they represent a breeding population of only 81 roosters and 334 hens from a total of 44 breeders (BLE, 2021). The German Langshan bantam (**GLB**) chickens are 1 of the 3 listed bantam breeds and began to be bred in northern Germany in 1910. GLB chickens are classified as critically endangered, with a population of 161 roosters and 517 hens from 82 breeders (BLE, 2021).

In the agricultural use of local chickens, individual studies have shown advantages among the indigenous breeds in terms of egg quality (Rizzi and Chiericato, 2005; Lordelo et al., 2020; Mori et al., 2020; Nguyen Van et al., 2020; Ianni et al., 2021), animal-welfare-related indicators (Damme and Schreiter, 2020; Tiemann et al., 2020, 2022), and meat quality (Mueller et al., 2018; Escobedo del Bosque et al., 2020; Nguyen Van et al., 2020) when compared to high-performing hybrid strains. However, the valid data are currently limited to a few breeds. In the absence of evidence-based findings for SaChi and GLB chickens in respect of their laying performance, egg quality, and integument conditions the objective of the present study was to characterize these traits over the first laying period in an extensive free-range system that is considered typical for local chicken husbandry.

MATERIALS AND METHODS

In this study, the performance traits, integument condition, and egg quality during the first laying period of the 2 local German chicken breeds were characterized and compared with high-performing laying hybrids that are commonly used in commercial layer farming. For this purpose, we selected the local chicken breeds of SaChi and GLB chickens (Figure 1), which are officially considered indigenous and endangered chicken breeds by the Advisory Board for Animal Genetic Resources of the German Society for Breeding Science (BLE, 2021). The original plumage colors of the breeds are black, white, and cuckoo in the

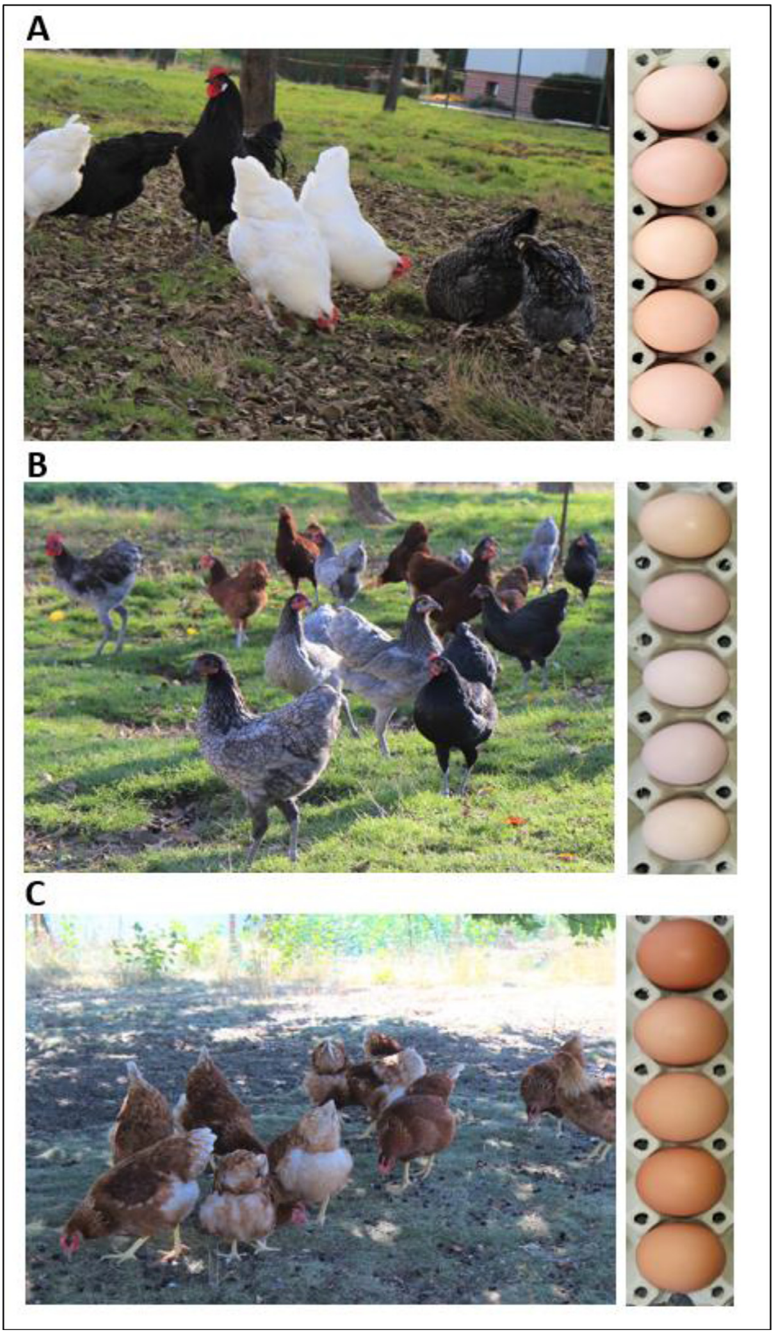


Figure 1. Phenotype of Saxonian chickens (A), German Langshan bantams (B), and Lohmann brown classic (C) and their eggs.

SaChi and black, white, blue-laced, and red in the GLB chickens (BLE, 2021).

Animals, Housing, and Management

The animals were kept on a private farm (Rump's Agricultural Farm, Dresden-Ockerwitz, Germany), which is a project farm at the Dresden University of Applied Sciences. In order to establish the study groups, hatching eggs of SaChi were purchased from 8 and of GLB from 7 private breeders, incubated and the hatched chickens reared in extensive free-range conditions (for more details, see Freick et al., 2022). The animals of the control group, who were from the high-performing hybrid strain of Lohmann brown (**LB**) chickens, were purchased at the age of 18 wk from a commercial rearing company (Geflügelzucht Brinkschulte GmbH, Senden, DE, Germany). At the beginning of the study, 60 hens and 6 roosters were present in each group (i.e., SaChi, GLB, and LB chickens). The sample size of the hens per plumage color is shown in Table 1. All chicks hatched in the same week. The observation period occurred from wk 21 to 80 of the chickens' lives.

