Desta and Wakeyo
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Reproductive characteristics of indigenous village chickens

Takele Taye Desta[1,2*] and Oli Wakeyo[3]

Abstract

Background Indigenous village chickens (IVCs) show a wide variation in production performance and reproductive characteristics. This high variation is occurred due to genetic and environmental factors and gene-environment interactions.

Results This work reports the results of a cross-sectional study conducted using a face-to-face interview with 119 small-scale farmers regarding their insights on the production performance and reproductive characteristics of IVCs. It was reported that pullets were sexually mature on average at the age of 5.5 months and cockerels at 6 months. This comparatively early sexual maturity by the standards of IVCs might be associated with the impact of uncontrolled gene flow from production breeds. However, there is high variation in age at sexual maturity at an individual bird's level. It was found that pullets mature earlier than cockerels ($t = 3.250$, $df = 159$, $p = 0.001$, 95% CI: -0.670, -0.166). According to the respondents, local hens laid on average 14 eggs per clutch. The average number of clutches per year was 4, which can culminate in the yearly production of 56 eggs. A significantly large proportion of the respondents reported that the dry season is appropriate for laying eggs (96.7%) and brooding chicks (94.1%). During the dry season, the scavenging feed resource is relatively abundant, the risk of infection is comparatively low, and the hot weather is suitable for laying eggs and brooding chicks. IVCs possess a long reproductive lifetime, that is, on average, 3 years in hens and 2 years in cocks, which makes them more productive than has been anticipated. For example, this study found that a hen, on average, can lay 174 eggs and hatch 58 chicks in its average reproductive lifetime of 3 years.

Conclusions The high intrapopulation variation in the reproductive performance of IVCs is vital resource in genetic improvement programs.

Highlights

- Indigenous village chickens exhibit a high degree of variation in reproductive characteristics.
- Attributable to considerable longevity, indigenous village chickens that are maintained under insufficient care produce a significant number of eggs and chicks.
- Environmental factors may contribute to the variation observed in the reproductive performance of indigenous village chickens.

Keywords Indigenous village chickens, Production performance, Reproductive characteristics, High phenotypic variation, Genetic improvement program, Enhanced management

*Correspondence:
Takele Taye Desta
takele_taye@yahoo.com
Full list of author information is available at the end of the article

Background

Hundreds of millions of small-scale farmers' families, although to a limited extent, make their livings from IVC production. Consequently, IVCs are commonly distributed across the agriculturally important world [1–3], particularly in the Global South. IVCs represent the most common poultry as well as domestic animal species [4], and they are adapted to a wide range of agroecology. Reproductive prolificacy, adaptive radiation, and multiple-uses make IVCs the most common livestock and poultry species. IVCs are an integral part of mixed crop-livestock agriculture, the local ecosystem, and the socio-cultural life of small-scale farmers [5]. IVCs play a significant role in the provision of animal protein and sociocultural and ecological services, primarily to small-scale farmers. IVCs can be used to study the demographic histories, pre-historical dispersion patterns, the historical network of ancient humans [2], and the socio-cultural constructs of rural communities. Nevertheless, IVCs are virtually associated with sedentary farming, and they are at best rarely associated with pastoralism [6].

Although small-scale farmers in the tropics usually adopt similar management practices and IVCs typically move freely according to their will, there is significant variation in the type and degree of care provided to IVCs [7]. This diverse practice is vital to inventing enhanced management that is aligned with the local context and small-scale farmers' aspirations. Essentially, the ancient management of chickens began around their putative centers of domestication. The traditional practice might then have been initially disseminated across the Old World through word-of-mouth conversation that might have also involved primitive sign languages. The ancient management practice might have been improved based on the knowledge gained during IVC's breeding and management history and according to the challenges encountered in a newly inhabited and highly diverse production environment. Farmers have developed a locally tailored management practice; however, it is not solely focused on highly sought-after specialty products and profit-earning [1]. This management practice, however, does not necessarily indicate that IVC production is a loss-making business. It has been reported that IVC production is highly profitable compared to commercial farms [8] that are operated using state-of-the-art technology and high-caliber conventional expertise. The limitation of IVC production is the economy of scale. Small-scale farmers seek various products and services besides the common products, such as eggs and meat. They usually engage in IVC production as a sideline (secondary) activity and earn their livings mainly from sibling agricultural and off-farm practices.

