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Genetic Diversity of Ethiopian Indigenous Chickens a Base for Sustainable Genetic Improvement: A Review

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ABSTRACT

The estimated chicken population of Ethiopia is about 57 million, of which 78.8% are indigenous characterized by low egg production, late maturing and long brooding behavior but celebrated for their hardiness, exceptional scavenging abilities and robust natural immunity against common diseases. The objective of this paper was to review the genetic diversity and improvement interventions of indigenous chicken populations. The review process was started by collecting research articles that were done on genetic diversity and chicken genetic improvement strategies by searching tools such as Google Scholar, PubMed and Web of Science with search terms genetic diversity, genetic characterization and chicken genetic improvement. Lastly, we organized ideas and the write-up was done. Indigenous chicken shows high genetic diversity within the population. The indigenous chickens have high number of alleles (6.25), an effective number of alleles (4.85), observed (55%) and expected (57%) heterozygosity and 90% within-population variation which is considerable variation as unselected African native chickens. Higher heterozygosity levels and considerable genetic variation warranted a further use of ecotypes in improvement through selective breeding. Genetic marker studies showed positive selection signatures of improved from unimproved local chickens. Selective breeding done on Horro chicken breed in Ethiopia saw a remarkable 107.7% and 176.4% improvement in body weight egg number. Uncontrolled dissemination and indiscriminate crossbreeding resulted in the erosion of adaptive local genetic resources. Therefore, improving and conserving indigenous chicken with selective breeding combined with molecular techniques and further studies on the genetic control of productivity traits are very crucial.

Key words: Chicken, Diversity, Genetic improvement.

The indigenous chicken is one of the most important animal species worldwide since it provides a higher proportion of animal protein in the human diet (Okumu *et al.,* 2017). In excess of 2 billion chickens are found in Africa today, producing approximately 2.4 and 5.7 million metric tons of eggs and meat, respectively, of which 80% are from indigenous stocks (Larus, 2022). Indigenous chickens are also kept for income and socio-cultural roles in the continent. Moreover, indigenous chickens are usually preferred over exotic chickens due to their pigmentation, taste, flavor and its adaptation to harsh environments. The estimated chicken population of Ethiopia is about 57 million (2.85% of chicken population of Africa) of which 78.85% were indigenous chicken (CSA, 2021) which have a great contribution to egg and meat production in the country. Ethiopian Indigenous chickens are endowed with high genetic variation and high local adaptation ability, which forms the basis of selective breeding and genetic improvement strategies through prioritizing and making informed decisions (Desta, 2015; Lawal *et al.,* 2018). Their diverse and unique genes will enable the indigenous chickens to have their niche, particularly under a semi-scavenging production system (Esatu *et al.,* 2022). Even though indigenous chickens have been naturally selected for their adaptive traits, are often poor in egg and meat production performance (Aberra, 2014). As a result, to improve the productivity of the poultry sector in Ethiopia, various organizations have imported and disseminated many exotic chicken breeds to rural farmers and urban-based poultry producers.

The imported Commercial breeds were productive under intensive management. However, the dissemination of pure exotic chickens in village production systems has

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failed (Wondmeneh, 2015), because commercial chicken breeds were developed for intensive management systems and are often unsuited to local conditions, requiring a high level of investment in feed, veterinary support and management (Birhan *et al.,* 2021). Wondmeneh (2015) also indicated that indiscriminate random mating among indigenous chicken and unplanned crossbreeding with exotic breeds can lead to a high inbreeding rate and genetic dilution. Rahsan and Atilla (2016) stated that the genetic diversity of local chicken populations is being lost due to substitution of local chicken populations by commercial populations. Alternatively, Yonas (2020) suggested, improving the local chicken through selective breeding is preferable and then improved breeds are best for crossbreeding with non-adaptive exotic breeds. Therefore, besides importation and dissemination of commercial breeds designing and implementing indigenous chicken selective breeding program could be the best alternative to improve and conserve local chicken for village chicken production system. The improved breeds developed through selective breeding are used for synthetic breed formation through reciprocal crossing. Moreover, adebabay (2018) revealed that Ethiopian indigenous chickens are diverse that have a greater advantage in developing sustainable breed improvement strategies through selection. Currently, the issue of chicken genetic resources conservation is also a hotspot topic for Ethiopia, a country facing with major agricultural productivity challenges (Adebabay, 2018). Apple information on phenotypic and genetic characterization of chicken breeds is important to conserve, reveal and exploit its genetic potential. As a result, previously, genetic diversity studies using molecular markers were conducted in different chicken populations of Ethiopia, these are Alemayehu *et al.* (2003); Hassen (2009); Wragg *et al.* (2012); Bekire (2015) and Adebabay (2018). Efficient maintenance of genetic diversity and improvement requires the understanding of the genetic diversity and its distribution among populations of interest. Therefore, the objective of this paper was to review the genetic diversity and improvement interventions of indigenous chicken populations of Ethiopia to be a base for indigenous chicken genetic improvement programs.

