Evaluation of live-body weight and the number of eggs produced for introduced and local chickens in Ethiopia

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ABSTRACT

Ethiopia's 60 million chickens are reared primarily in free range, smallholder systems. Therefore, upgrading smallholder poultry to small-scale commercial systems is central to rural development. With the aim of providing access to improved chicken by rural farmers in Ethiopia, the live body weight at week 17 and number of eggs per bird per week for one locally improved and three tropically adapted dual-purpose chicken strains was tested through a project called the African Chicken Genetic Gains. Both traits were analyzed by fitting a linear mixed model with week and pen as random effects, and station and breed as fixed effects. The result showed that both breed and station effects were significant for both traits. The introduced breeds performed better than the local improved breed for both traits. Thus, the introduction of system-appropriate high-yielding tropically adapted breeds has the potential to increase the productivity of chicken.

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INTRODUCTION

Ethiopia has a large chicken population (58.3 million, which is 60% of East African chicken population), of which 88.19% are indigenous breed, 5.36% hybrid and the 6.45% introduced breed (CSA, 2018). Indigenous birds are characterized by low productivity, particularly when compared with introduced strains. For example, Bogale (2008) indicated that the local chickens achieved a live body weight of 1.5 kg in 6 months (26 weeks), but the introduced strains can attain this weight in 12 weeks. Esatu (2015), in a controlled experiment, investigated the live body weight of chickens of indigenous and commercial strains and reported that live body weight of indigenous chickens was 684 g versus 1630 g for the introduced, at week 16. With respect to the number of eggs, local hens in Ethiopia produced, on average, about 66 eggs per bird per year in village systems. This performance is significantly lower when it is compared with layers of introduced strains, which produced about 280 eggs per bird under high input management conditions (Esatu, 2015).

With the objective of improving chicken productivity, different introduced breeds of chicken were introduced in the early 1950s (Avery, 2004) to Ethiopia and other developing nations. However, the program was not successful because of the high mortality rate of the introduced breed and low adaptability to the low input system (Dana et al., 2010). In other words, the introduction of the introduced breeds did not consider issues of genotype by environment interactions.

To increase the meat yield and egg number in a sustainable manner, one might consider at least two solutions. First, genetic selection within the indigenous breed might be one option. However, successful selection relies on accurate data recording, including pedigree, and the birds need to be raised in a similar environment where the selection programs have occurred. More importantly, a large population with a substantial number of active and reserve sire and dam lines is needed to allow exhaustive exploitation of genetic variations for the meat yield trait (Pym, 2013). As a result, running poultry breeding programs is
costly, and this solution is not feasible in terms of meeting the immediate needs for more animal source foods in developing countries. Second, the introduction of productive, yet tropically adapted chicken strains provides an opportunity to increase meat yield and egg number in developing countries like Ethiopia.

With the aim of providing access to improved chicken strains to rural farmers in Ethiopia and other two African countries (Nigeria and Tanzania), a project called African Chicken Genetic Gain (ACGG; https://africacgg.net/) has been testing (both on-farm and on-station) the performance of various traits including live-body-weight-at-week-17 (LBW17) and number-of-eggs-per-bird-per-week (EPBPW), survival, and trait preference of farmers for three imported tropically adapted chicken strains. However, prior to introducing these improved tropical strains country-wide, the superiority or otherwise of their performance relative to the available locally improved strains need to be evaluated by comparing them with any locally improved strains. In this study, the improved Horro strain which been selected in Ethiopia and has shown substantial genetic progress (Esatu, 2015) has been used as a reference strain for the evaluation procedure. For example, through mass selection, the live body weight for Horro at week 16 has increased by 95% in seven generations (Esatu, 2015). Thus, this study, which is a part of the ACGG project, is focused on testing LBW17 and EPBPW for three high yielding, tropically adapted dual-purpose strains: Kuroiler, a hybrid chicken from India (Ahuja et al., 2008), Koekoek, a strain developed in South Africa (Grobbeelaar et al., 2010), and SRIR(Sasso strain with some Rhode Island Red inheritance) France (SASSO Breeding Company, 2018) and locally improved Horro at two stations: Debrezeit Agricultural Research Center (DZARC) and Haramaya University (HU). DZARC (8.44° N, 38.38°E) is located Tepid sub-moist mid highlands agro-ecological zone (1900m.a.s.l.) in Central Ethiopia while HU (9.40° N, 42.03° E) is cold sub-moist highland agro-ecological zone (2043m.a.s.l.) in Eastern Ethiopia. DZARC has a mean maximum temperature of 28.3°C and mean minimum temperature of 8.9°C and a relative humidity of 60%. HU, on the other hand, has a mean maximum temperature of 28.5°C and mean minimum temperature of 12.6°C and a relative humidity of 65%.

