REVIEW

REVISED Strategies for promoting sustainable use and conservation of indigenous chicken breeds in Sub-Saharan Africa: Lessons from low-income countries [version 6; peer review: 1 approved with reservations, 1 not approved]

Previously titled: Strategies of promoting sustainable use and conservation of indigenous chicken breeds in Zambia: lessons from low-income countries

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Abstract

This review explores innovative and sustainable strategies for the utilization and conservation of indigenous chickens (IC) (Gallus domesticus) in Sub-Saharan Africa (SSA), drawing lessons from selected low-income countries. Small-scale farmers (SSF) have kept IC for hundreds of years to meet their households' nutritional needs, incomes, and social-cultural and religious uses. The commitment exhibited by SSF to keeping IC has made them the significant custodians of essential animal genetic resources AnGR in most low-income countries. Between 1991 and 2012, Zambia's private breeders invested over US$95 million in the commercial poultry sector, resulting in over a 100% increase in the annual production of day-old chicks to 65 million. However, high production costs and low market access hindered rural farmers' full participation, hence their continued dependence on IC breeds. The erosion of AnGR poses the biggest

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threat to IC in SSA. The Food and Agriculture Organisation, an international body of the United Nations, highlighted that over 3.5% (60) of chicken breeds were extinct, 21.3% (368) were at risk of extinction, and nearly 67% (1068) were under unknown risk status. The report stated that 12.3% of the known chicken breeds were not at risk. Poultry diseases, lack of sustainable conservation strategies and poor use have significantly contributed to these losses. In 2012, 60% of IC were reportedly diseased in parts of SSA. The continued loss of IC-AnGR may negatively impact rural livelihoods and impede future poultry research and breeding programs. This paper reviews the IC sector in SSA, the socioeconomic, cultural and religious roles of IC and lessons on researcher-community-stakeholder strategies from selected low-income countries. The paper concludes and outlines some recommendations for future research.

Keywords
Animal genetic resource, biodiversity, conservation, rural-community, small-scale farmer, poultry-sector

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Any reports and responses or comments on the article can be found at the end of the article.

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REVISED **Amendments from Version 5**

We made minor changes to version 5 to create version 6 of the review paper titled: Strategies for promoting sustainable use and conservation of indigenous chicken breeds in Sub-Saharan Africa: Lessons from low-income countries. Overall, minor changes were made to improve the quality, consistency, and readability of the review paper. The changes are:

1. Minor grammatical corrections in the conclusion sentences of the abstract.
2. Introduced the acronym (AER) for Agro-Ecological Region in the first paragraph of the introduction. This was done to maintain consistency with the subsequent papers we wrote or submitted to other journals based on 2021 Qualtrics survey data for 358 households in (AER I, II, and III), analysis of poultry market data from the Poultry Association of Zambia's website (express permission was granted), and short-term market interventions through Researcher-community-stakeholder engagements for Small-Scale Farmers producing indigenous chickens in Petauke district in Zambia.
3. Corrected the intext citation for (Alders and Pym, 2019) to (Alders and Pym, 2009). In the same context, we inserted an appropriate year of publication to reference number 5.
4. Reference number 45 on the list was replaced with an appropriate reference as shown in the tracked changes.
5. If there are questions arising from version 6, contact the corresponding author at ckanyama@myune.edu.au

Any further responses from the reviewers can be found at the end of the article

Introduction

Many countries in Sub-Saharan Africa (SSA) experience varying and distinct agroecological conditions. The region's diverse climate affects individual countries in a variety of ways. In this scenario, Zambia is not exceptional. The country has a total surface area of 752,618 square kilometres (75.3 million hectares), divided into three distinct Agro-Ecological Regions (AER) (I, II, and III), each with unique agricultural challenges concerning annual rainfall, vegetation, annual temperatures, soil type, and water resources. AER I and II occupy 54% of the total national land, mainly in Zambia's Southern, Western, Central, and Eastern parts (Phiri and Mukelabai 2010). Regions I and II average annual rainfall is between 800 mm and 1000 mm. In contrast, AER III, primarily in the Northern and North-western, also classified as a high rainfall zone, covers 46% of the national area, and receives more than 1000 mm of annual rainfall. Despite this climate variability across the country, and over 40% of fresh groundwater in Southern Africa being in Zambia, 90% of small-scale farmers (SSF) practice rain-fed agriculture (Hamududu and Ngoma 2019).

Climate-related problems experienced in agriculture may worsen by the next century. Some studies predict that by the end of the twenty-first century, there will be a three degrees Celsius increase in global temperature, a 0.6% reduction in annual rainfall, and a 13% reduction in available groundwater due to climate change (Pelletier and Tyedmers 2010; Hamududu and Ngoma 2019). The drastic climate variation will have more adverse effects in low-income countries, especially in SSA. Therefore, small livestock, such as goats, sheep, and indigenous chickens (IC) (Gallus domesticus), generally considered low-input enterprises, will be essential and expected to contribute substantially to improving livelihoods among rural communities (Simainga et al. 2011; Queenan et al. 2016). The significant contribution of IC may surpass that of broilers and layers because fewer SSF keep them in Zambia. Most of them have kept IC because of the low but stable performance under the free-range system (Bagopi et al. 2014; PAZ 2021). The low costs, easiness of rearing, profitability, favourable prices, and higher sustainability are some of the factors that have motivated more SSF to produce IC (Okeno et al. 2013; Bett et al. 2013).

Guèye (1998, 2000) highlighted that IC, which comprises the majority of rural poultry farming in SSA, have been kept by SSF for hundreds of years to meet their food and nutritional security, household incomes, poverty reduction, and empowerment of women and children. Some researchers have also documented more significant contributions of IC to farmers' adaptation and resilience to climate variations compared to larger livestock species, such as cattle, which demand more grazing land and water resources (Yayneshet and Treydte 2015). Studies conducted in various parts of SSA have identified the main motivations of easiness and negligible start-up capital for IC, especially under scavenging systems (Okeno et al. 2013). Some studies have considered IC an entry point to poverty reduction, as farmers could start with one chicken and realize significant benefits quickly (Bett et al. 2013; Dolberg 2007; Guèye 2000; Queenan et al. 2016).

Despite these critical roles of IC, rural communities have not achieved the full socioeconomic potential of producing these chickens. Loss of IC breeds, poultry diseases, poor nutrition, unsupportive policies, and low access to markets are partly the causes of the current status of the indigenous chicken sector (IC sector) in SSA. One of the strategies to mitigate the challenges in the IC sector is to exploit sustainable interventions generated through researcher-community-stakeholder engagements. This approach enables researchers to share information with the rural communities and stakeholders on the benefits of the desired community-based interventions (Rodríguez et al. 2011). Several innovations targeting rural

communities aimed at promoting sustainable utilization and conservation of animal genetic resources for food and agriculture (AnGR) by identifying challenges and exploring opportunities have resulted in increased adoption, enhanced adaptation, and socioeconomic gains among rural communities (Dumas et al. 2017; Mueller et al. 2015; Rodríguez et al. 2011).

This paper highlights the roles of IC, the main challenges faced by small-scale producers, available growth opportunities, and feasible strategies to mitigate the loss of IC-AnGR and its impact on rural communities in SSA. Further, we provide examples of researcher-community-stakeholder engagements. Highlights of other indigenous livestock illustrate the effectiveness and challenges of community-based intervention tools. Examples of other livestock suggest that community-based strategy promotes sustainable use and conservation of indigenous AnGR and improves rural livelihoods in low-income countries. In this paper, the definition of indigenous or native chickens is according to the Food and Agriculture Organisation (FAO), an international body of the United Nations. According to FAO, IC are found in locations where they have evolved for thousands of years (FAO 2015). These chickens are typically reared under low-input and low-output free-range system without improved feeds or housing (FAO 2015; Ochieng et al. 2013). This paper reports prices for chickens and other commodities in United States dollars (USD).

Importance of poultry in agriculture for Sub-Saharan Africa

Agriculture is the primary solution to global challenges such as increased cost of living, population growth, poverty, and inequality. Most studies have demonstrated that agriculture provides employment, food and nutritional security, livelihood assets, and gender equality among rural communities, potentially countering the highlighted concerns (Guèye 2000; Dolberg 2007; Boland et al. 2013). The World Bank indicated agriculture's 3-4% contribution to the global Gross Domestic Product (GDP) in 2020 (World Bank 2021). However, in certain countries, agriculture contributes a significant proportion to GDP. In low-income countries, up to 40-60% of the GDP comes from agriculture, employing nearly 1.3 billion inhabitants (Boland et al. 2013; FAO 2021). In 2020, agriculture added over 17% to the GDP for SSA (FAO 2021). A majority of SSF in low-income countries consider agriculture as a full-time occupation. Rural farmers in SSA have grown different crops for generations and kept IC for their livelihoods (Guèye 1998, 2000). In Zambia, the socioeconomic contributions of agriculture are equally evident, especially among rural communities. According to the Ministry of Fisheries and Livestock (MFL), up to 18% of Zambia's GDP is from agriculture, supporting over 12 million people and absorbing over 67% of the labour force (MFL 2017). However, in 2020, Zambia recorded a 3.4% value added to GDP by agriculture (FAO 2021). As we head towards the year 2050, agriculture will be crucial for job creation and meeting SSA's food and nutritional demands (Klingholz 2020).