Methods of review

The title was initiated since understanding genetic diversity and genetic merit of chicken is important to designing conservation and improvement strategies for diverse production environments and purposes to meet the growing worldwide demands for animal source proteins. The review process was started by collecting research articles that were done on genetic diversity studies conducted on Ethiopian indigenous chicken and the past genetic improvement strategies and its achievements on overall productivity of village chicken by searching tools such as Google Scholar, PubMed and Web of Science with search terms genetic diversity, Ethiopian indigenous chicken, chicken genetic improvement and genetic characterization of indigenous chicken. Then, after a screening of related and appropriate articles from different journal sites were downloaded and stored in the endnote library. Similar articles or duplicated articles were removed. Lastly, we organized ideas and the write-up was done.

Chicken genetic diversity and past improvement interventions

Genetic diversity

Understanding the current genetic diversity and beneficial traits of adaptation and production in indigenous breeds had an important role in order to meet the growing worldwide demands for animal source proteins (Tesfa *et al.,* 2024). Genetic diversity studies of livestock species are essential to know their genetic merit and then designing conservation and improvement strategies for diverse production environments and purposes (Malomane *et al.,* 2019). The indigenous chicken is an ample reservoir of the chicken genome and essential for improving and conserving the vast gene pool they represent (Ajayi, 2010). Indigenous chickens in developing countries are more genetically diverse than commercial breeds and their genetic structure can be used to conserve genetic variability (Adebabay, 2018). Therefore, the improvement and conservation of local chicken breeds are vital to meet future unforeseen breeding demands (Khanyile *et al.,* 2015). Indigenous chickens in Ethiopia have high genetic variation and local adaptation ability which is the basis for genetic improvement through selective breeding (Desta, 2015; Lawal *et al.,* 2018; Aberra *et al.,* 2021).

The main aim of genetic diversity studies on indigenous chickens is to examine allelic variability, genetic diversity, genetic relationships and differentiations across different regions using various molecular markers (Malomane *et al.,* 2021; Lawal and Hanotte, 2021). Since indigenous chickens are not selected for performance traits as result, high genetic diversity is expected (Zemelak *et al.,* 2011). Genetic diversity studies have been undertaken in indigenous chicken populations of Ethiopia. However, considering the diversity and wide land size of the country, the studies are not representative in terms of sample size and physical coverage. Among genetic diversity estimators, observed heterozygosity (N=7), the mean number of alleles (N=7) and polymorphic information (N=4) are most studied in diversity estimator studies in indigenous chicken populations of Ethiopia.

Allele variability

Allelic variability is one of the estimators used to measure genetic diversity with key relevance in genetic conservation programs (Toro *et al.,* 2014). The mean number of alleles (MNA) observed over a range of loci for different populations are a reasonable indicator of genetic variation. Breeds with a low mean number of alleles have a low genetic variation which might be due to factors like-genetic isolation, historical population bottlenecks, or founder effects and a high mean number of alleles imply great allelic diversity

which could have been influenced by admixture. The other estimators of allelic variability are the effective number of alleles (ENA) and allelic richness (Ar) (Allendorf *et al.,* 2010). ENA denotes the number of equally frequent alleles it would take to achieve a given level of gene diversity. It allows for comparing populations where the number and distribution of alleles differ drastically.

A study conducted by Adebabay (2018) on 27 distinct indigenous chicken populations of Ethiopia revealed that there is a very high genetic diversity within all Ethiopian indigenous chicken populations at LEI0258. The Indigenous chicken population in Ethiopia has had a mean number of alleles and the effective number of alleles of 9.45 and 7.04, respectively (Adebabay, 2018). Ethiopia's indigenous chicken populations have a comparable number of alleles to the indigenous populations of Rwanda (Richard *et al.,* 2020). Another study conducted in different locations of Ethiopia (Mehurena, Mehal Amba, Dawa and seden Sodo) has 4.8 mean numbers of alleles (Bekire *et al.,* 2015). Another study conducted on six chicken populations using 10-microsatellte markers revealed that the indigenous chicken population of Ethiopia has 4.7 with a minimum and maximum value of 2 and 7, respectively (Alemayhu, 2003). Hassen *et al.* (2009) also reported a 6.05 mean number of alleles for the village chickens of western Amhara.