Among the phenotypic attributes of IVCs, reproductive traits dictate the survival, fertility, and feasibility of the IVC production system. IVCs show wide variation in reproductive performance [3], which is attributed to high genetic diversity, wide environmental variation, and significant gene-environment interaction. This genetic variation could serve as a base for selecting elite birds that can be used as a replacement flock. IVCs provide various parental cares, including incubating and hatching eggs and brooding chicks [9], substantiating the self-reliance of the IVCs' production system. However, these maternal instincts are counterproductive to egg production. Consequently, local hens exhibit low hen-day egg production [9], which is the measure of egg productivity (also known as layer production index) and is expressed in terms of the number of eggs laid as a ratio of the number of hens found in the flock on that day. Usually, about one-third of hens lay eggs on a particular day [10].

The reproductive efficiency of flocks, as well as the production costs, determine the feasibility of IVC production systems. Systematic improvement in the production performance of IVCs increases the output of the family flock and improves the livelihood of small-scale farmers. Genetic improvement can be made by assessing the performance of the family flock and by alleviating major constraints limiting the productivity of the extensive production system. This study reports the laying performance and reproductive characteristics of the family flock and provides insights to identify and prioritize areas of intervention.

Materials and methods

The study sites

The study was conducted in the Wolaita zone, which is found in southern Ethiopia, with geographical coordinates of 6.4° and 7.1° north latitude and 37.4° and 38.2° east longitude. Wolaita has a total land area of 3,982 square kilometers. Its elevation ranges between 1,200 and 2,950 m above sea level (masl). Based on the customary classification of agroecological zones in Ethiopia, Wolaita is clustered into three agroecological zones: Kolla, or lowland (35%, < 1500 masl), Woina Dega, or mid-highland (56%, 1,500 to 2,400 masl), and Dega, or highland (9%, > 2,400 masl). The main rainy season, that is, summer, usually lasts from June to October, and the minor one from March to May (spring). Accordingly, November to February represents the dry season. The average annual rainfall is 1,014 mm, and the mean daily temperature is 19.9 °C. The daily temperature, however, usually ranges between 17.7 °C in July and 22.1 °C in February and March.

Sampling methods

A cross-sectional study was conducted in two districts of the Wolaita zone: Damot Gale, representing the highland region, and Humbo, representing the lowland region. This study involved six representative rural villages (three from each agroecological zone) selected in consultation with each district's office of livestock extension advisory service. The selected agroecological zones show a clearly defined ecological contrast. Respondents were selected using a systematic sampling method. Accordingly, after dividing the total number of farmers living in the sampled villages by 20 (the class interval), the first respondent was randomly selected from the first-class interval using the lottery method. The remaining 19 farmers were subsequently selected at fixed intervals. A semi-structured questionnaire, pre-tested on 10 respondents, was administered to 119 farmers, that is, 20 in each village, except Taba, where 19 respondents were interviewed.

The studied traits

Farmers were interviewed on the demographic characteristics, production performance, and reproductive characteristics of their flock. The agroecological zone and the sex, family size, and education level of the respondents were used as explanatory variables.

Statistical analysis

Effective reproductive lifetime and reproductive lifetime egg and chick production were respectively calculated using Eqs. 1, 2, and 3.

$$R_e = R_l - A_{fl} \tag{1}$$

where, R_e is the effective reproductive lifetime; R_l age at which a hen stops laying, and A_{fl} age at the first lay.

$$Egg_p = R_e \times N_c \times Egg_c \tag{2}$$

where, Egg_p is the number of eggs laid in the effective reproductive lifetime of a hen; N_c the number of clutches per year, and Egg_c the number of eggs laid per clutch.

$$Chick_p = R_e \times N_h \times N_{chick} \tag{3}$$

where, $Chick_p$ is the number of chicks hatched in the effective reproductive lifetime of a hen; N_h the annual frequency of hatching, and N_{chick} the number of chicks hatched as a batch.

The statistical analysis was performed using IBM SPSS Statistics 23 [11] and R [12]. The Chi-square-test, T-test, correlation test, and F-test were used to analyze the data. Outliers (extreme values) were removed from the data to improve the consistency of the responses, and to produce meaningful and robust results.