In a solid barn, a compartment with a floor area of 7 × 4 m was available for each breed as a single-level housing system. The floor area was littered with softwood shavings and straw pellets (Einstreuprofi, Seelingstädt, Germany). In addition, a total length of 12 m of wooden perches (3 × 5 cm) was available per compartment. Moreover, the animals had access to a free-range area (15 × 25 m per group) with grass vegetation for 8 h daily, and each compartment had a window area of 1.5 × 0.5 m. The lighting program in regard to the SaChi and GLB chickens was based on a regime specified for local chickens according to Damme and Schreiter (2020), while the program for the LB chickens was organized according to the specifications of the breeding company (Lohmann Breeders, 2021). High-frequency light sources (aviary lamps; Tageslichtlampen24.de, Kiel, Germany) were used. Feed was provided in 4 round feeding troughs per compartment (Heka, Rietberg, Germany), each with a feeding surface of 125 cm. Regarding the water supply, a nipple drinker (Kari Farming, Herzebrock, Germany) with 12 drinking nipples was available in each compartment. As for the additional environmental enrichment materials, pecking stones (Vilolith medium; Deutsche Vilomix Tierernährung GmbH, Neuenkirchen-Vörden, Germany) and hard-pressed alfalfa blocks (Einstreuprofi,

Table 1. Egg numbers (mean ± standard deviation) of the local German chicken breeds Saxonian chickens and German Langshan bantams (classified for their plumage color) and the high-performing hybrid strain Lohmann brown over the study period (weeks of age 21–80) and per laying year[2].

Breed/plumage color[1, 3]	Over the whole study period		Per laying year[2] (365 d)	
	Eggs per hen housed	Eggs per average hen	Eggs per hen housed	Eggs per average hen
Saxonian chickens				
Black ($n = 30$)	154.0 ± 23.4[b]	156.0 ± 23.9[b]	151.9 ± 23.1[c]	153.8 ± 23.6[b]
White ($n = 14$)	120.7 ± 15.0[a]	123.6 ± 17.8[a]	119.0 ± 14.8[a]	121.9 ± 17.5[a]
Cuckoo ($n = 16$)	165.1 ± 27.8[c]	168.9 ± 28.4[c]	162.8 ± 27.6[b]	166.5 ± 27.9[c]
Total ($n = 60$)	148.8 ± 31.2	153.1 ± 32.7	146.4 ± 30.8	150.4 ± 32.3
German Langshan bantams				
Black ($n = 19$)	116.6 ± 21.1[a]	118.9 ± 20.2[a]	114.9 ± 20.8[a]	117.2 ± 19.9[a]
White ($n = 12$)	123.4 ± 9.7[a]	123.4 ± 9.7[a]	121.7 ± 9.6[a]	121.7 ± 9.6[a]
Blue-laced ($n = 18$)	112.5 ± 17.2[a]	116.8 ± 17.8[a]	110.9 ± 16.9[a]	115.2 ± 17.6[a]
Red ($n = 11$)	84.3 ± 10.2[b]	92.8 ± 9.0[b]	83.2 ± 10.1[b]	91.5 ± 8.9[b]
Total ($n = 60$)	108.9 ± 20.7	115.3 ± 19.3	107.8 ± 20.4	113.7 ± 19.0
Lohmann brown				
Total ($n = 60$)	331.3 ± 17.1	348.6 ± 18.4	295.0 ± 16.8	308.2 ± 17.6

[1]Fixed effect of plumage color within each local breed for all traits: $P < 0.001$.
[2]First laying year—Saxonian chickens and German Langshan bantams weeks of age 25 to 76, Lohmann brown weeks of age 21 to 72.
[3]Sample size refers to hens housed.
[a,b,c]Different superscripts indicate column-wise significant differences ($P \leq 0.05$) between the means of the different plumage colors within a breed.

Seelingstädt, Germany) were offered in the barn ad libitum. Furthermore, a 2-phase feeding program was provided with a complete diet for the laying hens (period 1) from the wk 21 to 60 (ATR LHF 1, ATR Futtermittel, Grimma, Germany; 11.5 MJ ME/kg, 17.0% crude protein, 4.0% crude fiber, 0.42% methionine, 3.7% calcium, 0.52% phosphorus, and 0.18% sodium), as well as a complete diet for the laying hens (period 2) from wk 61 to 80 (ATR LHF 2, ATR Futtermittel, Grimma, Germany; 11.4 MJ ME/kg, 16.5% crude protein, 5.0% crude fiber, 0.38% methionine, 3.9% calcium, 0.51 % phosphorus, and 0.18% sodium). All diets were offered ad libitum in mash form. In addition, 2 g of grit per animal with a particle size of 2 to 4 mm (Geflügel-Magenkies, Einstreuprofi, Seelingstädt, Germany) was provided once a week.

Study Design and Data Collection

This study was reviewed by the Country Directorate of Saxony, Germany as the responsible animal ethics committee and was not classified as an animal experiment (reference DD25-5131/526/8).

During the laying period, the number of eggs was recorded daily. For this, electronic trap nests (Ei_Nest, Dietrich, Penig, DE, Germany) were used with 12 nest sites per group. The nests electronically registered the egg laying of the hens, which were all marked with RFID transponders (Ei_Nest disc transponder, Dietrich, Penig, Germany). Thus, an individual laying performance was available for each hen in the study. The total number of eggs per hen was recorded in 2 ways: i) over the entire study period (wk 21−80) and ii) for a laying year of 364 d. The start of the laying year (laying maturity) was determined by the age at which a certain laying performance per average hen was reached, that is, 50% for the high-performing hybrids and 10% for the SaChi and GLB chickens (Henning et al., 2017).