The meta-analysis result indicates that the Ethiopia chicken populations have 6.25 mean numbers of alleles (Table 1). Similar results were reported by Lyimo *et al.* (2013) in which the mean number of alleles ranged from 5.1 to 6.28 in the Tanzanian population. Mtileni *et al.* (2010) also reported a mean number of alleles per locus ranging from 3.52 to 6.62 among South African chickens. A similar number of alleles were observed in other free-ranging chickens reported by Muchadeyi *et al.* (2007) in Zimbabwean, Malawian and Sudanese chicken populations. However, a lower mean number of alleles in the Kenyan population were reported by (Okumu *et al.,* 2017) with an average number of alleles across all loci in all eight populations being 1.961 and a higher number of alleles was reported by Richard *et al.* (2020) with a mean number of 10.89 for Rwanda chicken populations. The lower MNA in the Kenyan populations shows the presence of a relatively limited sample of the gene pool and therefore there is a lower gene flow in the Kenyan populations (Okumu *et al.,* 2017).

Heterozygosity

The average expected heterozygosity (He) also called Nei's gene diversity; defined by Nei (1986) at n loci within a population; is the best general measure of genetic diversity within a population (Allendorf and Luikart, 2007). High heterozygosity values for a breed may be due to long-term natural selection for adaptation, to the mixed nature of the breeds, or the historic mixing of strains of different populations. A low level of heterozygosity may be due to isolation with the subsequent loss of unexploited genetic potential. A study conducted using microsatellite markers for four indigenous chicken ecotypes (Seden, Dawo, Amba and Aklie) indicated that the mean observed heterozygosity (Ho) and expected heterozygosity (He) values of 0.53 and 0.57 respectively (Bekerie, 2015). Higher observed heterozygosity (Ho) and expected heterozygosity (He) are reported by Adebabay (2018), 0.82 and 0.84, respectively. While lower observed heterozygosity (Ho) was reported by Wragg *et al.* (2012) in five chicken Ethiopian populations (Gondar, Konso, Gumuz, Sheka and Horro Guduro). Higher heterozygosity levels and exhibited considerable genetic distance warranted a further use of ecotypes in selection but also crossbreeding designed to create genetic stocks with improved productivity. Likewise, Hassen *et al.* (2009) studied indigenous chicken populations from seven different areas of northwest Ethiopia, three South African and RIR genotypes using microsatellite markers to determine genetic diversity. As a result, high genetic diversity was found in overall loci for all populations with observed heterozygosity (Ho) value of 0.77 and the RIR breed had a higher genetic distance with the Ethiopian chicken populations than South African breeds.

Indigenous chicken populations are rich in adaptive genes than commercial breeds (Aberra *et al.,* 2011). A study conducted on 27 indigenous chicken populations of Ethiopia confirmed that high diversity at microsatellite LEI0258 loci for the MHC region is associated with the disease challenges faced by indigenous chickens across various agro-ecologies of the country (Adebabay, 2018). Similarly, genomic regions have positive selection information associated with altitude-induced stresses, water shortage and the challenge of scavenging behavior (Gheyas *et al.,* 2021).

Ethiopian Indigenous chicken population shows 55% and 57% of observed and expected heterozygosity (Table 1) which is slightly lower than Rwanda chicken populations which have 61.6% and 68.8% of observed and expected

Table 1: Reported genetic parameter values on the indigenous chicken of Ethiopia across studies.

Estimators	Number of observations	Mean	Standard deviation	Minimum	Maximum
Mean number of alleles	7	6.25	2.2	4.7	9.45
Effective number of alleles	2	4.85	1.65	2.53	6.35
Private alleles	3	2.96	0.65	2.0	3.75
Observed heterozygosity	7	0.55	0.21	0.27	0.8
Expected heterozygosity	3	0.57	0.15	0.57	0.85
Polymorphic information	4	0.57	0.12	0.51	0.7