Results

This cross-sectional study reports the egg production performance and the reproductive characteristics of the sampled family flock. This study discusses the major factors that govern the variation observed in the production and reproductive performance of the family flock.

Age at first lay

According to the respondents, age at first lay, or age at first egg, ranged from 5–8 months, with a mean and standard deviation of 5.548 ± 0.613, a median of 5.55, and mode of 5. According to the Chi-square test, among the explanatory variables, respondents' education level has a statistically significant impact on the age at first lay (Chi-square = 26.935, df = 15, $p = 0.007$). It was discovered that as literacy level increases, the data is largely aggregated around the mid-value. This enhanced accuracy shows the importance of conventional education in developing the abstraction and recall abilities of farmers.

Age at sexual maturity (first mating) in cock

The respondents reported that age at first mating (natural service) ranged from 5–9 months, with a mean and standard deviation of 5.996 ± 0.946 and a median and mode of 6. The Chi-square test shows that age at the first mating of the cock was significantly affected by the sex of the respondent (Chi-squared = 16.954; df = 7; $p = 0.018$). Accordingly, male respondents reported the mean and standard deviation of age at first mating as 5.85 ± 0.921 (standard error of the mean = 0.1049); however, female respondents reported a value of 6.727 ± 0.786 (standard error of the mean = 0.237). Male respondents reported wide-ranging values (ranging from 5–9 months); nevertheless, most of the female respondents (81.8%) reported around mid-values (6–7 months). This disparity shows that women are more knowledgeable about the characteristics of the family flock. This accuracy may be attributed to the familiarity of women, who spend most of their time around the home looking after the family flock. However, the proportion of female respondents was significantly low (10.7%, χ-squared = 61.78, df = 1, p-value = 3.841e-15); therefore, this result should be interpreted given this concern. The findings of this study show that pullets, that is, juvenile female chickens, mature earlier than cockerels, young male chickens. Summary Independent-Samples T-test also corroborates statistically significant differences in age at maturity between juvenile sex groups (t = 3.250, df = 159, $p = 0.001$, 95% CI: -0.670, -0.166). Nevertheless, the reported age at first mating in cocks shows a low but statistically

Table 1 The time gap between the hatching of chicks and the onset of lay in months in the two agroecological zones

Agroecological zone	Mean	Std. Deviation	Std. Error Mean
Highland	4.246	0.997	0.1298
Lowland	3.500	0.631	0.0815

Table 2 The summary statistics for the reproductive lifetime of hens and cocks

Variables	Range	Mean	Std Dev	Median	Mode
Reproductive lifetime of hens (years)	2 to 8	3.356	0.948	3	3
Reproductive lifetime of cocks (years)	1 to 6	2.021	1.091	2	2

significant positive correlation with age at first lay in hens ($r = 0.319$; $p = 0.012$).

The time gap between hatching and the onset of lay

The time gap between the hatching of chicks and the onset of egg-laying was reported to vary from 2–7 months, with a mean and standard deviation of 3.87 ± 0.91 and a median and mode of 4 months. This report shows that the minimum age of the chicks at fledging was 2 months. Agroecology explains a statistically significant variation in the gap between hatching and the onset of lay, that is, brooding period (t = 4.888, df = 117, $p = 0.000$, 95% CI: 0.443, 1.048). The group statistics are presented in Table 1. Hens start egg-laying after hatching and brooding chicks earlier in the lowland region. This may have occurred because chicks fledged earlier due to the hot weather conditions in the lowland region.

Egg laying performance

The number of eggs laid per clutch ranged from 8–20, with a mean and standard deviation of 14.21 ± 2.591, a median of 14 and mode of 12. There is a significant variation in the number of eggs laid per clutch, which provides a broad genetic base (genetic diversity of the breeding population) for selection and to develop flocks with improved laying performance. However, while selecting for enhanced egg production, care needs to be taken not to adversely affect the genetic vigor of unfavorably correlated resilience and growth traits. Variation in laying performance may, however, not be solely affected by the genetic makeup of the bird but also by the level and type of care provided (gene-environment interaction) [5]. None of the explanatory variables considered imposed a statistically significant impact on the number of eggs laid per clutch.