Small livestock, such as chickens, will be critical in agriculture, especially for low-income countries. The Food and Agriculture Organisation classifies chickens in the top five crucial animal species, with the other four being cattle, sheep, goats, and pigs (FAO 2015). This international body has made it mandatory for countries to prioritize submitting biodiversity status reports for these farm animal species because they create opportunities for household incomes, food security, and employment across the globe. Among the poultry species, IC have the highest population and importance among rural communities due to the low production costs and their ability to thrive under harsh conditions (Ajayi 2010; Bett et al. 2013; FAO 2015). Although rural farmers practice low-input production systems, there are variations in environmental conditions across SSA and within countries depending on the farmers' socioeconomic status (Guèye 1998, 2000). Thus far, studies have revealed the socioeconomic functions of IC for rural communities in most low-income countries (Dolberg 2007; FAO 2015). Previous and current research agree on how chickens impact rural livelihoods through various socioeconomic and socio-cultural-religious benefits (Lebbie and Ramsay 1999; Guèye 2000; Aklilu et al. 2007; Duguma 2009; Queenan et al. 2016; Alders and Pym 2009). Rural farmers keep over 80% of chickens in the region (FAO 2015; Guèye 1998, 2000; Queenan et al. 2016).

Early studies demonstrated the value of the IC sector in SSA. Guèye (1998, 2000) reported the importance and relevance of the IC sector in SSA as far back as 1994 when over 1.1 billion IC contributed around 1.7 million metric tonnes (MT) of eggs and 2.1 million MT of chicken meat. However, comprehensive data on recent trends and the contribution of the IC sector to the region's poultry industry are not readily available. The proportions of IC compared to the national poultry population from 1989 to 2018 for selected countries in SSA were generally reported (FAO 2015, 2022; Guèye 1998, 2000; Vernooij et al. 2018). For example, in Nigeria, Kenya, Uganda, Tanzania, Malawi, Zimbabwe, and Zambia, the population for IC comprised up to 82% of the national flock (FAO 2022; Vernooij et al. 2018).

Despite the high percentage of IC in the total national chicken population, the IC sector has exhibited varying growth in the past decades compared to the commercial poultry sector across the region. The differences observed between the two sectors are highly associated with the high production costs, shortages of feeds, and outbreaks of poultry diseases, mainly affecting SSF (Guèye 2000; PAZ 2021; Vernooij et al. 2018). Other factors include regional climate variations, available breeds, and farmers' management practices (FAO 2015; Vernooij et al. 2018). However, from 2007 to 2018, the

poultry industry in Zimbabwe recorded a contraction of over 65% (FAO 2022). This change may be associated with the country's political, economic, and land reforms undertaken by the Zimbabwean government a few years earlier.

Notable developments in Zambia's poultry sector

In the past decades, Zambia's poultry sector has undergone significant changes in terms of growth motivated by policy shifts. In the 1990s, the Zambian government made economic reforms in the agriculture sector through a liberalized market system to promote private sector participation in delivering goods and services (Rakner 2003; Bonaglia 2009). During this period, the privatization of most government-run entities occurred. In 2005, a ten-year program explicitly for the poultry sector was established (Bagopi et al. 2014). The plan aimed to increase efficiency and productivity in the commercial poultry sector.

The agriculture reforms and poultry sector plan led to new chicken genetics, improved nutrition, enhanced health services and farming practices in the Zambian poultry industry. Within six years, integrated and standalone breeders, such as Zambeef-Rainball, Pioneer-Bokomo, Tiger-Ross, Country bird, Panda, and Hybrid, were established (Bagopi et al. 2014; PAZ 2021). Further, a US$95 million investment by Zambeef-Rainball breeders triggered unprecedented growth in the poultry sector. From 2007 to 2012, the production of day-old chicks rose by over 100% from 27 to 65 million per annum, and over 50,000 jobs were created (Bagopi et al. 2014).

In contrast, such changes occurred much earlier in highly industrialized nations, as demonstrated by policies governing their poultry industry and gains made by consumers and animal welfare advocates (Steinfeld and Gerber 2010). Generally, changes in Zambia's poultry industry encouraged SSF to participate in producing commercial chickens, such as broilers and layers, defying their conservative nature. However, the participation of SSF was shortened by the high production costs and anti-competition tendencies they faced in the commercial poultry sector (Bagopi et al. 2014; Mueller et al. 2015).

According to PAZ (2021), over 5% average annual growth was observed in Zambia's poultry sector in the past decade. The MFL estimated a 20% growth in the Zambian IC sector from 2012 to 2017, translating to a 4% annual growth (MFL 2019). The increased demand for chicken meat and eggs stimulated this development. With increased household incomes and a shift to protein-rich diets among urban households, the primary buyers of chickens and eggs, the potential of the IC sector rose (Queenan et al. 2016). The socioeconomic roles of IC have also been significant in this evolution. A study conducted in 2012 found that over one million smallholders out of 1,418,000 agricultural households interviewed raised over 12 million IC in Zambia (Lubungu and Mofya 2012). In this study, farmers in Eastern, Southern, and Central provinces owned half of the chickens, whereas the other half belonged to households in the seven regions. Over a decade later, the population of IC nearly doubled to 21 million birds among the 1.6 million households nationwide (ZAMSTAT 2022).

Production systems practiced by small-scale farmers

The method used to produce chickens significantly affects productivity and quality, resulting from management differences. In SSA, farmers practice three main systems of producing chickens. The most common is the low-input and low-output free-range system, where the chickens scavenge for feed without healthcare interventions (Ochieng et al. 2013). Other methods include the semi-intensive, in which the chickens are partially allowed to scavenge, coupled with feed supplementation, and the intensive, in which the chickens are entirely confined and fed throughout their growth period (Guèye 2000; Okeno et al. 2013). Free-range and semi-intensive systems are considered beneficial to SSF due to negligible start-up costs, i.e., feeds and drugs (Guèye 2000; Queenan et al. 2016).

However, improving practices on disease control, shelter, marketing, feed supplementing, and exploiting available feed resources may increase production, efficiency, and profitability among SSF in the region (Goromela et al. 2006). Generally, SSF can practice any of the three production systems depending on their constraints and socioeconomic status (Guèye 2000). The intensive production system used mainly by commercial chicken farmers is unsustainable for SSF because of the high production costs, disease prevalence, and the oligopolistic market controlled by big breeders and producers (Bagopi et al. 2014; Ochieng et al. 2013).

Productivity of common indigenous chicken breeds

Smallholder farmers rear different chicken breeds as part of their socioeconomic ventures. In Zambia, the Ministry of Agriculture and Cooperatives (MACO) highlighted IC breeds that rural communities raised. Some known IC breeds include the common Zambi, Naked Neck, Dwarfs or Short-legged, Frizzled, Feathered Legs, and Short-Tailed, with live body weights (BW) of 1.3-2.0 kg at over 180 days of age (MACO 2003; PAZ 2021). The size and weight at maturity vary between mature females and males. Studies in Nigeria and Botswana suggest significant differences in live BW between

mature female and male chickens, with the former weighing (0.7-2.1 kg) and the latter in the range of (1.2-3.2 kg) IC (Guèye 2000). In Benin, some common IC breeds, such as Koklogbo, Komaloe, Adjagble, Win, and Dingbannon, are reared by rural communities (Rodríguez et al. 2011).

Compared to broilers at 42 days, IC at the same age will be smaller due to the slow growth rate. The performance differences observed between IC and commercial chicken breeds are primarily controlled by genetics and environment (FAO 2015). Recently, Zambia's poultry sector saw the introduction of new exotic chicken breeds. Some semi-improved free-range chicken breeds include the Boschvelds, Kruoillers, Black Australorps, and Brahma (PAZ 2021). Although the improved free-range breeds are perceived to mature early and be more productive, the high prices for day-old chicks, increased management demands, and susceptibility to diseases render them inaccessible and unsustainable to resource-poor farmers in Zambia (PAZ 2021). In contrast, the negligible costs of producing the IC encourage farmers to keep indigenous breeds. Further, a high benefit-cost ratio in IC is economically vital as any selling price translates to profit (Simainga et al. 2011; Queenan et al. 2016).

Rodríguez et al. (2011) compared the production parameters of IC and exotic free-range chicken breeds in their studies. They assessed the impact of Newcastle disease (ND) vaccination programs on the profitability of the two ventures. They reported that IC laid ten eggs per cycle and achieved 2.4 cycles per year, 70% egg hatchability, 150 days of growth at 1.1 kg live BW, and 120 days for brooding and maintenance. In contrast, exotic free-range chickens had slightly higher productivity of 12 eggs per cycle, three cycles per year, an 80% hatching rate, and a somewhat short period of brooding and maintenance at 89 days (Rodríguez et al. 2011). They concluded IC were more profitable for the resource-poor farmers than exotic free-range chickens. The latter had higher nutritional and management demands with increased flock size.

Uses of indigenous chickens in Sub-Saharan Africa

SSA rural communities attach greater socioeconomic, cultural, and religious values to IC. This section discusses how communities obtain food security, household income, breeding stock, and social-cultural and religious uses from IC.

Food source

The contribution of IC to food needs for rural households is much more significant compared to larger livestock such as cattle and pigs. Rural families in SSA have met the much-needed animal-based protein by consuming chicken meat and eggs (FAO 2015; Melesse 2014; Ochieng et al. 2013; Queenan et al. 2016). Previous studies by Guèye (1998, 2000) demonstrated how a farmer who started with one pullet in Tanzania gained nearly 170 chickens, 1,100 eggs, and 47 kg of chicken meat in five years. This study demonstrated significant changes in the farmers' food and nutritional security and livelihood within five years.