heterozygosity, respectively, (Richard *et al.,* 2020). Similarly, the observed heterozygosity level of the Indigenous chicken population of Ethiopia is higher than village chicken of Kenya which is 33% (Wragg *et al.,* 2012). Mtileni *et al.* (2010) reported expected heterozygosity of 67 to 69% among South African free-range chickens. Lyimo *et al.* (2013) reported expected heterozygosity values of 58 to 67% in the Tanzanian populations. These differences in heterozygosity values may be attributed to variations in geographical location, chicken types, sample sizes, laboratory and sources of microsatellites used. The lower expected heterozygosity in the Kenyan population was reported with the expected heterozygosity ranging from 35.1 to 43.4% (Okumu *et al.,* 2017). An expected heterozygosity value of less than 0.5 may also be due to inbreeding and admixture as this occurrence is associated with population constraints and bottlenecks (Fariba, 2016).

Genetic distances and clustering of the indigenous chicken ecotype

Estimates of the genetic distance clearly indicate that the main source of genetic diversity between the studied local chicken ecotypes of individual variations. Genetic variation within the indigenous chicken populations of Ethiopia is 89% (Adebabay, 2018), 92% (Bekire, 2015) and 99.7% (Alemayehu, 2003). The observed patterns in genetic diversity where there is high variation within populations than among populations may be due to a high rate of genetic recombination within populations and a relatively high degree of gene flow between them, preventing genetic differentiation. A study conducted in 27 indigenous chicken populations of Ethiopia shows us the presence of six potential clusters of populations, with PC1 and PC2 jointly explaining 41.4% of the total genetic variance (Fig 1). While PC1 (25.95%) separates Improved Horro from the rest of the non-improved chicken populations. Jarso and Hugub populations were separated from Improved Horro and other populations by PC2 (15.45%). The remaining populations are placed quite close to each other in the PCA plot, although they could be separated into three more clusters (Adebabay, 2018). However, Bekrie *et al.* (2015) reported that Ethiopian ecotypes formed one large cluster and within this cluster, it seems that there are two sub-clusters. The chicken populations from Northwest Ethiopia to group into two major categories (Gojam and Gonder) with distributions running generally consistent with their geographical locations and marketing places (Hassen, 2009). This indicates that the proximity of the majority of the populations often reflected their geographic proximity. The clustering of these populations follows the geographical pattern which they are sampled from. Even though the genetic distance between the different ecotypes is moderate different ecotypes form branches of different bootstrapping values. The fact that the populations were assorted according to their geographical origin and the presence of distinct alleles in specific populations support the reliability of the results and the evidence that ecotypes are genetically distinct (Alemayehu, 2003).

The observed patterns in genetic diversity where there is high variation within populations than among populations may be due to a high rate of genetic recombination within populations and a relatively high degree of gene flow