The reproductive lifetime of hens and cocks

Reproductive lifetime refers to the time interval between the age at first lay (mating in cocks) and cease of egg production (dispose of the cock from the flock due to various reasons). The statistical analysis shows that hens have a prolonged reproductive lifetime compared to cocks (Table 2). The reproductive lifetime of hens and cocks shows a positive and statistically significant correlation ($r = 0.261$; $p = 0.004$). The reproductive lifetime of hens was significantly affected by agroecology (t = 2.069, df = 116, $p = 0.041$, 95% CI: -0.697, -0.015). Accordingly, in the highland region, the mean and standard deviation of the reproductive lifetime of a hen were 3.178 ± 1.033 years (standard error of the mean = 0.1345), whereas in the lowland region, it was 3.534 ± 0.825 (standard error of the mean = 0.1073).

Similarly, the reproductive lifetime of cocks significantly differed between agroecological zones (t = 2.098, df = 116, p = 0.038, 95% CI: 0.023, 0.807). Unlike hens, the reproductive lifetime of cocks was significantly higher in the highland region. Consequently, in the highland region, the mean reproductive lifetime of a cock was 2.229 ± 1.267 years (standard error of the mean = 0.165), whereas in the lowland it was 1.814 ± 0.84 (standard error of the mean = 0.1094). The result shows that in the lowland region, the respondents were interested in or were able to keep hens productive for a longer time compared to the highland region; quite the opposite, in the highland region, the respondents have kept cocks for a prolonged time than in the lowland region.

Reproductive lifetime laying performance

T-test analysis show that there is no statistically significant difference in the length of an effective reproductive lifetime between agroecological zones (t = 0.588, df = 71, p-value = 0.558, 95% CI: -0.620, 0.337). Similarly, there was no statistically significant difference between agroecological zones in the number of chicks hatched (t = 0.186, df = 70, p-value = 0.853, 95% CI: -10.078, 12.152), and the number of eggs laid (t = 1.226, df = 71, p-value = 0.224, 95% CI: -19.657, 82.458) during the effective reproductive lifetime of hens. However, there was a statistically significant difference between the two agroecologies in the number of hatchings per year (t = 4.180, df = 71, p-value = 8.196e-05, 95% CI: -0.637, -0.225). The analysis of variance shows the statistically trivial effect of sex, education level, and family size of the respondent on the length of effective reproductive lifetime, the frequency of annual hatchings, the number of chicks hatched, and the number of eggs laid during the effective reproductive lifetime ($p > 0.08$).

This study shows that, on average, a hen lays 174.4 eggs and 58 chicks during its average effective reproductive lifetime of 3 years. Therefore, considering only the annual production of eggs in the context of IVCs does not justify their real economic value and leads to an unfair comparison with production breeds. The summary statistics for effective reproductive lifetime production of eggs and chicks are presented in Table 3.

Longevity

Longevity in hens ranged from 2–10 years, with a mean and standard deviation of 4.322 ± 1.334 and a median and mode of 4. Univariate analysis shows that the education level of the respondents has a statistically significant impact on the longevity of hens ($F = 2.892$, df = 3, $p = 0.044$). There is a sort of trend that shows an increase in longevity as literacy levels of the respondents increase. Longevity in cocks ranged from 1–8 years, with a mean and standard deviation of 2.992 ± 1.577, a median of 2.75 and mode of 2. Univariate analysis shows that agroecology has a statistically significant effect on the longevity of cocks (F = 6.450, df = 1, $p = 0.014$). The t-test statistics also substantiate that there is a significant variation in the longevity of cocks between highland and lowland regions (t = 6.617, df = 116, p-value = 0.000, 95% CI: 1.152, 2.136). Accordingly, the mean and standard deviation of the longevity of cocks in the highland region was 3.814 ± 1.714 years with an established standard error of the mean of 0.223, whereas this value was 2.169 ± 0.839 with a standard error of the mean of 0.1092 in the lowland region. This study substantiates that a hen usually lives longer than a cock.

The ideal season for egg production

The dry season (winter) was usually reported as an appropriate time for laying (96.7%); nevertheless, a few of the respondents reported the wet season, that is, summer (0.8%) and summer to autumn (1.7%). The reported reasons for seasonal variation in egg production are presented in Fig. 1. Seasonal variation in egg production has been impacted by a relative abundance of feed (97.5%; multiple responses exist) and hot weather conditions (2.5%). Accordingly, egg production increases during the dry season with better feed stock and hot weather condition.