Feed consumption was determined for each of the 2 groups via a continuous initial and back-weighing measurements (scale: Defender 3000, Ohaus, Parsippany, NJ) in increments of 28 d. The mortality was recorded daily.

Investigations regarding the internal and external egg quality were performed at 7 time points. At each date, 3 daily collections per group were examined and the measurements took place on the day following the laying date. The sample size of the eggs varied depending on the laying performance of the groups at the observation dates (wk 25: SaChi n = 21, GLB n = 18, LB n = 161; wk 30: SaChi n = 79, GLB n = 49, LB n = 167; wk 40: SaChi n = 100, GLB n = 63, LB n = 162; wk 50: SaChi n = 82, GLB n = 68, LB n = 154; wk 60: SaChi n = 78, GLB n = 44, LB n = 141; wk 70: SaChi n = 47, GLB n = 24, LB n = 134; wk 80: SaChi n = 21, GLB n = 18, LB n = 123). In order to calculate the egg shape index (egg width/egg length × 100), the eggs were measured at their maximum height and width via the use of digital calipers (Bröring Messschieber, Bröring Technology GmbH, Lohne, Germany), as per the procedures detailed by Anderson et al. (2004). The weights of the eggs, yolks, albumens, and shells were measured by using a scale (Kern 440-43, KERN & SOHN GmbH, Balingen, Germany), as well as the breaking strength of the eggshells (Fast Egg Shell Tester, Bröring Technology GmbH, Lohne, Germany), the eggshell thickness (Bröring Messtaster, Bröring Technology GmbH, Lohne, Germany), and the albumen height (Albumen Altimer, Bröring Technology GmbH, Lohne, Germany), according the procedures followed by Galic et al. (2023). The individual weight of each egg and its components were used in order to calculate the albumen percentage (albumen weight/egg weight × 100), yolk percentage (yolk weight/egg weight × 100), and shell percentage (shell weight/egg weight × 100) (Dottavio et al., 2005). Based on the egg weight and albumen height, the Haugh unit (HU = 100 × log [albumen height − 1.7 × egg weight$^{0.37}$ + 7.69]) was calculated for the purposes of characterizing the albumen consistency (Haugh, 1937).

In order to indirectly quantify the occurrence of feather pecking, integument scoring was performed in all animals during rearing at 9 time points (wk 20, 25, 30, 35, 40, 50, 60, 70, and 80). In addition to integument scoring, the individual body mass of each animal was recorded (scale BAT1, Veit Electronics, Moravany, CZ, Germany).

Integument scoring for plumage loss and foot pad swelling was performed according to the Welfare Quality® (2009) guidelines. These traits were divided into 3 scores (plumage: 0 = intact plumage, 1 = moderate PD with one or more featherless areas ≤5 cm, 2 = severe PD with one or more featherless areas >5 cm; foot pad swelling: 0 = feet intact, no or minimal proliferation of epithelium, 1 = necrosis or proliferation of epithelium or chronic bumble foot with no or moderate swelling, 2 = swollen—dorsally visible). Plumage was scored in 2 body regions, that is, the dorsal neck and belly. Baldinger and Bussemas (2020) found an increased back plumage loss in groups of roosters and hens in local chicken flocks due to mating without an association with feather pecking. Therefore, the back plumage was not scored in our study. In addition to the 2 individual scores for the plumage regions, a total plumage score was calculated for each animal by adding the individual scores (Schreiter et al., 2020). Integument scoring was performed by 3 observers who completed a training period on 300 animals in order to determine interobserver reliability.

Statistical Analyses

Microsoft Excel (Version 2013, Microsoft Corporation, Redmond, WA) was used for the data collection and processing and the creation of the selected diagrams. For further descriptive and inferential statistical analyses, the IBM SPSS Statistics program (Version 23, SPSS Inc., Chicago, IL) was used.

A normal distribution of the residuals was found for body mass, egg number per average hen, egg number per hen housed, feed consumption, and all egg quality traits (i.e., egg weight, egg shape index, albumen consistency, eggshell thickness, eggshell breaking strength, as well as for the proportions of yolk, albumen, and shell) using the Kolmogorov-Smirnov test and graphical analysis in Q−Q plots (Wei, 1999).

In order to describe the laying performance, egg numbers per hen housed and the average hen were calculated (Schreiter et al., 2018; Rizzi et al., 2013) for the respective groups (i.e., breed, plumage color within the local breeds, and breeder within the plumage color of the local breeds). Regarding the statistical evaluation of the laying performance, 1-factor ANOVA linear models were used (du Prel et al., 2010). In a first step, 1-factor ANOVA linear models with the fixed effect of breed were calculated to compare the performance between SaChi, GLB, and LB. In a second step, 1-factor ANOVA linear models with the fixed effect of plumage color were computed separately for SaChi and GLB to analyze the effect of the plumage color within each local breed. To analyze the breeder effect, in a third step, 1-factor ANOVA linear models with the fixed effect of breeder within breed and plumage color were used.

Regarding individual animal body mass analysis, as well as all the egg quality traits during the laying period, ANOVA linear models were used. These models were conducted with the breed as between-subject effect, the age as within-subject effect and the interaction breed*age because of repeated measurements structure of the data (Rasch et al., 2010).