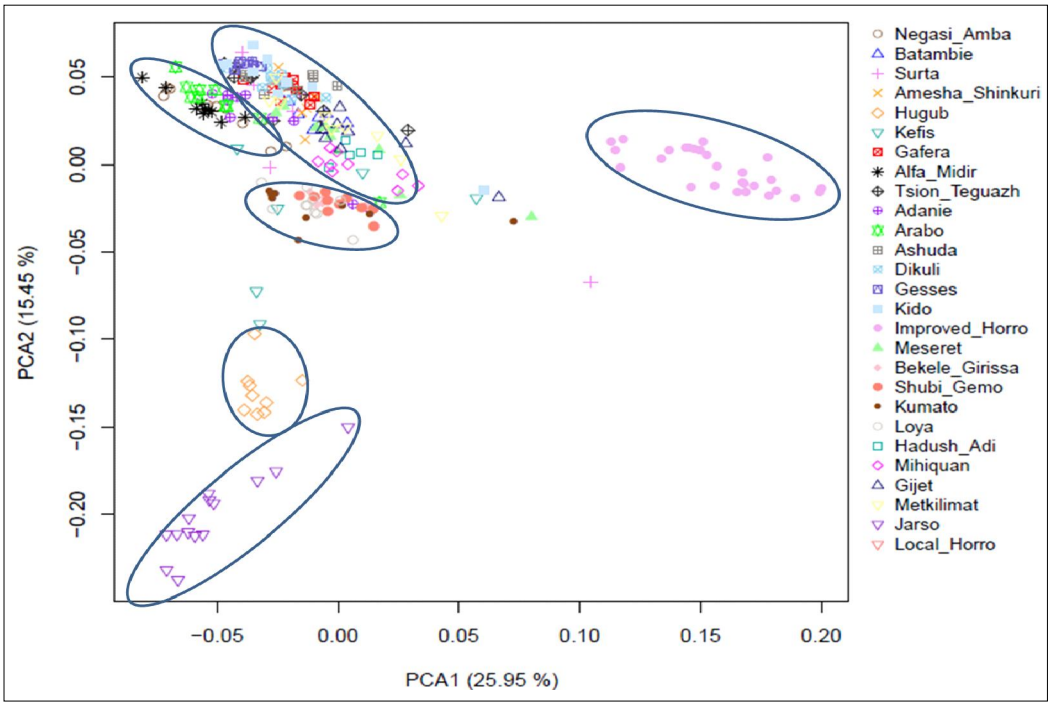


Fig 1: Principal component analysis plot on 27 indigenous chicken populations of Ethiopia (Adebabay, 2018).

between them, preventing genetic differentiation (Bekrie *et al.,* 2015). According to Bekrie *et al.* (2015) the genetic distance among the indigenous chicken ecotypes of Ethiopia is 0.034 to 0.074 which is lower than the values reported by Alemayehu (2003), there is a considerable genetic distance between the local ecotypes from Fayomi breed and Swedish chicken population. The highest mean genetic distance (d = 0.94) was between Alfa Midir and Batambe followed by the former and Gafera (d = 0.90) populations (Adebabay, 2018). According to Alemayehu (2003) Fayoumi fowls had the largest genetic distance to all local chicken ecotypes; Jarso ecotype (0.35) followed by Chefe ecotype (0.336) were the most distant ecotypes from the Fayoumi breed and the smallest genetic distance to the reference breed was identified for the Tilili ecotype (0.251). Similarly, the results of this study showed the presence of considerable genetic distance between Tepi and Chefe ecotypes, Tepi and Jarso ecotypes, Tilili and Jarso ecotypes and Horro and Jarso ecotypes.

Attempts of genetic improvement of indigenous chicken in Ethiopia

Crossbreeding

Genetic improvement in egg production, egg weight, age at sexual maturity and body weights are important breeding goals for commercial chicken layers (Chandan *et al.,* 2019). Previous studies indicate that indigenous chicken produces 30-60 eggs per year under farmers management condition which is very low as compared to commercial breeds which 325 eggs per year (Hailu *et al.,* 2019). To upgrade the productivity of village chicken production, governmental and non-governmental organizations were imported exotic chicken breeds for cross-breeding purpose. Moreover, research centers, higher learning institutes and private commercial farms introduced different breeds at different years. Even though the introduced breeds are effective under intensive management, they were not performed as expected in the village production system (Wondmeneh, 2015), because commercial chicken breeds were developed for intensive management systems and are often unsuited to local conditions, requiring a high level of investment in feed, veterinary support and management (Birhan *et al.,* 2021).

Cross breeding of chicken between exotic males and local females resulted hybrid chickens that are average in production performance and adaptive to village chicken production system (Yonas, 2020). Past attempts have had shown had shown a positive impact of crossbreeding interims of egg production and growth and the cross breeds have higher performance as compared to local chickens (Sola-Ojo and Ayorinde, 2011; Habte *et al.,* 2013; Alem, 2014). In Ethiopia, Rhode Island Red (RIR) is the most common commercial breed used to get dual-purpose chickens by crossing with indigenous chickens (Berhanu *et al.,* 2010; Khawaja *et al.,* 2012). The crossbred hens can produce up to 200 eggs/hen/year and reach more than 2.0 kg live-weight at 10-20 weeks of age under farmers' management conditions (Alem, 2012; Tadelle and Wondmeneh, 2017, Chencha Chebo *et al.,* 2022). Crossbred of RIR with local chickens in West Shoa Zone resulted in higher laying %, egg weight (hybrids 50.23 g and locals 42.76 g); clutch size (hybrids 22.17 and locals 14.23 eggs) under on-farm conditions (Negawo, 2007).