An ideal season for the rearing of chicks

Most of the respondents (94.1%) reported the dry and warm season (winter) as an appropriate time for brooding chicks, which was then followed by the minor rainy season (spring, 5.0%) and summer (cool and wet season) to autumn (0.8%). Reported reasons regarding the appropriateness of the dry season for chick rearing are summarized in Fig. 2.

Table 3 Effective reproductive lifetime, annual frequency of the laying cycle, and chick production in hens

Trait	Minimum	Maximum	Median	Mean	Std. Dev
Effective reproductive lifetime (years)	1.4	7.5	2.6	2.956	1.016
Laying cycle frequency per year (n)	1	2	2	1.63	0.486
Effective reproductive lifetime chick production (n)	15	146	55	58	23
Effective reproductive lifetime egg production (n)	56	640	148	174.4	109.267

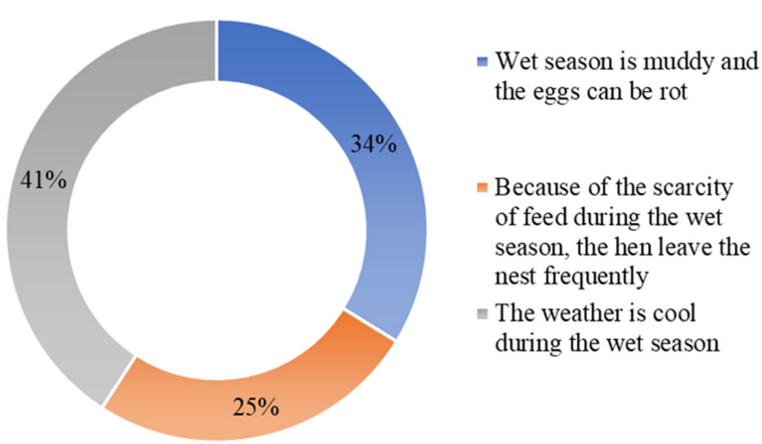

Fig. 1 The reported reasons for seasonal variation in egg production in indigenous village chickens

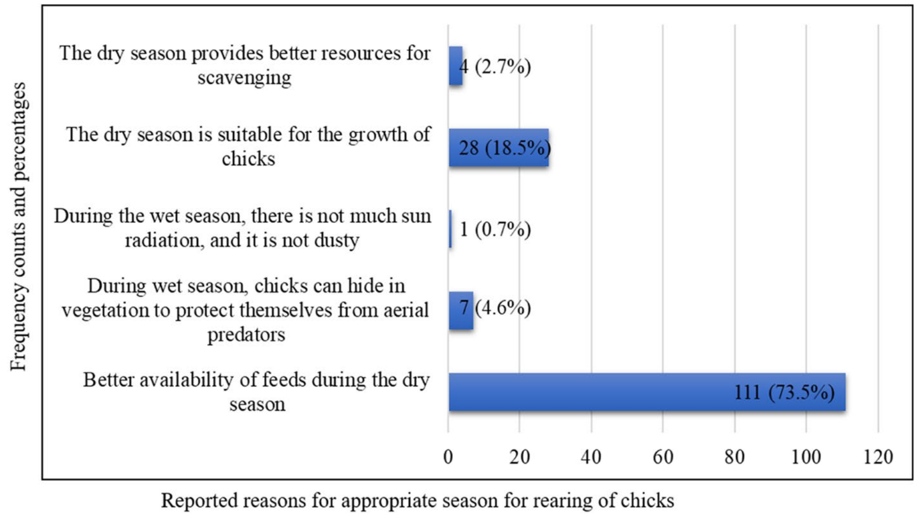

Fig. 2 Reported reasons regarding the appropriateness of the dry season for the rearing of chicks in indigenous village chickens

In contrast, small-scale farmers reported seasons that were less favorable for chick rearing. Accordingly, the wet season (summer) was the least favorable one (89.0%), whereas minor rainy (spring, 7.6%) and dry (winter, 3.4%) seasons were rarely itemized. The reported reasons for the inappropriateness of the wet season for the rearing of chicks are presented in Fig. 3.