Production trends between 2009 and 2017 in selected countries in SSA highlight the contribution of native chickens to national food security through the supply of poultry meat and eggs (FAO 2022; Vernooij et al. 2018). In 2016, IC comprised 82.4% of Kenya's 40.4 million chickens, and the sector produced over 1,530 million eggs annually. In contrast, in Uganda, 26.6 million, equivalent to 66.5% of the total chickens' population, were IC, and the poultry sector produced over 856 million eggs. In comparison, Tanzania had over 37 million IC representing 55.2% of the national flock and producing above 1,780 million eggs annually (Vernooij et al. 2018). The growth in the IC sector was reported between 2010 and 2020, in which Benin had 37.6% growth from 16.5 million total flocks, Nigeria dropped by 13.7% from 192 million, while Zambia expanded by 17.4% from 35 million, and the Gambia's IC sector rose by 64.7% from 0.85 million (FAO 2022). These reports and other studies demonstrate the role played by IC in addressing the demand for animal-based protein in the region.

Several factors influence consumption levels for poultry and poultry products. These factors include chickens' health status, productivity, and general performance. Communities that experience higher chicken mortalities due to poultry diseases exhibit low consumption of IC and associated products. In these communities, fertilized eggs are strictly kept for hatching and replacement stock, while mature chickens are sold to raise household incomes (de Bruyn et al. 2018). There has been a steady increase in chicken meat and egg intake globally. From 2004 to 2012, a 9% increment in consumption of chicken meat to 63 million MT and a 20% rise in egg consumption to 55.5 million MT were reported (FAO 2015). The quantity of eggs consumed annually per person varies from one country to another. Between 2009 and 2017, Kenya, Tanzania, and Nigeria experienced per capita egg consumption reductions by 16.7% to 0.5, 6.3% to 1.5, and 43.8% to 0.9, respectively. Generally, the egg consumption rates in SSA were significantly low at 2.1 eggs/person/year compared to the global consumption of 13-151 eggs (Vernooij et al. 2018). The global estimate is consistent with the reported average of over 150 eggs per person per year in 2017, as stated by FAO (2022).

The consumption of IC meat and eggs also highly depends on the community's socioeconomic status and productivity and, in the future, the human population's growth (FAO 2015; Guèye 1998, 2000; Klingholz 2020). In Tanzania, the SSF consumed less than half of the chickens they produced and sold the rest to rural areas, whereas in Zambia, the rural families consumed more than half of IC and only sold 20% to urban areas (Queenan et al. 2016). Further, communities assisted with sustainable interventions to improve productivity exhibited changes in consumption patterns for chicken meat and eggs (Dumas et al. 2017).

Household income

Free-range IC enterprises are considered low input because of the low capital requirements. The minimum standards create an easy way out of poverty for most resource-poor communities in SSA (Guèye 1998, 2000; Dolberg 2007). These chickens significantly contribute to household incomes and livelihood assets for rural communities in the region. Farmers acquire finances to meet their daily needs and possible future investments (Dumas et al. 2017; Guèye 2000). For example, when family A raised US$180 from selling 30 chickens, they allocated US$72 for daily household needs, US$54 for buying clothes, US$36 for business, and US$18 for purchasing replacement stock (Guèye 2000). Some farmers invest their incomes during surplus and purchase food sources in times of hunger (Dumas et al. 2017). The meticulous allocation of revenues from IC highlights how valuable the chickens are for rural livelihoods. Farmers could also use IC as a medium of exchange. For example, in the Gambia, SSF exchanged five full-grown hens with an mature sheep and 25 hens with one mature cow (Guèye 1998, 2000). This trend also illustrated how owning IC was as good as having money in savings accounts, enabling rural communities to access other livelihood assets.

Gender empowerment

Indigenous chickens are also considered socioeconomic and gender equalizers, favouring women and children in most parts of SSA (Kitalyi 1998; Guèye 2000; Moreki et al. 2010; Simainga et al. 2011; Queenan et al. 2016). Over 70% of IC in SSA are owned and managed by women and children, enabling them to access various livelihood assets (Guèye 2000; Dolberg 2007). However, some researchers are sceptical and cautious about the contribution of IC to gender equality in rural communities. For example, in certain societies in Tanzania, women and children could only manage the chickens, but 76% of men had the power to decide on the marketing and use of IC (Guèye 1998). Previous research documented similar trends in Mozambique, where prolonged wars and floods significantly reduced the number of cattle and goats, increasing men's interest and control over IC (Guèye 1998, 2000).

Social-cultural-religious uses

Some social-cultural and religious functions of IC among rural communities are usually a combination of incomes, consumption, gifts, medicinal and other uses (FAO 2015). In SSA, rural communities sacrifice IC during traditional ceremonies and rituals, share cocks as gifts to their guests at cultural events such as weddings, and use the cocks for traditional medicines, including sexual stimulation for men and general hygiene through scavenging (Guèye 1998, 2000). White feathered chickens are vital for traditional medicines and sacrifices in Somalia, Cameroon, and Zambia (Guèye 2000). Attaching value to the colour or appearance of indigenous livestock is also a pricing technique under traditional markets in low-income countries (Mueller et al. 2015). The cultural significance of IC is exhibited during the migration of people from one community to another. For example, when families relocate from rural communities and urban areas, they carry food and plants and may introduce chicken breeds to their new settlements (FAO 2015).

Other uses

Indigenous chickens are significant in local interventions such as community-based breeding programs. During these programs, farmers share and incubate fertilized eggs for desired breeds of chickens within the communities (Dumas et al. 2017; Guèye 2000). Farmers also use IC as security against risks, as ornaments during social events, and as hobbies. For example, farmers secured nearly 71% IC in Ghana for breeding purposes (Guèye 1998, 2000). These communities strategically selected desired males and females for continued production (FAO 2015; Guèye 2000). Similarly, eggs are incubated and hatched in Ethiopia for continued chicken production in rural communities. Guèye (1998, 2000) also reported combined uses for IC in terms of income, consumption, and Barter in Zimbabwe and Nigeria.

Threats to the indigenous chicken sector in Sub-Saharan Africa

Most rural farmers keeping IC face several challenges, including loss of indigenous chicken animal genetic resources (IC-AnGR), poultry diseases, poor policies, unstable markets, and poor poultry infrastructure. This section discusses these challenges and their impact on the IC sector in SSA.

Loss of indigenous chicken animal genetic resources

Continued loss of IC-AnGR is a concern that may potentially affect researchers and rural communities in SSA. Some of the negative results of the loss of IC-AnGR may be irreversible if not mitigated in time (FAO 2015). The world's animal biodiversity status report highlighted that from 2005 to 2014, the livestock breeds classified at risk of extinction increased

by 2% from 15%, while 58% were in the unknown risk status group (FAO 2015). The report stated that chicken breeds were the most vulnerable among the avian species, with the highest numbers at risk. The report revealed that 3.5% (60) of chicken breeds were extinct, 21.3% (368) were at risk, a combined sum of chicken breeds in the critical, critical maintained, endangered, and endangered maintained.

Further, 63% (1089) were under unknown risk status, and 12.3% were considered not at risk (FAO 2015). Some of the factors identified by the report as drivers of the erosion of IC-AnGR were uncontrolled cross-breeding, economic forces, change in market demands, damage to natural resources, climate change, and disease outbreaks, among others (FAO 2015).

FAO's second report on biodiversity for agriculture provides a warning and insights on the status of chicken breeds whose erosion may have future socioeconomic impacts on rural communities. Over 80% of rural farmers in SSA keep IC, significantly contributing to the IC sector and making them primary custodians of IC-AnGR in the region (Dolberg 2007; FAO 2015; Guèye 2000). These communities are likely to suffer if there are no measures to stop or reduce the loss of IC-AnGR. Adopting exotic chicken breeds may suppress the highly adapted IC breeds, which are suitable and sustainable for scavenging and natural brooding methods (Riise et al. 2004; Rodríguez et al. 2011).

Poultry diseases

Poultry diseases are among the challenges that have affected small-scale producers of chickens in SSA. Most farmers have resorted to keeping IC which cope relatively well in diseased environments (FAO 2015). Reconsideration of rearing IC is a viable socioeconomic strategy in that livelihoods would improve sustainably because of the easiness of managing these chickens. However, the gravity and impact of disease on the IC sector require effective and sustainable interventions (Guèye 1998, 2000; Simainga et al. 2011). Some researchers suggest that the low-input, low-output scavenging systems are less successful than the intensive systems that produce broilers and layers due to uncontrolled poultry diseases (FAO 2015; Rischkowsky and Pilling 2007). There are significant losses recorded among rural farmers resulting from poultry diseases. Queenan et al. (2016) reported that suspected ND and fowl pox potentially causes 40-100% mortalities of IC, especially towards the end of the dry season in SSA. Poultry diseases equally afflict Zambia's IC sector. In 2017, the highly pathogenic H5N8 avian influenza negatively impacted the country's poultry sector, leading to thousands of birds being culled (PAZ 2021). Common diseases such as typhoid, infectious coryza, Gumboro, worm infestation, and external parasites have also contributed to the poor performance and high mortalities experienced in the IC sector (Phiri et al. 2007; Simainga et al. 2011; Mubamba et al. 2018).