Nonlinear regression models were used to predict the laying rate per average hen of each breed. For this purpose, we computed the models reviewed in Narinc et al. (2014) and determined the model with the best fit. The fit criteria estimated were the coefficient of determination (R^2) and the goodness-of-fit, which were determined by a final loss (L_f) of a loss function: sum of observed minus predicted data to the second power (data not shown). Consequently, we used the formula given by Narushin and Takma (2003) as the final model: $y = (at^3 + bt^2 + ct + d)/t^2 + et + f)$, where y is the daily laying rate per average hen; t is the age of the hens in weeks; and a, b, c, d, e, and f are the proportionality coefficients. The predicted data were visualized as a laying curve over the first laying period.

A concordance analysis was performed to quantify the degree of agreement in integument scores. For this purpose, the prevalence-adjusted and bias-adjusted kappa (**PABAK**) was calculated as a characteristic of the interobserver reliability according to Gunnarsson et al. (2000). With regard to the extent of agreement, the generated PABAK values were interpreted according to Landis and Koch (1977) and Kwiecien et al. (2011) as follows: ≤0.20 insufficient, 0.21 to 0.40 low, 0.41 to 0.60 moderate, 0.61 to 0.80 good, and >0.80 very good.

Binary logistic regression (**BLR**) models (Baltes-Götz, 2012) with total plumage score or foot pad score as dependent variables, and breed and age as independent variables were fitted to the data. For the models, independent variables and interactions were retained using a backward selection approach when $P < 0.1$ in an attempt to reduce the type II error risk while maintaining a stringent type I error risk of 5% (Hosmer and Lemeshow, 2000). Multiple logistic, rather than ordinal, regression models were used because some scores were occupied by only very few observations. For multiple logistic regressions, the ordinal data scaling (as defined by Welfare Quality®, 2009) was transformed into nominal scaling (score was 0 for scores of 0 and 1 for scores of ≥1). The absence of multicollinearity was ensured by calculating the Pearson's correlation coefficient and performing a collinearity diagnosis with the variance inflation factor and condition index (Menard, 2002; Field, 2013). We also calculated Nagelkerke's R^2 values to explain the extent of variation in the dependent variables explained by the model. Nagelkerke's R^2 values ≥0.5 were considered as very good, values in the range of $0.4 \geq R^2 < 0.5$ were considered as good and values between $0.2 \geq R^2 < 0.4$ as moderate (Backhaus et al., 2008).

In all of the described inferential statistical analyses, differences were considered statistically significant for $P \leq 0.05$ and tended to be significant at $0.05 > P \leq 0.1$.

RESULTS AND DISCUSSION

Performance Traits

The laying maturity threshold for local chickens of a 10% laying rate per hen housed was reached in SaChi at 169 d of age and in GLB chickens at 167 d of age. The LB hens reached a laying maturity (≥50% laying rate per hen housed as the threshold for commercial layer hybrids) within 146 d of age. The laying rate of the 3 breeds over the first laying period is shown in Figure 2 and the egg numbers are summarized in Table 1. The laying performance of all breeds differed significantly ($P < 0.001$). Moreover, an effect of the plumage color ($P < 0.001$) was observed in the egg number per hen housed, as well as per average hen within each of the local breeds, that is, the SaChi and the GLB chickens. Furthermore, a breeder effect in regard to the laying performance was evident in black ($P \leq 0.037$), white ($P \leq 0.016$), and cuckoo SaChi ($P < 0.001$), as

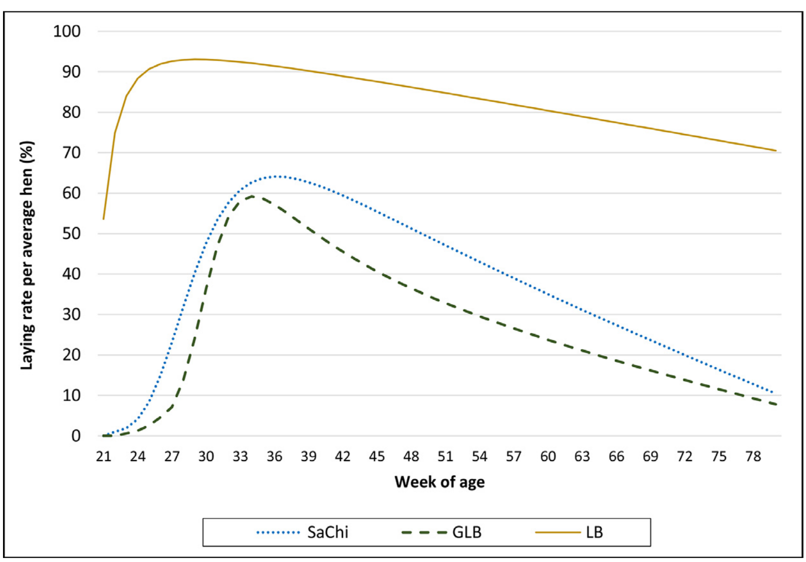


Figure 2. Nonlinear regression curves of the laying rate per average hen during the first laying period (weeks of age 21–80) of the local German chicken breeds Saxonian chickens (SaChi) and German Langshan bantams (GLB) and the high-performing hybrid strain Lohmann brown (LB).

well as in respect to the black GLB chickens ($P = 0.006$), which was not present in the blue ($P \geq 0.069$), red ($P \geq 0.781$), and white (only 1 breeder) GLB chickens. The numerically largest differences in the mean egg number between the hens of different breeders were found in the cuckoo SaChi with 64.9 eggs per hen housed over the laying year.

As expected, the laying performance of the local breeds was considerably lower than in the commercial laying hybrids. The observed egg numbers of the local chicken hens were in the range of other studies that investigated German breeds. In regard to the above, Henning et al. (2017) calculated annual egg numbers in the range of 92 to 148 in the 10 local chicken breeds. Furthermore, Damme and Schreiter (2020) reported 141 eggs in Augsburg chickens, and Hörning et al. (2020) counted 124 eggs in German Faverolles and 155 eggs in Vorwerk hens, but 178 eggs in purebred Marans and 181 eggs in Bielefelder chickens. However, several studies consistently showed that the laying performance of purebred chickens is below that of crossbred chickens of local breeds, which, in turn, could not reach the level of high-performing laying hybrid strains (Baldinger and Bussemus, 2020; Hörning et al., 2020; Jahn and Tiemann, 2022). This confirms the assumption of Jahn and Tiemann (2022), who consider crossbreeding approaches as the preferred option for the inclusion of local breeds in respect of commercial farming.