Discussion

IVCs exhibit a wide variation in production performance and reproductive characteristics [13]. This variation can be originated from the high intrapopulation genetic variation [14] and disparity in small-scale farmers' nonconventional management practices. Attributed to the high diversity of the agroecology of the tropics, a significant gene-environment interaction exists, which considerably impacts the performance of IVCs. It has been well-established that most of the genetic variation observed in IVCs is captured by within-population variations [14]. This variation is a vital resource for selection forces to act contentedly. With moderately stringent selection intensity, rapid genetic gain can be attained in a population with high genetic variation [5]. However, before embarking on genetic improvement programs, the

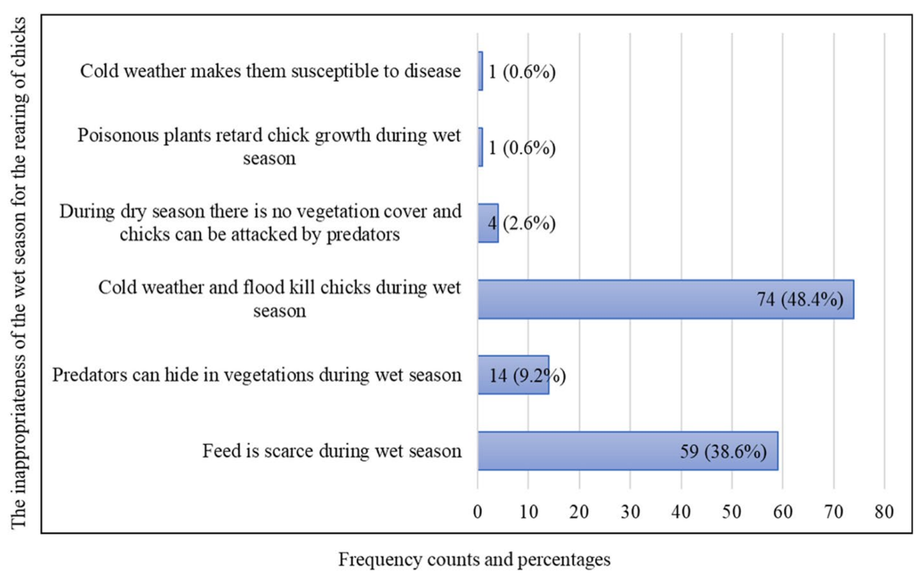

Fig. 3 The reported reasons for the inappropriateness of the wet season for the rearing of chicks in indigenous village chickens

carrying capacity and suitability of the production system need to be meticulously assessed. Small-scale farmers, particularly women, who are very knowledgeable and spend most of their time caring for the family flock around the home, should have their knowledge and wisdom taken into consideration in this evaluation.

This study shows that pullets mature earlier than cockerels. There may be disagreement among findings regarding the difference in age at sexual maturity between the sexes [3]. Sexual maturity is a genetically determined trait, and it is significantly influenced by sex hormones [15]. In this finding, women respondents, despite being few (10.7%), reported a high and less fluctuating value for age at first mating in cocks, whereas male respondents reported wide-ranging values, which might be partly associated with the large number of male respondents. However, despite the low number of female respondents in this study, our finding agrees with contemporary findings [16, 17], which could be associated with the intimacy established between women and the family flock [18]. This disparity may call for male and female disaggregated studies and the need to sample a comparable number of male and female respondents to identify the knowledge gap that entails the social construct of sex groups regarding IVC production [5]. IVCs are reported to be late maturing [19], and this is an adaptive mechanism in IVCs delivering various products and services and that are kept under suboptimal management system. However, this study found earlier sexual maturity, which might be linked to the genetic dilution of local chickens because of the frequent distribution of cockerels and pullets from a commercial poultry multiplication center that is closely located to the study sites.

The number of eggs laid per clutch is well aligned with reports (14 and 15 eggs) [20, 21]. This laying performance shows significant variation among birds, which could serve as a base to increase egg production through selective breeding. This variation also shows that some of the local hens are better at laying, whereas others are persuaded towards traits of maternal instinct. This genetic divergence, though small, could help to develop local chicken populations that are good layers but possess satisfactory maternal instincts and/or those that are good at maternal care but lay an adequate number of eggs to make the best use of the family flock for traits that are virtually unfavorably correlated [22]. The significant loss of rare alleles as it has been scored in production breeds [23] needs to be scrutinized in the genetic improvement program of IVCs.