Inadequate disease control measures among SSF have exacerbated the prevalence of poultry diseases. Most small-scale producers in the IC sector depend on natural remedies for controlling poultry diseases (FAO 2015). For instance, Guèye (2000) reported that over 79% of rural farmers use traditional herbs and plants to treat poultry diseases and that 50% of mortalities in the IC sector occurred within the first four weeks of chicken raising. Researchers reported concerns about using traditional remedies to treat diseases by rural farmers. In 2012, over 27% of SSF in Zambia relied on traditional medication, and less than 15% used veterinary drugs, resulting in 60% of the IC dying (Lubungu and Mofya 2012). According to FAO, poultry diseases and poor disease management are rated at 28% among factors responsible for the erosion of chicken breeds (FAO 2015). Other causes include the introduction of exotic breeds at 22%, uncontrolled cross-breeding at 63%, and climate change at 16% (FAO 2015). Recent studies identified the scavenging system, mainly practiced by SSF, among the factors responsible for spreading ND in East Africa (Mujyambere et al. 2022). These studies advocate for cheap vaccines, innovative extension methods, and improved disease control skills for farmers. Despite the disease prevalence observed in IC, there are some beneficial adaptability and genetic gains through natural selection which farmers can exploit.

High input prices and nutritional limitations

Poor nutrition is among the factors for the poor performance of the IC sector in SSA. These nutritional problems are mainly due to high feed costs, poor chicken feeding regimes, and feed shortages (Melesse 2014; PAZ 2021). In SSA, the high feed costs are also attributable to the continued price increments in feed ingredients such as soya beans and maize (Bagopi et al. 2014; Vernooij et al. 2018). In the past five years, prices for poultry feed, feed ingredients, and live inputs have increased significantly in Zambia. Analysis of PAZ's weekly reports for the first quarter from 2016 to 2021 highlights the depth of this problem. The reports highlighted the following variations in prices; the solvent-extracted soybean meal increased by 27.7% from US$23.50 per 50 kg, broiler starter increased by 45.3% from US$20.10 per 50 kg, and prices for broiler grower increased by 44% from US$19.30 per 50 kg. The price for broiler finisher increased by 45.9% from US$18.50 per 50 kg, while a 49% increase in layer mash from US$ 14.70 per 50 kg was observed (PAZ 2021).

Costs of live inputs also went up during the same period. The prices for the (1-7) day(s) old chicks of improved free-range chickens, layers, and broilers increased by 87.5%, 83.3%, and 125% from US$0.80, US$0.60, and US$0.40 per bird,

respectively. The high prices for feed and other live inputs have seriously hindered the active participation of poor-resource farmers in SSA's commercial poultry sector (Vernooij et al. 2018; PAZ 2021). Other valuable market data analyzed included prices for live pullets, broilers, spent layers, and IC, which increased by 64.8%, 57%, 38.5%, and 61.5% from US$8.90, US$3.00, US$2.60, and US$3.90 per bird, respectively (PAZ 2021). In contrast, the data also illustrated the market opportunity for producers of IC attributed to favourable prices per bird. Previous studies compared the effects of feed costs and profitability of enterprises for exotic and IC under a free-range system. Researchers found that the costs for feed increased sharply with the increase in flock size for exotic free-range chickens, while there was minimal or no change in production costs with the rise in flock sizes for IC (Rodríguez et al. 2011).

Limited supplementary feeding and a lower plane of nutrition under the scavenging system lead to mortalities and reduced consistency in the quality, quantity, and size of chickens and eggs (Queenan et al. 2016). Usually, the scavenging system leaves the birds to roam and scavenge for feed. Notable feed sources include insects, termites, seeds, grains and earthworms, kitchen waste, maize bran, leafy vegetables, and other cheap feed sources that are valuable in the free-range system (Mwalusanya et al. 2002; Goromela et al. 2006; Mapiye et al. 2008).

There are also fluctuations in the availability of scavenged feed resources between each harvest under rain-fed farming systems in SSA (de Bruyn et al. 2018). For example, in Zambia, the scavenging chickens have access to high-protein insects and earthworms in the rainy season (December to April) and high-energy feed sources, mainly from grains during the harvest time from May to August. However, a severe shortage of nutritious feeds in the hot and dry season leads to poor health, malnutrition, and high mortalities (Queenan et al. 2016). The dry season requires deliberate feed supplementation by farmers to mitigate adverse effects on the chickens' performance (de Bruyn et al. 2018). In other parts of SSA, the breeding of black soldier fly larvae and maggots as protein sources are being experimented with and may improve nutrition in the IC sector, especially in periods of feed scarcity (Kenis et al. 2014).

Inadequate policies and regulations to support the Indigenous chicken sector

The existing policies in the poultry sector are generally inadequate and widely vary across SSA. Most policies and trade restrictions favour commercial poultry producers (FAO 2015). For example, in Namibia, poultry producers legally brine broiler meat at 20%; in Botswana, commercial producers can supply 75% of poultry meat demand, although brined poultry meat is not allowed (Bagopi et al. 2014). There is also inadequate support for infrastructure development in the IC sector, especially among rural communities. Infrastructure development is biased toward larger enterprises (Dolberg 2007). Most governments in SSA allocate more funds to infrastructure development, favouring larger livestock enterprises, predominantly run by commercial entities.

Furthermore, minimal attention to SSF involved in the production of IC, despite these farmers being part of the primary sources of data when designing policies on livestock infrastructure and funding (Dolberg 2007; FAO 2015). For instance, Zambia's livestock infrastructure support project funded by African Development Bank focused on constructing dairy and beef infrastructure. Further, the Second National Agriculture Policy of 2016 to 2020 in Zambia did not provide a good roadmap for value addition and market participation for small-scale producers of IC (MFL 2017). These inadequate policies exacerbate the problems experienced in the IC sector, and rural farmers feel neglected by political leaders and poorly represented by scientists (Bagopi et al. 2014; Dolberg 2007).

Researchers claim that low-income countries have witnessed economic growth, particularly in the private sector. They suggest that the growth trends are motivated by inadequate regulations and weak policies promoting unsustainable production, harming ecosystems, AnGR and markets (FAO 2015). For example, poultry products worth millions of dollars are imported into SSA from overseas, negatively impacting the local poultry sectors in the region. In 2018, South Africa imported frozen poultry products of mixed parts valued at over US$65 million from different sources in Brazil (PAZ 2021). These posed a public health threat because they lacked traceability and affected the local poultry sector.

Deliberate interventions are required to protect the local poultry sector. The Poultry Association of Zambia highlighted instances where some countries had implemented protective measures for their poultry sector. In Ghana, over US$60 million of poultry products were imported into the country, flooding the local market in 2018 (PAZ 2021). These importations prompted the Ghanaian Poultry Association to engage the government in introducing quotas on poultry imports to protect local poultry farmers. In Namibia, the government banned the importation of poultry products to cushion the impact on the local poultry industry. In Zambia, the Poultry Association continued to engage the Zambian government to promote policies capable of protecting and enhancing both commercial and IC sectors (PAZ 2021). Policy researchers propose the inclusion of consumption and other considerations in current policies and legislation regarding livestock production and environmental management (Steinfeld and Gerber 2010). This approach aims to improve strategies, maximize community benefits, and minimize food waste.

Low access to formal and stable markets

Access to organized markets by small-scale producers is essential for the sustainable development of the IC sector. In SSA, farmers in this sector face barriers preventing them from accessing formal markets. These obstacles are associated with market standards and requirements such as selling frozen whole or portions of chickens, packaging, labelling, and selling from standard outlets (Bagopi et al. 2014). Small-scale producers in the IC sector cannot compete with larger commercial entities because they neither own the required facilities and brands nor organized sales outlets (Simainga et al. 2011; Bagopi et al. 2014; Queenan et al. 2016). With many obstacles to the established markets, few SSF can only sell their chickens or eggs directly to these markets through group contractors and intermediaries who manage most market channels (Bagopi et al. 2014; Queenan et al. 2016). This way is also limited, making it difficult for small-scale producers to succeed.

Generally, most rural farmers in Zambia sell their chickens through informal places like the roadside, village markets, direct to consumers, and through their backyards (Queenan et al. 2016; Mubamba et al. 2018; PAZ 2021). However, in some parts of the country, informal markets have recently transformed into essential selling points, making it possible for some farmers to organize and meet consumers' demands on quality and quantity. For example, "Tuesday and Saturday markets" have become popular in urban and rural areas of the country (Tschirley and Munguzwe 2010). In the Northern part of Zambia, this traditional market is called "Munada," where communities and traders agree on the date and place for a weekly market day at which most agricultural products are exchanged or sold (Nyirenda 2016). According to Nyirenda (2016), "Munada" is a concept derived from East Africa for open markets practiced by local traders who regularly travel from village to village selling their goods.

Low access to reliable markets generally affects IC sales, prices, and consumption dynamics in rural communities. For example, farmers in Tanzania sold twice more village chickens and eggs to rural areas than they consumed and sold IC at US$3.72 per live bird (Queenan et al. 2016). In contrast, producers of IC in Zambia ate more than half of their chickens and only sold 20% to urban areas at an average price of US$3.37 per bird (Queenan et al. 2016). The variation in selling points, prices, and consumption levels shows how undefined and informal the markets for IC are in SSA.