The large differences in egg production between the breeds indicate a different selection intensity for the performance traits in the breeding flocks. Regarding the view of the divergence between the targets for laying performance, as specified in the local chicken standards and the status quo, it seems advisable to direct more attention toward the performance traits in local chicken breeding. However, considerable differences between the hens of the different breeders within a breed also show that a general statement on the laying performance is of limited value. This underlines the necessity of recording individual or breeder-specific performances within laying performance tests.

The 3 breeds differed significantly in terms of their body mass ($P < 0.001$). All 3 groups showed a significant increase in the body mass from the start of the laying period to wk 35, at which point they reached a plateau. The SaChi possessed body masses of 1,632 ± 159 g (wk 20); 1,942 ± 257 g (wk 25); 2,117 ± 263 g (wk 30); 2,266 ± 251 g (wk 35); and, after this point, then averaged 2,318 ± 313 g (wk 40−80). In respect of the GLB chickens, their body masses were as follows: 820 ± 89 g (wk 20); 941 ± 136 g (wk 25); 1,023 ± 135 g (wk 30); 1,088 ± 141 g (wk 35); and 1,107 ± 143 g (wk 40−80). The LB hens' body masses were as follows: 1,665 ± 132 g (wk 20); 1,809 ± 147 g (wk 25); 1,965 ± 146 g (wk 30); 2,002 ± 157 g (wk 35); and 1,966 ± 182 g (wk 40−80).

The daily mean feed intake per hen was 124.1 ± 8.7 g in regard to the SaChi, 115.4 ± 9.2 g for the GLB chickens, and 126.8 ± 6.8 g in respect of the LB chickens. Therefore, the production of 1 kg egg mass required 6.117 ± 0.717 kg of feed in the SaChi, whereas it was 7.351 ± 0.849 kg for the GLB chickens, and 2.358 ± 0.287 kg in regard to the LB chickens. The lower efficiency in egg mass production was a result of the significantly lower egg numbers among the local breeds and the fact that they were not selected for efficient feed conversion rates.

During the study period, 3 (5.0%) of the SaChi, 7 (11.7%) of the GLB chickens, and 6 (10.0%) of the LB chickens died.

Egg Quality

In all investigated traits regarding internal and external egg quality, we detected significant breed and age effects (each $P < 0.001$) (Figure 3). Indeed, the egg weights of all 3 breeds differed significantly from one another ($P < 0.001$; mean ± SD over all observation dates: SaChi—55.5 ± 4.8 g, GLB chickens—40.0 ± 2.9 g, and LB chickens—63.4 ± 5.3 g); moreover, these weights increased over the laying period. Thus, the SaChi achieved, on average, an egg weight of 55 g, as specified in the breed description (BLE, 2021), whereas the GLB chickens' eggs were 2 g below this target value. In the study by Henning et al. (2017), the SaChi eggs weighed 61.5 g at wk 55 of age. Over the whole laying period, however, 67% of the eggs weighed more than 55 g.