**Data collection and management**

The birds were maintained in deep litter house during the brooder phase for eight weeks from hatching. At the end of week eight, the sex of each bird was determined, and male and female birds were penned separately during the grower phase from week 9–20. During the brooder phase, we tested each strain in eight replications (pens), with each replicate having 24 birds (HU) and 23 (DZARC) and randomly allocated to 29 experimental pens at HU and 32 pens at DZARC. Thus, the average number of birds per pen was 24 at HU and 23 at DZARC. Male birds exited the flocks when they weighted 2 kg or at 20 weeks of age, whichever occurred first. Recording for LBW17 commenced from the brooding phase until the birds exited the experimental flocks. In the laying period, we tested each strain in four replications (pens) for both stations, which means in total, we used 32 pens to test the birds for number of eggs per bird per week (EPBPW). Recording for EPBPW commenced from week 21 to week 62. At HU station due to technical difficulties, there was no record for EPBPW for week 40–43 inclusively. The birds were vaccinated for major diseases at appropriate ages (Marek’s, New Castle Disease, Gumboro, Fowl typhoid, and Fowl pox) and received treatment when needed. Feed for Parent Stock layers chicken was formulated at DZARC using Feed Win software® according to the recommendations of each breeder’s manual. Improved Horro was fed with standard layer ration containing 17.9% CP, 2784.8 kcal/kg ME. The following ingredients were used: white maize, bone and meat meal, linseed cake, soya bean meal, wheat middling, limestone, DL-methionine, L-lysine, vitamin-premix, and salt were used. Feeders and waterer were placed in the house per pen according to the recommendations of each breeder’s manual. Water was given ad-libitum to all chickens in the experiments, but the amount consumed was recorded.

The trait of interest was live-body-weight-at-week 17 (LBW17) and number-of-eggs-per-bird-per-week (EPBPW). For the measure of live body weight, each

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**Materials and methods**

**Testing sites and protocol**

The African Chicken Genetic Gains (ACGG) team imported fertile eggs of four introduced, tropically adapted chicken strains into Ethiopia in 2016. The strains were Koekoek, Kuroiler, SRIR and Sasso. The first three imported strains and a locally improved strain named Horro were tested at two experimental stations in Ethiopia: Debrezeit Agricultural Research Center (DZARC) and Haramaya University (HU).
bird was weighed weekly at DZARC and biweekly at HU using sensitive balances. Though the grower phase ended at week 20, we chose week 17 because a substantial number of male individuals from Kuroiler and SRIR left the experiment at week 18 and 19. However, 34 Koekoek, 63 Kuroiler and 71 SRIR birds left the experience because they weighted 2 kg or more before week 17. For these birds, their final weight was taken as their recorded weight when they exited the experiment. If we had analyzed body weight at week 18 or 19, the number of exited birds would have further increased. For instance, if week 19 was taken, 7 improved Horro, 77 Koekoek, 65 Kuroiler and 115 SRIR birds exited the experiment. Therefore, week 17 was chosen to take the final body weight of birds for analysis to avoid loss of data and is a reasonable age for marketing of live birds in Ethiopia. Data on the total number of eggs laid each day in each pen and total number of laying birds were also collected. We computed EPBPW by taking the ratio of the total number of eggs collected to the total number of laying birds. Performance measurements were done by trained enumerators using Open Data Kit system (ODK).