Poor housing facilities

Researchers have identified the lack of suitable housing for IC as an obstacle to the growth of the IC sector. This problem is prevalent among resource-poor farmers who cannot afford such facilities. As a result, the absence of reliable and functional housing facilities for IC in scavenging systems has impeded the progress of the IC sector in the region (Melesse 2014; Mujyambere et al. 2022). Some farmers keep their chickens in undeveloped poultry structures at night to secure them from predators and bad weather (Simainga et al. 2011). In many cases, chickens seek shelter in trees, making them vulnerable to predators, such as cats and dogs (Guèye 2000; Melesse 2014; Simainga et al. 2011). Because of the poor status of chicken housing, theft, predation, and environmental hazards are common, significantly contributing to losses observed in the IC sector. For instance, in the Western province of Zambia, a survey of 243 farmers found that 93% and 84% of the households interviewed attributed chicken losses to predation and thefts, respectively (Simainga et al. 2011). Some attribute the housing problem to non-uniform practices and a lack of appropriate management information among smallholder producers across SSA (Mujyambere et al. 2022). To assist SSF, innovative extension systems to impart skills are recommended.

Growth opportunities for the indigenous chicken sector in Sub-Saharan Africa

Opportunities and strategies can enhance the sustainable growth of the IC sector in SSA, leading to improved conservation of IC-AnGR and livelihoods. This section highlights that research, innovation, and stakeholder engagement are critical strategies for achieving the desired outcomes for the IC sector in SSA.

Increased consumer demand for indigenous chicken meat and products

Despite the barriers and challenges experienced by SSF in the IC sector, most rural communities and consumers have continued benefiting from the industry. In the past decades, the consumers' demand and preferences for IC have steadily grown (Bett et al. 2013; Melesse 2014). The increased importance of IC results from the consumers' perceived good taste, delicate texture, and health benefits, with some preferring male chickens for their large size and hens for their tenderness (Guèye 2000; Queenan et al. 2016). Although in South Africa, studies by Dyubele et al. (2010) found that consumers preferred broiler meat to IC due to tenderness and other attributes. Generally, the increased demand for IC meat has led to a substantial increase in the prices over commercial chicken, potentially creating an opportunity for SSF (Alders and Pym 2009; Guèye 2000; Melesse 2014; PAZ 2021; Queenan et al. 2016).

Studies in parts of SSA have demonstrated consumer preferences and the ability to pay for IC and products. For example, in Benin, consumers preferring IC were willing to pay US$2.67 per bird compared to US1.30 for each exotic chicken

(Queenan et al. 2016; Rodríguez et al. 2011). Similar trends were reported in Zambia in the past five years, where IC sold nearly twice the broiler price (PAZ 2021). The Poultry Association of Zambia highlighted that in 2016, live IC sold at US $4.0 per bird, which was 33% higher than broilers, while in the first quarter of 2021, and IC fetched US$6.40 per bird, which was 73% higher than the price for broilers. This trend is consistent with some studies, where IC prices were high, mainly when sold to consumers in traditional markets and familiar places, as proof of buying authentic native chickens (Guèye 2000; Queenan et al. 2016).

Population growth and food demand

The growth in the human population will have an equally significant impact on the demand for animal-based foods. The need for healthy livestock products such as IC meat, eggs, and other chicken products will likely increase, and consumers' willingness to pay for the desired food quantities will improve in SSA (FAO 2015; Melesse 2014). Projections from FAO show that from 2005 to 2050, the global human population will grow to 9.8 billion, of which over 46% of growth is projected in SSA, and a 60% increase in food demand forecast (Alexandratos and Bruinsma 2012; FAO 2015). Food consumption of less than 2500 (Kcal/person/day) and annual undernutrition levels 20% higher than other regions are projected during this period (2005-2050) and require a proportional increase in food supply to mitigate hunger (FAO 2015). Farmers' commitment and related policy support from the government through agribusiness may turn human population growth into opportunities for producers of IC in the region. Policy researchers have identified an increased need for youths to participate in agribusiness and farming to contribute to food security and socioeconomic demands for SSA in the next three decades (Klingholz 2020).

Food consumption patterns

Apart from increased food demand, population dynamics are likely to affect the consumption pattern for animal-based protein, which accounts for 40% of the total protein consumed by humans (Lebbie and Ramsay 1999; Boland et al. 2013; Mueller et al. 2015). Some scholars also predict that the emergence of the middle class will highly influence meat consumption in low-income countries, requiring technology and innovation to meet the demand for meat during 'the livestock revolution' (Steinfeld and Gerber 2010). Globally, from 2000 to 2050, researchers predict an 82% increase in meat consumption, equivalent to 233-271 million MT, of which 88 million MT is poultry meat and over 183 million MT from bovine, ovine, and pig combined (Alexandratos and Bruinsma 2012; Boland et al. 2013; FAO 2015). Other regions will experience a slow but gradual increase in meat consumption. However, the volumes demanded in areas such as SSA, where the farming population will get older, and a majority will migrate to urban areas as the middle class expands, will be substantial (Klingholz 2020). The second report on the status of biodiversity warns that the changes in consumption patterns will potentially contribute to the loss of AnGR (FAO 2015). Therefore, deliberate policies on consumption need to be considered by governments in SSA.

Adaptation of indigenous chickens to uncontrolled environments

Indigenous animals have adapted well to the local environment where they have existed for thousands of years. Researchers have found that certain indigenous animal breeds have developed resistance to some livestock diseases due to adaptation and natural selection (FAO 2015). Most IC breeds have equally evolved in their environments for decades, evident by their resistance to poultry diseases such as ND and thriving in harsh environments characterized by poor-quality diets (Mapiye et al. 2008; Gizaw et al. 2010; Queenan et al. 2016). The ND is a devastating infectious disease endemic to parts of the world. Among the 75 avian breeds that show unspecified resistance to ND, 56 were chicken breeds (FAO 2015). Some of the IC breeds are more resistant to diseases. In Nigeria, Naked neck and Yoruba chickens resisted viral infections and eliminated the diseases resulting in recovery (Adeyemo et al. 2012; Bobbo et al. 2013).

Further, novel genes and the pathways signaling the resistance of avian influenza in poultry were analyzed by Wang et al. (2014). The traits of disease resistance, which are superior in IC compared to commercial breeds, may be essential in future chicken breeding programs (Mapiye et al. 2008). Gizaw et al. (2010) suggest that adaptive traits are equal to or more important than production traits in indigenous livestock production systems. The attribute to resist particular diseases in these breeds could be an exploitable opportunity in SSA, especially for farmers practicing free-range production systems.

Workable approaches to promote the conservation of indigenous chicken breeds

This section covers selected strategies to promote the sustainable use and conservation of IC-AnGR and improve rural livelihoods in SSA.

International guidelines on the conservation of animal genetic resources

The Food and Agriculture Organisation promotes five strategic areas for using and conserving indigenous AnGR. In the second report on biodiversity for agriculture, the international body provides guidelines on conserving AnGR (FAO 2015). These are: (i) enhancing knowledge on the characterization of local animals, (ii) developing sufficient

institutional frameworks for AnGR management, enhancing linkages among livestock farmers and stakeholders concerning policies and programmes, and (iii) enhancing awareness through education, training, and research in significant areas of AnGR management, (iv) Enhancing breeding strategies and programs to harness available AnGR and match them with environments of production and requirements of societies and (v) increase diversification of conservation programs and possibly mix some approaches that use existing livestock breeds in the typical production environment and consider gene banks' use to store genetic materials.

To implement the five areas, FAO requires individual countries to undertake various programs towards the stated strategies by forming AnGR conservation committees and submitting biodiversity status reports to the FAO Commission on Biodiversity (FAO 2015). Zambia is among the countries in SSA that have tried to implement biodiversity conservation programs based on FAO's guidelines. The government implements these programs through research and extension services of the Ministry of Fisheries and Livestock and other line ministries. Agendas such as farmer engagements and capacity building with support from donors on climate resilience have motivated the implementation of workable interventions. The Zambian government embarked on projects establishing livestock breeding centres nationwide and encouraging farmer-driven innovation, such as community-based interventions on IC. The multiplication of IC breeds at Mazabuka research station in the Southern province is ongoing (MFL 2019).

Through the African Union InterAfrican Bureau for African Animal Resources, Zambia formulated and launched the National Strategic Action Plan in 2018-2019 to develop sustainable use and conservation of indigenous livestock breeds, including IC-AnGR (MFL 2019). The country is also working on the plant biodiversity program through the Community Network, a non-governmental organization aligned with IFOAM to undertake a Gwembe Valley project that promotes on-farm sustainable use and conservation of selected crops (FAO 2019). This committee's model could work equally for conservation projects targeting IC-AnGR.

Farmer mobilization and sustainable interventions

Although researchers agree on the socioeconomic roles of IC in SSA, there are fewer attempts to holistically find solutions to challenges faced in the IC sector, including the continued loss of IC-AnGR and low socioeconomic benefits among rural farmers (Dolberg 2007; FAO 2015). The Poultry Association of Zambia expressed similar concerns regarding obscure solutions for smallholders in Zambia's poultry sector. The problems in the IC sector are confounded by unsustainable use of IC-AnGR, lack of management and disease control skills among farmers, and absence of value addition (Guèye 2000; Mueller et al. 2015; PAZ 2021). There are also barriers associated with a lack of information and un-uniform practices by SSF when keeping chickens (Mujyambere et al. 2022). Interventions to foster sustainable development of the IC sector and conservation of IC-AnGR are crucial to improving rural livelihoods in SSA (Rodríguez et al. 2011). Organizing farmers in formal groups would facilitate the flow and sharing of helpful information and offer farmers much-needed bargaining power in their agribusinesses (Melesse 2014). The involvement of rural farmers in community-based interventions can potentially empower the communities through decision-making and livestock business ownership (Dumas et al. 2017; Mueller et al. 2015).