Unlike production breeds, IVCs are late-maturing [19]; however, they possess long reproductive lifetimes, which could significantly compensate for the few eggs they are laying annually. Therefore, egg production in IVCs needs to be considered for the entire reproductive lifetime, not on an annual basis as in the case of commercial layers. Competing demands, such as selling birds to generate income and slaughtering birds to meet the family's animal protein needs, fulfilling ritual commitments, welcoming honored guests, and losses attributed to predators, diseases, and theft can reduce an IVC's reproductive lifetime. However, there is also a naturally programmed age limit for laying eggs. The lowland region is comparatively drier compared to the highland region; hence, it might be less favorable for pathogens to proliferate; consequently, a low disease burden improves the survival rate of hens. Conversely, cocks are found to have a longer reproductive lifetime in the highland region. This extended longevity in cocks may be linked to fewer chicken deaths attributed to predators in the comparatively sparsely forested but densely populated highland region. Hence, predators disproportionately kill more cocks, with an inherently high preference for roaming in the lowland region with a higher cover of acacia forest and thickets of thorny bushes [24].

Like companion traits, there is a wide variation in the longevity of hens and cocks. Our findings show that as the education level of the respondents' advances, the longevity of hens increases. Enhanced literacy may have enabled small-scale farmers to improve their husbandry practices and provide better care to hens, ultimately improving hen longevity [1]. Roaming around in vegetation free open land in the highland region and relatively high human traffic have reduced the impact of predators' challenges on cocks, which has then made them live longer. Usually, hens live longer than cocks. Nutrition, diseases, and predators could affect longevity. Cocks are aggressive and defensive [25] and always keep themselves alert; therefore, all these physiologically demanding activities cause stress, and subsequently, cocks often have a short lifespan. Nevertheless, overt aggression by cocks is vital for the continued survival of domestic fowl as a species. Poulin [26] suggests that cocks might be more susceptible to parasitic infection compared to hens.

Most of the respondents preferred the dry (hot) season, that is, winter, for laying eggs and rearing chicks. The dry season is characterized by a low incidence of disease; hens do not expend much energy to maintain body temperature and warm their chicks, and chicks better survive during the dry season [27]. Although IVCs are not seasonal breeders, plenty of sunlight during the dry season may improve their laying performance. Presumably, there is high market demand for eggs during the crop harvesting (dry) season. For example, farmers usually buy eggs for family consumption using the income generated from the sale of surplus grains and crop by-products during the crop harvesting (dry) season. Therefore, farmers need to produce more eggs to satisfy the augmented seasonal demand.

Conclusion

Our study corroborates the high intrapopulation variation in egg production and reproductive characteristics of IVCs. This high phenotypic variation in reproductive characteristics is an important resource for the genetic improvement of IVCs. Seasonally-induced variation in the eggs production and rearing of chicks calls for interventions that consider the impact of the season on the family flock performance. Considerable knowledge and skill gaps were observed between male and female respondents in IVC production, which calls for a gender-disaggregated study and the need to sample a comparable number of male and female respondents. Regardless of the small proportion of female respondents, this gender-wise disparity shows the indispensable role of women in improving the performance and resilience of the scavenging chicken production system. Gender disparity in IVCs production knowledge base could be narrowed down by enhancing the formal education of farmers. Moreover, season wise difference in egg production and reproductive characteristics need to be thoroughly studied to develop season-sensitive interventions and to assess season by agroecology interaction effects.

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Authors' contributions
TTD and OW collected the data; TTD analyzed the data and wrote the manuscript. OW significantly contributed to the improvement of the manuscript.

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Availability of data and materials
The data could be available from the corresponding author upon reasonable request.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The involvement in his study was strictly voluntary, and all information gathered from the respondents is kept confidential and only used for research purposes.
Informed verbal consent was obtained from all the respondents.

Consent for publication
The authors fully agreed to publish the manuscript.

Competing interests
The authors declare no competing interests.

Author details
[1]Wolaita Sodo Agricultural, Technical, Vocational, Education and Training College, Wolaita Sodo, Ethiopia. [2]Present address: Department of Biology, College of Science and Mathematics Education, Kotebe University of Education, Addis Ababa, Ethiopia. [3]College of Agriculture and Environmental Science, Arsi University, Asela, Ethiopia.

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