**Experimental design**

We conducted the study using a randomized complete block design with eight treatment combinations (strain *station) in each of the 61 pens for LBW17 and 32 pens for EPBPW. Thus, the eight treatment combinations follow a full factorial design, comprising of four levels of strain and two levels of station, in $4 \times 2$ factorials. The number of observations in each treatment combination in each of the 61 pens for LBW17 and 32 pens for EPBPW were different; thus, the data were unbalanced. We did not investigate the sex of birds as a factor for LBW17 because the male and female birds were penned separately during the growing phase, implying that sex was confounded with pen effects. Therefore, pen effects also accounted for sex differences.

In total, for LBW17, 1454 birds were used for the data analysis at both stations. The number of birds per strain for each sex in each station is shown in Table 1. Furthermore, Table 2 shows the total number of laying hens for each strain in each station at the start of the laying period (week 21) and end of the laying period (week 61), more importantly, it showed the percentage of laying hens survived until week 61.

**Model**

Linear-mixed model (LMM) was applied to analyze the data because LMM consider both fixed and random effects. A linear mixed-effects model was built in R (R Core Team, 2017) using the packages lme4 (Bates et al., 2015) and the function lmer was applied to fit LMM to the data. We selected the best model using lsmeans was used to compute the least square means and the standard error.

The model for LBW was:

$$y = X\beta + Zp + e$$

where $y$ is a vector of observed live-body-weight-at-week-17; $\beta$ is a vector of fixed effects, with incidence matrix $X$ linking observations to fixed effects (strain,
station), \( p \) is a vector random pen effects and \( Z \) the incidence matrix linking observed live body weight to pens, with \( p \sim N(0, \text{I}_n \sigma^2_p) \) where \( \text{I}_n \) is an identity matrix of 61 by 61, and \( \sigma^2_p \) is the pen variance and \( e \) is vector of residuals where \( e \sim N(0, \text{I}_n \sigma^2_e) \) \( \text{I}_n \) is an identity matrix of 1454 by 1454 and \( \sigma^2_e \) is the residual variance.

We applied the model above for EPBPW with the same fixed effects but with two random effects: pen with identity matrix 32 by 32 and week with identity matrix 39 by 39.

### Results

Both fixed effects (strain and station) and random effect (pen) were statistically significant at the \( p < .0001 \) for LBW17. The main effect (strain) yielded an \( F \) ratio of \( F(3, 56.104) = 39.2, p < .0001 \), indicating that at least for one of the strains, the mean live body weight differed from the other strains. The main effect of the station yielded an \( F \) ratio of \( F(1, 13.8) = 13.8, p < .0001 \), indicating that the mean live body weight for a given strain differ significantly between DZARC and HU. With respect to the random effect, it significantly differed from zero \( (p < .0001) \), and more importantly, it improved the fit of the model as shown by lower AIC with the random effect (AIC of the model with random effect was 20417.09 and with no random effect was 20897.63). The intraclass correlation coefficient (ratio of variance due to pen, with the sum of variance due to pen and residual) was 0.20 for LBW17. This implies that the pen effect accounted for 20% of the variation in live-body-weight-at-week-17.

We employed the same linear mixed model with an additional random effect (week) for EPBPW, including the random effects week and pen improved the fit of the model as shown with lower AIC (model without the random effect AIC 4114.76 and model with the random effects AIC equals 3474.46). Both fixed effects (strain and station) were significant for EPBPW \( (p < .0001) \), implying that at least one of them differed for number-of-eggs-per-bird-per-week when we compared across strains. The main effect (station) was significant, indicating that the mean-egg-number-per-bird-per-week-for any given strain different at both stations. The variance due to both random effects of pen and week for EPBPW differed from zero. The intraclass correlation coefficient for EPBPW (ratio of the variance due to week and pen, with variance due to week, pen and residual) was 0.51, implying that 51% of the variation in egg-number-per-bird-per-week were accounted for by pen and week effects.

As the data was unbalanced, least square means (lsmeans) were computed for live-body-weight-at-week-17 and number-of-eggs-per-bird-per-week for each of the strains in both stations (Table 3). Overall, Kuroiler was the heaviest strain followed by SRIR and Improved Horro being the least in live-body-weight-at-week-17. This trend is true in both stations, and the number of eggs per bird per week for any given strain is larger in DZARC station than HU station.