Researchers found that community-based interventions were more sustainable for conserving local AnGR because they are judicious, offer continuous improvements, and are more reliable as long-term interventions (Mueller et al. 2015). In a few decades, SSF working in isolation in SSA may face more constraints than those working collectively (Livingston et al. 2011; Melesse 2014). Farmers belonging to organized groups would improve production and productivity. These are achievable through good management skills, sustainable use and conservation of IC-AnGR, improved disease control, improved nutrition, and value addition among producers of IC (Livingston et al. 2011; Mueller et al. 2015; Queenan et al. 2016).

Contextualizing rural communities when designing interventions

Developing an innovation based on the local context is essential in promoting the conservation of IC-AnGR, enhancing socioeconomic gains, and increasing adoptions among SSF in the IC sector. There are guidelines and principles for designing community-based interventions, as highlighted by FAO (2015), Guèye (2000) and Mueller et al. (2015). A collective approach based on shared interests among researchers, communities, and stakeholders would create sustainable and workable strategies to conserve IC-AnGR in SSA. Governments in SSA need to design sustainable agriculture programs, increase investment in research and promote sound policies that encourage the participation of youths in agribusiness and food production (Alexandratos and Bruinsma 2012; Klingholz 2020). Any socioeconomic safety net program targeting rural communities needs a common ground with the rural community by understanding their culture, beliefs, and traditions (Bryman 2016; FAO 2015; Mueller et al. 2015). Researchers must promote the voices of the farmers before, during and after implementing such programs.

Creating market linkages

Mobilizing SSF into organized groups would make it easy to link farmers to formal markets for their chickens, eggs, and other products (Bagopi et al. 2014; Livingston et al. 2011; PAZ 2021). Further, farmers would have opportunities to negotiate for better policies affecting the IC sector, access an equitable market share and gain bargaining power (Melesse 2014; PAZ 2021). The existing local market niches such as Munada in rural Zambia, Saturday, and Tuesday in the urban areas can potentially increase incomes among producers of IC. These market linkages, mainly driven by consumer preference for IC meat and eggs, may motivate farmers to increase IC flock sizes, improve rural livelihoods and create opportunities for sustainable use and in situ conservation of IC-AnGR in SSA (FAO 2015; Rodríguez et al. 2011).

Community-based interventions and outcomes in selected low-income countries

There are practical examples of Stakeholders' engagements and their impact on SSF in low-income countries. Farmers involved with other indigenous animal species are covered in this section to illustrate how practical and universal this approach is in designing solutions, improving livelihoods, and increasing productivity among SSF.

Mueller et al. (2015) outlined the process required for establishing community-based interventions and gave examples of such programs, where they worked in low-income countries, and the challenges faced. Mueller and others highlighted features of sustainable community-based interventions. These programs are initiated by either the community or government research institutions, have well-formulated breeding objectives based on indigenous or local breeds, the existence of institutional support, and should have measurable outcomes or changes (Dumas et al. 2017; Mueller et al. 2015; Rodríguez et al. 2011). For instance, pork farmers in Vietnam achieved between 40% and 100% increment in pork prices by working with government institutions to identify market and pricing challenges and design solutions (Mueller et al. 2015). In Kenya, SSF experienced fast growth in the goat population and an over 300% increase in goat milk yields up from 0.25 litres per goat per day after implementing community-based solutions. In Ethiopia, positive testimonies and knowledge-sharing among SSF led to the widespread adoption of sheep breeding strategies among rural communities (Mueller et al. 2015).

Some specific examples of community-based interventions targeting the IC sector in SSA exist. Researchers in Benin mobilized farmers to participate in a vaccination program against ND and facilitated improved poultry management of IC and exotic chickens. Before this program, exotic chickens sold 20% more than IC, whereas native chickens were 58% more profitable (Rodríguez et al. 2011). Vaccinations against ND reduced mortality by 5% in both flocks, and exotic chickens sold 53% more than IC. However, the rapid increase in flock sizes of exotic chickens resulted in increased feed costs by 300% and a reduction in overall profits by 38%. In contrast, feed costs for IC flocks under a free-range system remained negligible regardless of the change in flock size.

In Zambia's Luangwa Valley, researchers implemented two community-based programs targeting farmers producing IC in Mambwe and Lundazi districts of the Eastern province (Dumas et al. 2017). Firstly, ND vaccination programs and workshops provided guidelines on improved flock management. In the second program, researchers facilitated and supported the construction of semi-intensive egg production and breeding structures in 24 communities, and each group had up to five farmers managing 40 hens. After implementation, researchers found that the flock sizes increased by over 135% within four years, from over ten birds, and that the annual incomes from poultry rose 138% from US$16.89 per household (Dumas et al. 2017). However, the consumption of chickens and eggs did not change much as farmers mainly sold the birds to raise incomes.

The impacts of the second intervention included an over 62% increase in egg production, an average group income rose to US$30 monthly, consumption of eggs increased by 118% among producers, 167% up from 0.9 eggs per week in women, and 263% up from 0.8 eggs per week among children (Dumas et al. 2017). The two interventions not only improved communities' livelihoods but also promoted sustainable alternatives to the consumption of bush meat, which was detrimental to the ecology of the protected area.

Valuable lessons from selected low-income countries

Generally, there are issues related to community-based interventions, including instances where particular challenges hindered the progress of these interventions. Mueller et al. (2015) highlighted a lack of trust in financial matters and technical problems that potentially affected the sustainability and continuation of particular interventions. For example, in Bolivia, where the objective of the intervention was to improve the fibre quality of wool from llamas, problems such as political and financial mistrust and lack of funds resulted in low sustainability and the eventual collapse of these innovations.

Promoting poultry development plans based on exotic breeds instead of IC would be less valuable to resource-poor farmers in SSA. The newly introduced exotic chicken breeds may not efficiently adapt to the uncontrolled environment in

rural communities compared to IC breeds (FAO 2015). The IC sector faces most of these problems due to low literacy, lack of records, lack of information on poultry breeds and associated diseases, high feed prices and increased costs of production which hinder progress (Mtileni et al. 2016; Mueller et al. 2015; Mujyambere et al. 2022; Rodríguez et al. 2011; Sebho 2016).

Considering the local context, sustainable use of selected chicken breeds and promoting ownership of the formulated interventions are essential. The continuous engagement of researchers and stakeholders may encourage the development and sustainable conservation of IC-AnGR in SSA. Erosion of IC-AnGR is an urgent problem requiring immediate interventions and concerted efforts by all stakeholders, including rural communities in the region. The voices and views of the targeted rural communities and understanding the local situation are essential when designing interventions and promoting developmental programs for the IC sector (Patton 2010; Bryman 2016).

Analysis of various community-based interventions in low-income countries showed that research institutions and government support were crucial in achieving the established objectives (Dumas et al. 2017; Mueller et al. 2015; Rodríguez et al. 2011). Institutional support motivates farmers to open up to their challenges, work hard and feel a sense of ownership of the program.

When planning an intervention, stakeholders' roles should be defined, and the possible value chains for IC should be understood clearly to create effective, sustainable, and beneficial innovations for the communities. The successes of researcher-community-stakeholder engagements in identifying problems and designing solutions highlight the determination of the researchers to reduce poverty in rural communities (Dumas et al. 2017; Mueller et al. 2015; Rodríguez et al. 2011).

Selective adoption of workable approaches based on lessons learnt from other community-based interventions is necessary. Low-income countries would increase the use and conservation of native chicken breeds and improve rural livelihoods (FAO 2015; Guèye 2000; Mueller et al. 2015). Adopting fundamentals and practical principles from guidelines of rural poultry farming, FAO, and community-based interventions justifies why projects targeting rural communities are well placed for the IC sector in SSA.

Conclusion

In conclusion, indigenous chickens are an integral component of agriculture among resource-poor communities in Sub-Saharan Africa. These chickens have the potential to contribute to food and nutritional security, increase household incomes, and access to livelihood assets for small-scale farmers in the region. Addressing concerns about the loss of indigenous chicken genetic resources and the low socioeconomic gains among rural communities requires strategies that include the targeted communities. Researchers must consider the context of farming and production systems where communities thrive. Researchers and stakeholders need to share their views on current and future values of indigenous chickens with the full participation of rural communities.

Understanding available opportunities and challenges would enable stakeholders to design appropriate interventions whose outcomes include improved livelihoods, sustainable use, and conservation of indigenous chickens in Sub-Saharan Africa. Some notable areas that need urgent attention in the indigenous chicken sector include developing farmer skills in poultry management, productivity, value addition, disease control, and linkages to formal markets. A sustainable indigenous chicken sector would enhance rural livelihoods and increase the sustainable conservation and utilization of indigenous chicken breeds in Sub-Saharan Africa.

Recommendations

The extensive coverage of Zambia's poultry industry in this review may be a useful starting point for case studies there. Future research could examine consumer consumption habits and identify needs for the indigenous chicken market. We encourage government institutions and stakeholders to provide fundamental, practical knowledge of nutrition management to farmer groups to supplement semi-improved diets compounded from easily accessible and reasonably priced energy and protein-rich feed ingredients. Supplementing of feed is particularly crucial during the dry season when scavenged feeds are scarce.