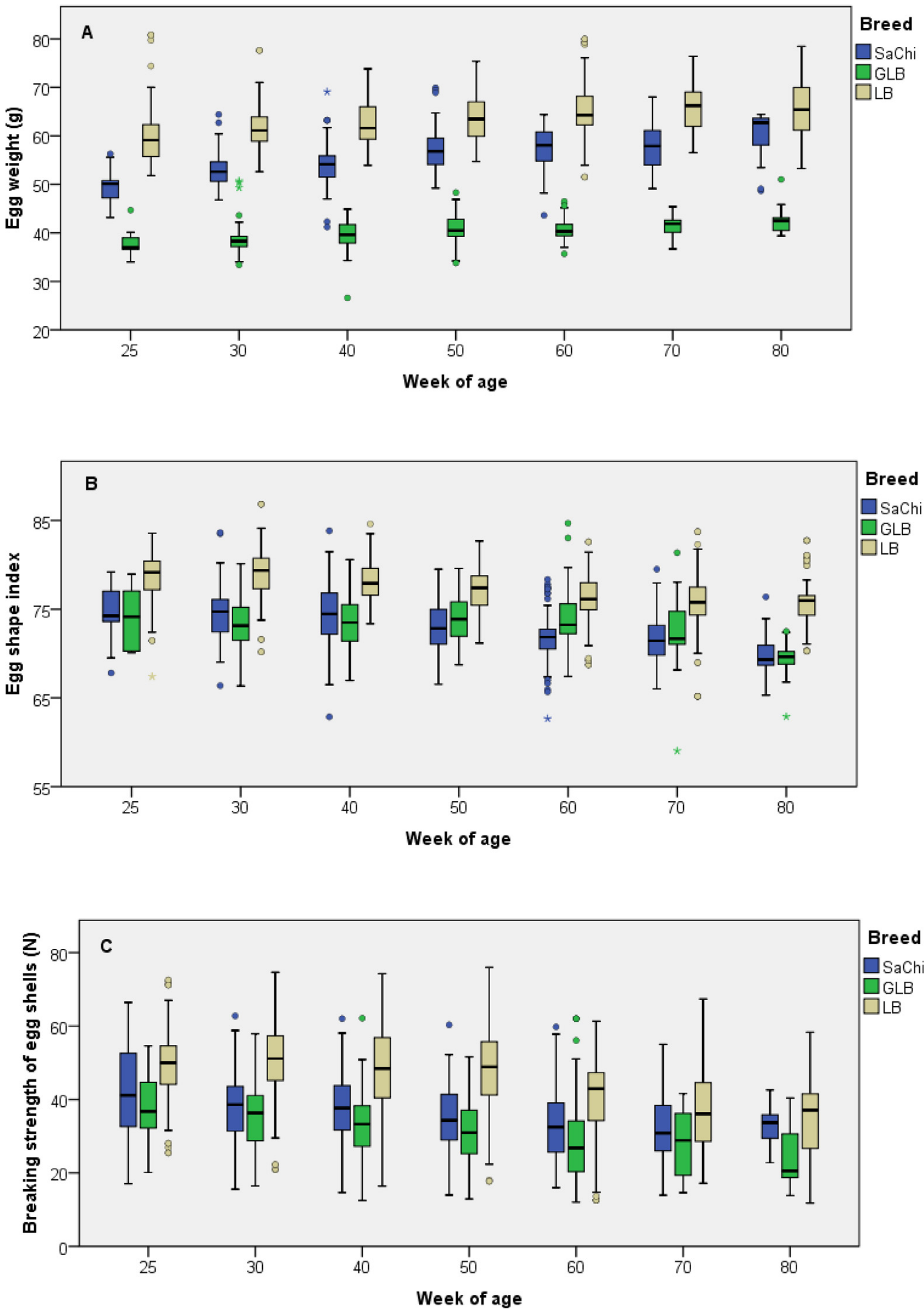
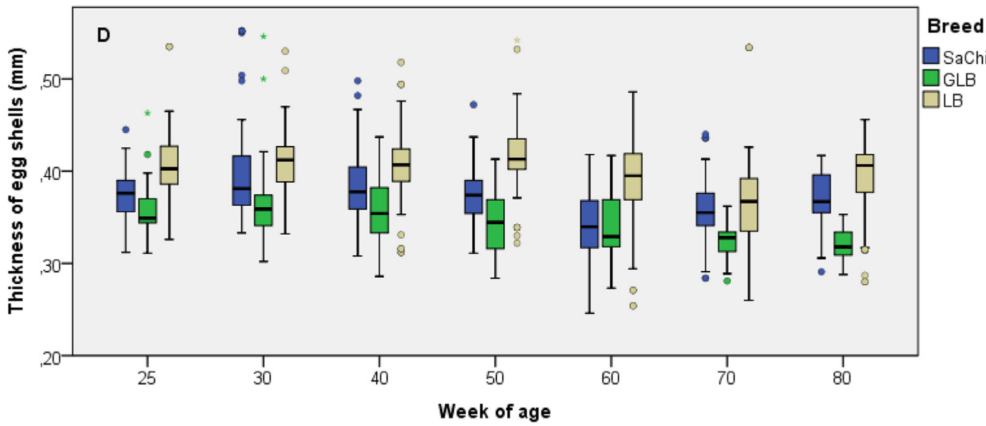


Figure 3. Egg quality traits of the local German chicken breeds Saxonian chickens (SaChi) and German Langshan bantams (GLB) and the high-performing hybrid strain Lohmann brown (LB) during the first laying period. Significant breed and age effects (each $P < 0.001$) were identified in egg weight (A), egg shape index (B), breaking strength of the eggshell (C), eggshell thickness (D), and albumen consistency (E). N = Newton; HU = Haugh Unit (Haugh, 1937).



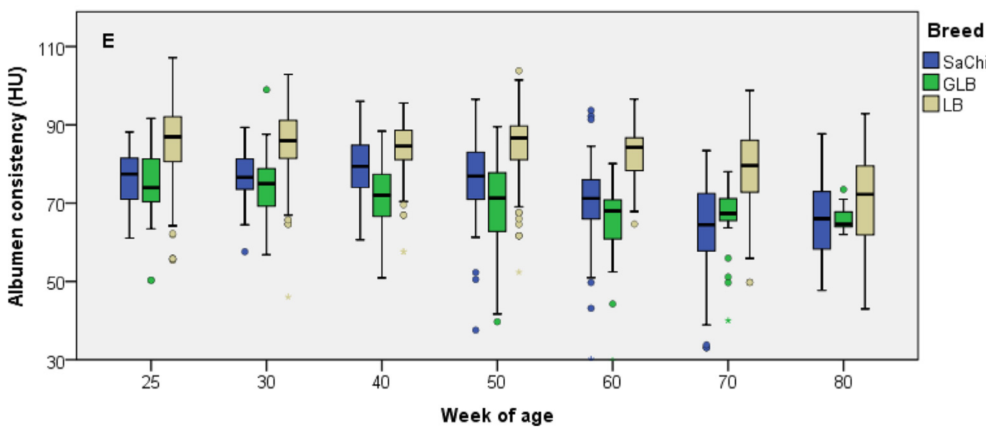


Figure 3 Continued.

SaChi (73.1 ± 3.3) and GLB chicken (73.1 ± 3.1) eggs possessed a lower egg shape index than the LB chicken eggs (77.3 ± 3.0) ($P < 0.001$), with a lower breaking strength (SaChi 35.59 ± 5.00 N, GLB chickens 32.26 ± 5.27 N, and LB chickens 44.36 ± 7.32 N) ($P \leq 0.041$). The eggshell thickness was found to be lower in the GLB chickens (0.35 ± 0.04 mm) when compared to the SaChi (0.37 ± 0.05 mm) ($P \leq 0.025$), which, in turn, possessed thinner eggshells than the LB chickens (0.40 ± 0.04 mm) ($P \leq 0.020$). Lordelo et al. (2020) and Baldinger and Bussemas (2020) also found thicker eggshells with a higher breaking strength in the commercial laying hens when compared to local chickens. The breaking strength of the eggshell is of high economic importance in commercial egg production. Furthermore, commercial strains have been intensively selected for this trait (Preisinger, 2018). It is likely that the lack of selection for this trait in local chickens is the main reason for the differences in eggshell thickness.