### Discussion

Increasing meat yield and egg numbers are essential to supply the high demand required by the growing population both globally and in Ethiopia. Introducing tropically adapted strains of chicken may increase the meat yield and egg number in Ethiopia and other developing nations. We investigated the potential of three tropically adapted strains and one improved local strain on two stations in Ethiopia. Our findings show that there is a considerable difference in live bodyweight among the strains, with Kuroiler and SRIR being the heaviest and Improved Horro the lightest, and the live bodyweight of any given strain was heavier at DZARC than HU station. SRIR and Keokoek had the largest EPBPW and Improved Horro had the smallest EPBPW. Similarly, the EPBPW for any given strain was larger at DZARC than HU. We attribute the differences in performance between the two stations to differences in climate (ambient temperature and relative humidity).

The lsmeans for live-body-weight-at-week-17 for Kuroiler was 2.1 kg, which was substantially higher than the weight of the other three strains, particularly compared with the Improved Horro. As can be seen in Table 4, the performance of the two introduced strains, Kuroiler and SRIR was considerably larger than the indigenous Horro. For example, Kuroiler was 64% (812 g) and SRIR was 40% (500 g) larger than the live body weight of the indigenous Horro. This result is consistent with other on station

### Table 3. Type III analysis of variance table with Satterthwaite’s method for live-body-weight-at-week-17(LBW17) and number-of-eggs-per-bird-per-week (EPBPW).

| Trait    | Fixed factor | Mean squares | NumDF | DenDF | F value | Pr(>F)  |
|----------|--------------|--------------|-------|-------|---------|---------|
| LBW17    | Strain       | 2,682,841    | 3     | 56.10 | 39.268  | <.0001  |
| LBW17    | Station      | 946,231      | 1     | 13.85 | 13.850  | <.0001  |
| EPBPW    | Strain       | 63,832       | 3     | 54.56 | 8.7318  | <.0001  |
| EPBPW    | Station      | 30,6685      | 1     | 41.95 | 41.9525 | <.0001  |
experiments in developing nations (FAO 2010). In Vietnam, for example, the live body weight of the local Ac strain at 768 g at week 16 is significantly lower than our on-station results for both Kuroiler and SRIR. Furthermore, the weight of the local Nocobari strain in India was 1055 g at week 20, which is again substantially lower than the weight of Kuroiler and SRIR (Sunder et al., 2005).

The superiority of the Kuroiler and SRIR in live body weight is not limited to on station experiments. They are superior in live body weight when they are compared even under on farm testing. For example, Sharma et al. (2015) illustrated under scavenging condition in Uganda, the weight of male Kuroiler at week 25 was 2.6 kg but the indigenous was 1.6 kg, meaning the weight of Kuroiler is larger by 1 kg (62.5%) relative to the indigenous. In the ACGG project, we tested these strains under on-farm conditions, and the same results, larger performance of Kuroiler and SRIR was obtained when compared with indigenous Horro (Lozano-Jaramillo et al., 2019). Thus, if developing countries introduce system-appropriate, introduced strains, meat yields can substantially increase, particularly if coupled with a proper management system.

The Ismeans for number-of-eggs-per-bird-per-week (EPBPW) for the three introduced tropically adapted strain was larger than the indigenous Improved Horro (3) in both stations. As can be seen in Table 5, the performance of the three introduced strains, Koeokek, SRIR and Kuroiler was considerably larger than the indigenous Horro in both stations. For example, at DZARC station SRIR was 29% (0.87 eggs per week per bird), Koeokek was 22% (0.66 eggs per bird per week) and Kuroiler 11% (0.34 eggs per week per bird) larger than EPBPW Improved Horro at DZARC station. To have a good measure, we computed the total number of eggs collected for each strain during the entire experimental period (40 weeks), as shown in Figure 1. SRIR, Koeokek and Kuroiler produced about 150 eggs at DZARC station, which was substantially greater than the 80 eggs produced by the Indigenous Improved Horro. This result is higher than the result of other on-station experiments in the developing world. For example, in Vietnam, within eight months the Ac laid about 63 eggs and in Egypt the Fayoumi breed laid about 65 eggs per year. Therefore, the SRIR, Koeokek and Kuroiler produced twice as many eggs as the performance of comparable strains, such as the Fayoumi and Ac (Hossary & Galal, 1994).