Selective breeding

Selection is a powerful means to increase body weight and rate of gain (Pandian *et al*., 2022). The sustainable chicken breeding program should not only depend on the importation of commercial breeds; rather improvement of indigenous chicken through selective breeding can better fulfill the target for low input and tropical systems (Adebabay, 2018). Thus, alternative approaches to improve performance and conserve the local chickens through selective breeding were launched; Horro chicken selective breeding was initiated in 2008 at Debere zyiet Agricultural research center (Nigussie *et al.,* 2011) and Tilili chicken selective breeding was initiated 2021 at Andassa livestock research center (Wondmeneh *et al.,* 2022) with the objective to improve local chicken productivity through selective breeding for higher productivity and adaptive capacity. The initial breeding goal of the ongoing breeding program was to genetically improve the indigenous chickens for egg production and growth traits without losing their ability to adapt to harsh environments (Nigussie, 2011; Wondmeneh 2015, Wondmeneh *et al.,* 2022). The mean body weight of the day-old Base population of Tilili chicken was 30.4 gram with high variation between the smallest and highest birds (Wondmeneh *et al.,* 2022). The male body weight of selection candidates at the time of selection decision at week 16 was 1100 grams. This body weight was higher than the mean body weight of the base population of Horro chicken at the beginning of the improvement program (Chencha Chebo *et al.,* 2022). The hens of the base population of Tilili chicken produce 39 eggs per 17 weeks under intensive management (Wondmeneh *et al.,* 2022) which is higher than the base population of horro hen (34 eggs per 24 weeks).

Through selective breeding, Improved Horro chicken has again increased average body weight at age of 16 weeks by about 74%, increased egg production by 124% (75 eggs) by week 45 and age at first egg reduced from 203 to 148 d by five generations of selection (Wondmeneh, 2015). Chick survival rate has also improved from less than 50% in the first generation to 98% in the seventh generation. Horro breed is at its 10th generation (Hussen *et al.,* 2020) had shown huge performance improvement than from its based population (Nigussie, 2011) as well as from the 7th generation (Wondmeneh, 2015). A series of evaluation results of Horro breed showed that selective breeding is successful for bodyweight, egg-laying and chick survival traits of local Horro (Getachew *et al.,* 2016; Wondmeneh *et al.,* 2016; Wondmeneh and Tadelle, 2019; Hussen *et al.,* 2020). Similarly, after three generation of

selection Tilili chicken has increased average body weight at 16 weeks of age about 68.1% and increased 24 weeks cumulative egg number after the onset of egg lay by 111.5% (Birhan *et al.,* 2024).

Constraints of genetic improvement interventions

Regardless of few success stories, the importation of commercial chicken breeds has resulted a reduction in the indigenous chicken population (35.4%), genetic dilution of indigenous chickens (18.8%) and happening of higher cannibalism behavior (13.8%) under traditional production systems (Tadelle *et al.,* 2020). Different scholars reported that there was no systematic and planned breeding of the chicken in Ethiopia (Adebabay 2018; Berhanu *et al.* 2020). This leads to the occurrence of inbreeding and loss of reproduction traits related to the vigour and fertility of indigenous chickens (Nega *et al.,* 2016). Moreover, exotic chickens are easily attacked by predators, highly sensitive to feed changes and have poor adaptive ability to harsh environments (Matawork, 2016). The other challenge under very small chicken flock size in the free scavenging system was the high probability of inbreeding. For instance, Berhanu *et al.* (2020) reported inbreeding coefficients of the local chickens ranged from 7% to 12.8% for different agro-ecologies of Ethiopia (Chencha Chebo *et al.,* 2022). According to Yonas (2020) currently, unplanned introduction, dissemination of exotic chickens and breeding the major burdens of indigenous chicken genetic erosion. This unplanned dissemination breeding also results low performance of exotic breeds under village chicken production systems (Tilahun *et al.,* 2017).

CONCLUSION

Overall, the past genetic improvement through introduction of exotic chicken resulted erosion of indigenous chicken genetic resources. The molecular studies conducted on in the Ethiopian chicken populations' are inconsistencies in describing the ecotype clustering across studies and some populations are done repeatedly while others are very limited. Most of selection signature studies focus on the diversity of genetic control of adaptive and disease challenge traits. Genetic diversity studies indicated that Indigenous chicken ecotypes of Ethiopia possess a greater genetic variation within populations, which gives an opportunity for within ecotype improvement through selective breeding. Even though, the ongoing selective breeding programs takes a long generation to show an impact, it give an insight that local chicken can be improved through selective breeding and they are a good genetic resource for further research and developments. Therefore, future research should focus on the diversity of the genetic control of growth and egg production traits to assess directly the potential of the indigenous chicken population for these traits and to map candidate genes and genomic regions associated with egg and meat production to maximize their long term sustainability.

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Disclaimers

The concept and conclusions explained in this article are solely those of the authors and do not entirely designate the views of their respected institutions. The authors are also responsible for the accuracy and comprehensiveness of the information provided.

Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal Care and Handling Techniques were not applicable for this review article.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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