The eggs of the local breeds (SaChi 73.54 ± 10.25 HU; GLB chickens 70.28 ± 9.36 HU) showed a lower albumen consistency than the LB chicken eggs (82.15 ± 10.13 HU) ($P < 0.001$). According to the classification for albumen consistency based on the United States Department of Agriculture (2021), the SaChi and LB eggs show a firm albumen (>72 HU), whereas the GLB eggs fall into the class of reasonably firm (60−72 HU).

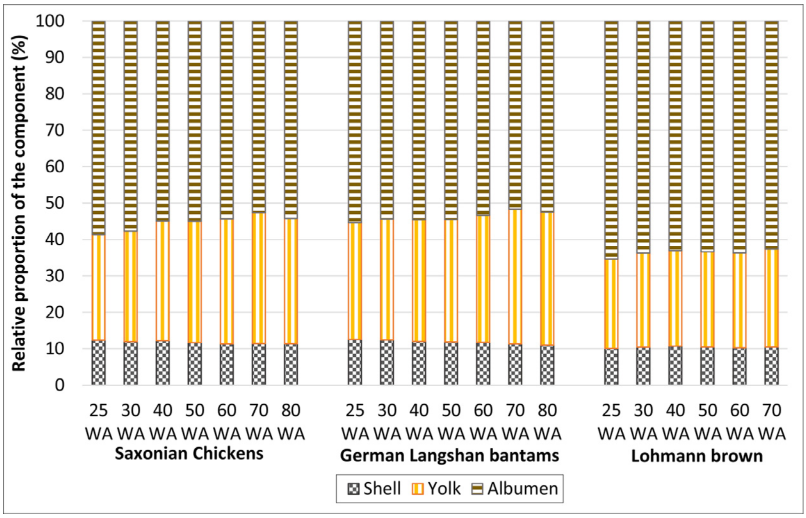


Figure 4. Egg composition in the local German chicken breeds Saxonian chickens (SaChi) and German Langshan bantams (GLB) and the high-performing hybrid strain Lohmann Brown (LB) during the first laying period. Significant breed and age effects were identified in the relative proportions of yolk, albumen, and eggshell (each $P < 0.001$). WA = week of age.

Breed*age interactions existed within the breaking strength ($P < 0.001$), eggshell thickness ($P = 0.015$), and albumen consistency ($P = 0.012$), but not in relation to the egg weight ($P = 0.070$) and egg shape indexes ($P = 0.410$).

The effects of breed and animal age ($P <$ 0.001 each) were observed in the gross composition of the chicken eggs (Figure 4). The yolk content in the GLB chickens (mean ± SD over all observation dates: 34.03 ± 3.69%) and the SaChi (32.97 ± 3.88%) was higher than that of the LB chickens (26.04 ± 2.37%) ($P < 0.001$). Between the SaChi and the GLB chickens, the yolk proportion only differed in wk 25 and 30 ($P \leq 0.001$), but not at the other time points ($P \geq 0.05$). Likewise, the relative proportion of the albumen only differed between the 2 local breeds in wk 25 and 30 ($P \leq 0.017$). Across all of the observation dates, the LB chicken eggs (63.48 ± 2.70%) possessed a higher proportion of albumen than those of the SaChi (55.23 ± 3.86%) and the GLB chickens (53.99 ± 3.71%) ($P < 0.001$). Moreover, the eggs of the local breeds, that is, the SaChi (11.80 ± 1.16%) and the GLB chickens (11.98 ± 1.11%), did not differ in terms of shell percentage ($P \geq 0.119$), but were different from the LB chicken eggs (10.48 ± 1.09%) ($P < 0.001$). A significant interaction in respect of the breed*age indicates a different course regarding the relative proportions of the albumens, yolks, and shells between the breeds over the laying period ($P < 0.001$). Baldinger and Bussemas (2020) also found these interactions in different dual-purpose strains as well as in the Lohmann Sandy strains. Indeed, these results were observed with a simultaneous increase in the proportion of yolk with an increase in animal age.

When compared to eggs from high-yielding hybrid strains with a yolk content of 24 to 28% (Grashorn, 2022), several studies found higher yolk percentages in the local chickens (e.g., 32−34% in 4 Portuguese local breeds (Lordelo et al., 2020); 30−31% in 2 Italian local breeds (Rizzi and Chiericato, 2005); 31−34% in 10 German local breeds (Henning et al., 2017), 36% in Augsburg chickens (Damme and Schreiter, 2020); 31% in Australops; 30% in Rhode Island Red (Mori et al., 2020); and 31−33% in Asian local breeds (Nguyen Van et al., 2020)). In addition, Rizzi and Chiericato (2005), as well as Lordelo et al. (2020) used commercial laying hybrids as the control groups in their studies, which showed significantly lower yolk percentages. The 2 main reasons for these differences should be discussed. On the one hand, there is a negative correlation between egg weight and relative yolk content (Flock et al., 2007), which gives an advantage to the mostly smaller eggs of the local breeds. On the other hand, the yolk content of eggs from commercial laying hens has been reduced in recent decades as a result of the selection for high laying performance and efficient feed conversion (Flock et al., 2007; Grashorn, 2022). In terms of nutritional value, Ianni et al. (2021) found that eggs from the tested Italian local chickens tended to possess lower cholesterol contents, higher levels of saturated fatty acids, palmitic acid, palmitoleic acid, and lower levels of oleic acid when compared to the eggs from commercial laying hybrids. Moreover, the authors concluded that the eggs of local breeds possess special nutritional characteristics that may lead consumers to prefer these niche products. However, recent studies on eggs from 2 Japanese local breeds showed that their amino acid contents in respect of yolk and albumen are lower than those found in the eggs from commercial laying hens (Goto et al., 2022).