The performance of any given strain for both traits (LBW17 and EPBPW) was higher in DZARC station than HU station. Still, the rank of the performance of the strains stayed the same, the performance of any given strain is larger in DZARC might be due to the tropical climate, which is more similar to the strains’ origins. Alternatively, HUs station climate is highland, which means the environment may not permit the birds to express their genetic potential. In other words, the birds need to expend some energy for maintenance, which might reduce the growth rate. Furthermore, the management system (individual (the person who cares the birds) difference in managing the birds) may be a reason for the difference. More importantly, both factors climate and management system might contribute for the difference in live body weight for a given strain.

In parallel with introducing high-yielding tropically adapted strains, we recommend starting a breeding program with the local breed or crossbreed the local breed with these or other similar introduced strains. The breeding program will allow the indigenous breed to express their potential for the targeted trait, in this case, live body weight and number of eggs. For

### Table 4. Least square means for live-body-weight- at-week-17 (LBW17) in grams and number of eggs per bird per week (EPBPW) with standard error for each of the strains at Debrezeit Agricultural Research Center (DZARC) and Haramaya University (HU) stations.

| Strain          | DZARC Mean | HU Mean | EPBPW Mean | HU Mean |
|-----------------|------------|---------|------------|---------|
| Improved Horro  | 1279.00 ± 57.4 | 1085 ± 59.1 | 3.00 ± 0.21 | 1.98 ± 0.19 |
| Koeokek         | 1669.00 ± 54.7 | 1475 ± 57.0 | 3.66 ± 0.20 | 2.63 ± 0.18 |
| Kuroiler        | 2091.00 ± 59.8 | 1896 ± 63.3 | 3.34 ± 0.20 | 2.31 ± 0.20 |
| SRIR            | 1782 ± 57.3 | 1588 ± 57.0 | 3.87 ± 0.19 | 2.85 ± 0.18 |

### Table 5. Pairwise least square mean comparison for LBW17 and EPBPW.

| Traits          | DZARC       | EPBPW       |
|-----------------|-------------|-------------|
| LBW17           |             |             |
| DZARC           |             |             |
| HU              |             |             |
| EPBPW           |             |             |
| DZARC           |             |             |
| HU              |             |             |

Notes: * refers the mean comparison is significant at p value .05 and b refers not significant at p value .05. Note that the pairwise mean comparison between each strain is identical because there is no interaction between strain and station.
example, using mass selection for Improved Horro breeding program, the live body weight at week 16 was increased by 95% in seven generations (Esatu, 2015). Thus, if the breeding program runs for several generations with a right tool for selection of parents such as using pedigree information, genomic information, the genetic gain of Horro breed will increase further. There is also a handful of evidence indicating very good performance of improved local breed for various traits in other developing countries, for example, Fayoum in Egypt, Fulani in Nigeria, and Mia in Vietnam (Sørensen, 2010). Thus, establishing a well-organized breeding program with the local breed should be one of the main long-term goal to improve the poultry productivity. In addition to increasing the productivity of these local breed, the breeding program will help to maintain the genetic diversity of the breed.

This paper primarily tested LBW17 and EPBPW traits. However, the profit of raising chicken depends on several economical important traits such as feed intake, survival etc. Thus, research could consider other economically important traits, together with LBW17 and EPBPW, such as feed intake and survival, to select the best performing strain. More importantly, research needs to integrate the economic value of traits (unit price of meat, price of an egg etc.) to select the most appropriate strain(s) that necessitate selection index. In other words, we need to develop multi-selection indices that consider the true breeding value of these traits with the appropriate economic value. We can use the selection index to make recommendations for the appropriate strains to the small-holder farmer. One final point, we evaluated the birds for this study under controlled experiments. Thus, we expect the performance of the bird for these traits to be substantially lower under on small holder management system because of the genotype by environment interaction. The ACGG project, in-parallel with this on-station testing, also evaluated these strains for live body weight and the number of eggs on-farm.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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