Furthermore, we advise that the researchers, stakeholders, and community in Sub-Saharan Africa to practice the selection of best-performing breeding stock from within the current indigenous chicken breeds to promote overall flock performance while maintaining the adaptive traits of these breeds. We also advise investigating the impact of poultry diseases, poor market access, and COVID-19 on the indigenous chicken sector and the adaptive capacities of rural

communities since 2020. Such studies would advance our understanding of rural communities' sustainability, recovery, and resilience strategies.

Data availability

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Open Peer Review

Current Peer Review Status: ✗ ?

Version 4

Reviewer Report 22 May 2023

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?

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The paper explores the strategies for promoting the utilisation and conservation of indigenous chickens from Sub-Saharan Africa via deep investigation. The review introduced the importance of indigenous chicken industry in SSA and the use of indigenous chicken in SSA and the threats to the indigenous chicken in SSA. The review is relatively complete, which contained comprehensive thinking for the current status of indigenous chicken in SSA. I have several recommendations to this paper.

Q1: The development of indigenous chicken can be supported by both government and small-scale farmers. But the benefits of farmers should be increased. The benefits are influenced by productivity of breeds, the quality of products(meat and egg) and the efficiency of feed management. So the bottleneck of the indigenous chicken development might be discussed from the above aspects.

Q2: The loss of AnGR appeared in all the world, which was led by high productivity of commercial lines and the changing environment. How to solve this problem? How to balance the productivity

and conservation? Some strategies and recommendations should be come up.

Q3: The pressure brought by he increasing cost of feeding is another threat. Breeding and management are both important. Improving the FCR is a pathway to solve it. The author can discuss it from this insight.

Is the topic of the review discussed comprehensively in the context of the current literature?
Partly

Are all factual statements correct and adequately supported by citations?
Yes

Is the review written in accessible language?
Yes

Are the conclusions drawn appropriate in the context of the current research literature?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Protection and utilization of poultry germplasm resources

We confirm that we have read this submission and believe that we have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however we have significant reservations, as outlined above.

Author Response 29 May 2023

Christopher Kanyama

Our responses to questions and suggestions made by reviewers in the report in this link: https://f1000research.com/articles/11-251/v4#referee-response-170653

In response to the reviewer's questions and suggestions, we refer to the Reviewer Report on Version 4 of our review article, which the corresponding author and co-authors received on 22 May 2023, also attached.
22 May 2023 | for Version 4
Yadong Tian, College of Animal Science and Technology, Henan Agricultural University, Zhengzhou City, Henan Province, China
Wenting Li, College of Animal Science and Technology, Henan Agricultural University, Zhengzhou City, Henan Province, China

The reviewers introduced their report as stated below:
The paper explores the strategies for promoting the utilisation and conservation of indigenous chickens from Sub-Saharan Africa via deep investigation. The review introduced the importance of indigenous chicken industry in SSA, the use of indigenous chicken in SSA,

and the threats to the indigenous chicken in SSA. The review is relatively complete which contained comprehensive thinking for the current status of indigenous chicken in SSA. I have several recommendations to this paper.

They asked mainly three questions and made some suggestions, as stated in the report. We recognised the importance of the questions and the value added to our review article. We shall state each question asked and respond according to the order they were presented.

Q1: The development of indigenous chicken can be supported by both government and small-scale farmers. But the benefits of farmers should be increased. The benefits are influenced by the productivity of breeds, the quality of products (meat and egg), and the efficiency of feed management. So the indigenous chicken development bottleneck might be discussed from the above aspects.

Our Response to Question 1:
In our review article, we have identified the government as a significant stakeholder in the development of the poultry industry. For example, the government mainly provides policy direction and infrastructure development for the industry, as shown in Zambia during the 1991-2005 agriculture reforms. These reforms promoted active private entities' participation in the agricultural and poultry sectors. We also demonstrated how governments in other parts of SSA had implemented policies to protect the local poultry industry using policies tailored to that objective. For example, Namibian Government restricted the importation of poultry products in 2018 to protect the local poultry sector.

In the same way, governments are mandated to provide extension services that would improve farmers' skills in terms of poultry management, disease control, enhancing nutrition using abundant feed resources, value addition, and expanding agribusinesses that contribute to their livelihoods. As we stated in the paper, mobilizing farmers into organized groups and cooperatives would make it easy to provide the required skills, monitor progress and funds aimed at improving the indigenous chickens sector regarding productivity (quantity), value addition (marketing and quality) and profitability (reasonable pricing and organised outlets). Livingston et al. (2011) stress the need for farmers to belong to established groups or cooperatives for easy access to services and funding opportunities in the future.

Q2: The loss of AnGR appeared in all the world, which was led by the high productivity of commercial lines and the changing environment. How to solve this problem? How to balance the productivity and conservation? Some strategies and recommendations should be come up.

Our response to Question 2:
Several studies agree on the suitability of indigenous chickens among resource-poor rural farmers in Sub-Saharan Africa. These chickens are easy to manage due to their low-input-low output nature. However, factors such as the farmers' financial status would affect farmers' decision to adopt either commercial or semi-improved exotic or indigenous chicken breeds. If they choose improved exotic chickens, they must adjust the nutrition, disease control, and marketing according to the management demands for the type of

chickens. Research has demonstrated that exotic free-range chicken breeds perform well, grow quicker, and are slightly bigger than indigenous chickens.

However, with the increased flock size, exotic free-range chickens' management demands are higher regarding feed supplementation and disease control (Rodríguez et al., 2011). We also recommended that to maintain the adaptive traits, which took thousands of years to develop in indigenous chickens, researchers, government, and stakeholders are encouraged to promote selecting the best-performing parent stock of IC from within existing IC breeds. Selecting within a breed will cushion the contamination attributed to uncontrolled crossbreeding and the introduction of new chicken breeds among rural farmers.

Q3: The pressure brought by the increasing cost of feeding is another threat. Breeding and management are both important. Improving the FCR is a pathway to solve it. The author can discuss it from this insight.

Our response to Question 3:
It is well known that indigenous chickens are relatively poor feed converters compared to commercial chickens' strains. However, supplementing these chickens with improved feeds positively affects their overall performance. That is why in our reviews' recommendations, we outlined how extension services could impart skills on nutrition and simple feeds compounded using locally available resources of feed ingredients. We have also highlighted that government plays a crucial part in ensuring that farmers are skilled in indigenous chickens and agribusiness gross margin analysis to determine the profitability of their farming enterprises.

Conclusion:
We hope that our responses adequately addressed the concerns raised by the reviewers of our article, including the international guidelines on the conservation and use of Animal Genetic Resources provided by the Food and Agriculture Organisation (FAO, 2015). We also state that the paper highlights several strategies to improve the performance of the indigenous chicken sector in Sub-Saharan Africa.

Competing Interests: No competing interests

Version 2

Reviewer Report 15 June 2022

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I have read the revised paper and acknowledge that the authors have addressed some of my previous suggestions. The paper, however, still needs improvement before it can be indexed in an international scientific journal. First, the manuscript needs thorough editing for grammar, tense and punctual errors. These errors are just too many to mention one by one. **I also suggest that, to ensure that ALL comments are addressed, the authors should include a response to reviewer letter that specifies how they addressed each of the comments below**.

Although there is improvement, I am still concerned about flow of ideas in the manuscript. As I indicated my previous comments, all sentences in a single paragraph should be supporting the main idea of the paragraph. For example, page 5 second last paragraph, what is the main idea of the 'paragraph'? Page 7 Paragraph 1 under "Diseases and poor nutrition", diseases and nutrition could be discussed in two different paragraphs. Without well-written paragraphs that flow logically from one idea to the next, the manuscript will be difficult to comprehend.

There is repetition in the document. For example, the section on "diseases and poor nutrition" briefly highlights nutritional challenges faced by the indigenous poultry sector in sub-Saharan Africa but there is also another section on "nutritional challenges".

Paragraphs 2 and 4 on page 5 also have repeated information. There is more information which I think is repeated in the document, try to rectify this.

Page 3 paragraph 2 - Why are small stock important in the face of climate change? In this paragraph or the next one (I think these two paragraphs should be combined – see comment on paragraphing), authors should justify why the focus is on indigenous chickens.

Page 4 Paragraph 1 - "This paper highlights the role of indigenous poultry…". Shouldn't it be "indigenous chickens"? These terms are used interchangeably throughout the document. This should be corrected. The same applies to the terms IC-AnGR and AnGR.

I think the section on "roles of agriculture and the value of indigenous chicken genetic resources in low-income countries" should be replaced by something like "The Sub-Saharan poultry industry" or "The Zambian poultry industry". The section should mainly discuss the structure of the poultry industry including statistics, need be.

Page 5 Paragraph 1 - The statistics given here are just too old. Some over thirty years ago. Do they still hold value? Just like I emphasized in my previous comments, it is important that authors use young literature throughout the review.

Page 6 paragraph 2 - The topic is on chickens, but authors discuss guinea fowls in this section. Digression.

The section "Zambia's poultry industry" can be merged with section on "roles of agriculture and the value of indigenous chickens…" and renamed "The Sub-Saharan poultry industry" or "The Zambian poultry industry". See comment above.

More literature should be covered on the indigenous chicken breeds found in Zambia. Which breeds are common? Their performance? Are there pure breeds?…etc.