Integument Condition

The PABAK values of 0.92 for plumage condition and 0.91 for foot condition indicated very good interobserver reliability.

Moreover, the final BLR models investigated the effects of the independent variables on the breed and age on the occurrence of plumage damage and foot pad dermatitis (Table 2). Both independent variables were kept in the significant final models ($P < 0.001$) after backward selection. The Nagelkerke's R^2 values of 0.231 (plumage condition) and 0.310 (footpad condition) indicated that the models possessed a moderate explanatory power. Breed and age were found to be significant effects ($P < 0.001$) in the BLR for the occurrence of plumage damage and footpad dermatitis. The 2 local breeds, that is, the SaChi and the GLB chickens, incurred less plumage loss and footpad dermatitis than the LB hens (Figure 5).

As improved animal welfare appears to be necessary in regard to the marketing of products when using regional breeds (Escobedo del Bosque et al., 2021), the plumage condition that is easily visible to consumers is of particular interest. Accordingly, it appears valuable that the local breeds in our study possessed lower plumage damage than the LB chickens. The plumage condition was used to indirectly quantify the occurrence of severe feather pecking (Schwarzer et al., 2022). Indeed, Meuser et al. (2021) demonstrated that there are also significant differences in respect of the fear and exploration behaviors between commercial laying hens, as well as regarding commercial dual-purpose hybrids and the Rhinelander, which is another local breed.

Hörning et al. (2020) found lower plumage damage during the laying period in pure breeds

Table 2. Results of logistic regression models: effects of breed and age on the occurrence of plumage damage and foot pad dermatitis in the local German chicken breeds Saxonian chickens (SaChi) and German Langshan bantams (GLB) and the high-performing hybrid strain Lohmann Brown (LB) from weeks of age 21 to 80.

Trait	Score 1 (%)	Coefficients (SE)	Odds ratio (95% CI)	Individual P value	Overall P value
Total plumage score					
Breed					<0.001
LB	19.4	Reference	Baseline		
SaChi	9.8	−0.89 (0.19)	0.41 (0.28−0.59)	<0.001	
GLB	3.1	−2.15 (0.28)	0.12 (0.07−0.20)	<0.001	
Age		0.05 (0.01)	1.05 (1.03−1.06)		<0.001
Intercept		−3.76 (0.28)			
Foot pad dermatitis					
Breed					<0.001
LB	23.7	Reference	Baseline		
SaChi	4.3	−2.04 (0.24)	0.13 (0.08−0.21)	<0.001	
GLB	0.4	−4.48 (0.71)	0.01 (0.01−0.05)	<0.001	
Age		0.03 (0.01)	1.03 (1.02−1.04)		<0.001
Intercept		−2.71 (0.26)			

CI: confidence interval; SE: standard error; Score 0: intact plumage; Score 1: integument damage.

A

B

Figure 5. Plumage (A) and foot pad condition (B) in the local German chicken breeds Saxonian chickens (SaChi) and German Langshan bantams (GLB) and the high-performing hybrid strain Lohmann brown (LB) during the first laying period. In (A), the proportion per score refers to the arithmetic mean of the 2 plumage regions examined (dorsal neck and belly plumage). Logistic regression models showed a significant breed effect on plumage and foot pad condition ($P < 0.001$). WA = week of age.

(Vorwerk chickens, Marans, Bresse, German Faverolles, Bielefelder) compared to crossbreds of Bresse × White Rocks or New Hampshire. The dual-purpose hens in Baldinger and Bussemas (2020) differed in the belly plumage scores in wk 72. Hens of Bresse and Bresse × New Hampshire had less plumage loss than Bresse × White Rocks. However, the laying hybrid strain Lohmann Sandy was at the same level as the breeds with the best plumage condition.

Damme and Schreiter (2020) found differences in the plumage condition between the hen groups of the different breeders within the Ausgburg chickens. The authors concluded that significant differences in the genetic predisposition, in regard to severe feather pecking, also exist within the local breeds.

Although only a few severe foot pad swellings were found in this study, the food pad condition was better in the SaChi and the GLB chickens when compared to the LB chickens. In contrast, Tiemann et al. (2020) found that more foot pad dermatitis occurred in purebred chickens when compared to commercial laying hybrid and dual-purpose strain chickens. Indeed, in the study of Hörning et al. (2020), several local breeds did not differ in terms of their footpad condition.

Certain limitations in the study design must be considered in terms of the generalizability of the results. By not separating the breeds by plumage color, a good representation of the common housing conditions among local poultry breeders was provided, as well as those in respect of potential small-scale niche production. However, this methodology did not allow us to draw conclusions regarding the predisposition of severe feather pecking between the chickens with different plumage colors. Future studies should endeavor to include several groups per genotype (e.g., compartments per breed and plumage color).

CONCLUSIONS AND APPLICATIONS

This study provides insights into the performance, egg quality traits, and welfare indicators for 2 endangered German chicken breeds during the laying period.

1. In terms of the classical production traits (e. g., egg numbers, feed conversion rate), the local breeds were found to be considerably inferior to the high-performing hybrids.
2. Regarding the local breeds, differences in the performance traits exist between the breeders. Private breeders are recommended to select for an appropriate performance level (according to the breeding standard).
3. The characteristics of the SaChi and the GLB chickens in terms of percentage yolk and integument condition underline the necessity of preserving old chicken breeds as an animal genetic resource.

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Ethical Statement: The study was reviewed by the Country Directorate of Saxony, Germany as the responsible animal ethics committee and not classified as an animal experiment (reference DD25-5131/526/8).

DISCLOSURES

All authors declare no conflicts of interest.

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