Page 9 - I suggest you include a subtopic on strategies to improve indigenous chicken production in Sub-Saharan Africa or Zambia. Maybe this can replace "research innovation and application"?

Is "increased consumer demand for indigenous chickens" a strategy to increase indigenous chicken production?

I am failing to understand how subtopics such as "increased consumer demand for indigenous chickens", "population growth and food demand", "food consumption patterns" fit under "research innovation and application"

Page 9 paragraph 4 - The statistics in the last sentence is outdated, from 21 years ago.

Page 9 paragraph 5 - what is the meaning of the phrase 'period under review"? this should be corrected throughout the document. The sentence "…US$1 was equivalent…" should be deleted. In this paragraph, authors highlight an important point that there is a market gap for indigenous chickens. So how can this market gap be addressed? Are indigenous chickens producers aware of this gap? I think the creation of market linkages can be a very useful strategy in promoting sustainable productivity of indigenous chickens in SSA. Authors might want to comment on this

Page 10 - Maybe the subtopic " Farmer mobilisation and sustainable interventions" can be changed to "intervention strategies for…"

Page 10 paragraph 1 - Authors highlight the issue of loss of IC-AnGR. IC-AnGR should be defined on first mentioning in text. This should be the case with all abbreviations and acronyms.
The loss of indigenous chicken breeds and strains is a big challenge in SSA. Authors should include more literature on this under the subtopic "Threats to the indigenous poultry sector in Sub-Saharan Africa". Why are some of challenges highlighted here (continued loss of IC-AnGR, lack of skills in animal management and absence of value addition) not discussed in detail under the subtopic "Threats to the indigenous poultry sector in Sub-Saharan Africa"?

Page 10 paragraph 2 - Authors tend to revert to discussing livestock and AnGR in general. They should focus on indigenous chickens. As I emphasized in my previous comments, authors should find a logical way to order and link their sentences, paragraphs and sections of the review. I would expect the review to start with a very brief broad background on livestock or just indigenous

livestock, move on to poultry and then narrow towards indigenous chickens, not the other way round.

Page 10 paragraph 2:

- What exactly is involved in CBIPDP and CBBP?
- "Examples of community-based interventions"...should that be a subtopic?
- "Outcomes of CBBP" authors should avoid using acronyms in subtopics

Page 11 Paragraph 1 - For CBBP, authors gave examples for sheep and goats, are there any examples for chickens? Is the African chicken genetic gain program which covers countries such Zimbabwe and Kenya a good example? Authors should highlight what exactly is involved in these CBBP for chickens. The subtopic is on CBBP but authors go on to discuss vaccination programs under the same subtopic.

Chicken vaccination programs in SSA, including Zambia, should also be discussed. Check Dumas *et al*. (2017)[1] and the Mawa project in Zambia.

Page 11 Paragraph 2 - The reference "Mueller" should be cited correctly.

Page 11 Paragraph 3 and 4 - See my comment on paragraphing above.

Page 11 Paragraph 6 and 7 - Contextualize.

References

1. Dumas S, Lungu L, Mulambya N, Daka W, et al.: Effect of sustainable poultry interventions on household food security and resilience in game management areas of Zambia's Luangwa Valley: a before-and-after study. *The Lancet Global Health*. 2017; **5**. Publisher Full Text

Is the topic of the review discussed comprehensively in the context of the current literature?

Partly

Are all factual statements correct and adequately supported by citations?

Partly

Is the review written in accessible language?

Partly

Are the conclusions drawn appropriate in the context of the current research literature?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Sustainable livestock production

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Author Response 04 Jul 2022

Christopher Kanyama

The reviewers' report made important observations and offered helpful guidance. The following are our responses to concerns raised by the reviewer.

1. The paragraphs that had repetitions were either revised, summarized or merged. For example, the two paragraphs covered nutritional challenges and disease and poor nutrition. The same was done for some repeated information (deleted, or revised).

2. In the paragraph addressing small livestock on page 3 the paragraphs were combined and justification for promoting sustainable use of indigenous chickens was highlighted.

3. Page 4: The use of AnGR and IC- AnGR was rectified and consistently used throughout the article.

4. Section on the role of agriculture, we focused on The sub-Saharan poultry industry with some instances of figures from selected countries including Zambia.

5. Page 5: The old statistics revisited and replaced with more recent statistics/ new literature, particularly on the proportion of indigenous chickens to the national flock, egg production per year and per capita egg consumption for selected countries in West, Southern and East Africa.

6. We changed the subtitle for the role of agriculture to the poultry industry in Sub-Saharan Africa's poultry industry

7. Page 6, paragraph 2: data on guinea fowls was revised as it was misplaced in the text.

8. The section on Zambia's Poultry industry was merged with roles of agriculture or SSA's poultry industry.

9. Common breeds are those highlighted in the paper. However, the literature on the performance of these Zambia indigenous chicken breeds is not adequately documented. Although the ministry booklets have some unpublished performance data. Should this be used?

10. Page 9: research innovation was replaced with opportunities and strategies to improve the indigenous chicken sector in SSA-This enabled us to cover the current status which translates into opportunities and strategies that included community-stakeholder engagements.

    - Population growth, increased demand and consumption patterns were considered opportunities for small-scale farmers to sell their chickens and chicken products because the demand is likely to be driven by those factors.

    - Outdated statistics were deleted.

    - Term period under review and the exchange rate was deleted from the text. And the creation of market linkages was considered as one of the possibilities when mobilizing farmers through community stakeholder engagements.

    - Farmer mobilization was included as a sub-heading under sustainable interventions.

    - Searched for possible additional literature on the loss of indigenous chickens Animal genetic resources (IC-AnGR)- -More common ones and details are from biodiversity status reports by FAO (2007/2015).

    - The mention of other indigenous livestock was mainly useful in illustrating instances where Community-based interventions have worked in low-income countries and what challenges have been faced in those regions.

    - Community-based programs are interventions that emanate from engagements between the researcher and the community. The main objective is to address a challenge related to indigenous livestock and breeding potential. So, solutions are created by researchers working together with farmers. The Community based indigenous poultry development program was a concept which would use some common principles found in CBBP such as working with small-scale farmers and focusing on Indigenous livestock breeds etc

    Page 10: Acronyms were removed from most parts of the paper except the following: SSF, IC. IC-AnGR etc because of the number of these terms used in the paper.

11. Page 11: So community-based breeding program was taken as community-based interventions

    - The approaches to interventions by Duma et al. (2017) was a very good example of a community-based intervention approach in that there is engagement between the researcher and the community when designing solutions. This was very helpful.

    - Mueller was cited properly as Mueller et al. (2015).

This concludes our responses to the queries raised by the reviewer. We hope that would help.

Competing Interests: None

Version 1

Reviewer Report 08 April 2022

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The manuscript entitled “Strategies of enhancing rural livelihoods and promoting sustainable use and conservation of indigenous chicken breeds in Zambia” discusses the importance of and ways to improve indigenous chicken production in Zambia. I think the effort is useful and provides a perspective on the role of indigenous chickens on resource-poor households in Zambia. I am, however, concerned about the organization, readability, and flow of ideas in the manuscript. The manuscript is difficult to comprehend and needs to be edited carefully. I encourage the authors to improve the manuscript after paying attention to the comments below:

- I suggest “Strategies of promoting sustainable use and conservation of indigenous chicken breeds in Zambia” as the title.

- Generally, although it is important to make the review of broad interest, the authors should avoid digressing. The topic and objective suggest that the review is on indigenous chicken production in Zambia, but the manuscript ended up covering the whole of Sub-Saharan Africa and even other countries such as Ghana, Senegal, Kenya, Gambia, Morocco, Nigeria, Tanzania etc. While it is important to compare indigenous chickens production in Zambia to other developing regions, it is more important not to lose focus.

- The authors need to find a logical structure for the review. There is no clear flow of ideas. For example, the introduction starts with a discussion/background on chicken production and then, in paragraph 3, the focus shifts to goats, sheep and poultry in general. The authors then go back to indigenous chickens in the last paragraph. Initial sections of the review were on indigenous chickens but broadened towards all livestock or, maybe, all indigenous livestock. Authors should find a logical way to order and link the sentences, paragraphs and sections of the review.

- The document has too many acronyms. This makes reading and understanding the manuscript difficult. Acronyms such as RPF, IC, RCS, IPS, SSF, AER, ARF, FRS and SIS can be avoided.

- Throughout the document, some statements/facts are not backed by relevant citations.

- Paragraph 1, line 8 – "...IPS in Zambia and parts of SSA". Is Zambia not part of SSA? Authors should also justify why the review focuses on Zambia in the same paragraph

- Paragraph 1, line 9 - "Therefore, the main objective of ..." should be changed to "Therefore, one of the main objectives of ..."

- The section entitled "Agriculture and indigenous chickens" focuses on chickens. Less, if anything, is on other agricultural practices. The title should be revised.

- Page 4, Paragraph 2 - Avoid starting a paragraph with the word "therefore". Paragraphing in the manuscript needs to be improved. A paragraph should start with a "topic sentence" which introduces the idea to be discussed in the paragraph and the rest of the sentences in the paragraph should be linked to or be an expansion of the topic sentence.

- Page 4, paragraph 3 - What is the difference between this section and the preceding section?

- Page 4, paragraph 3, line 8 - Is livestock production not part of agriculture?

- Page 4, paragraphs 5 and 6 - Does this fit into the sub-topic "Use of agriculture and indigenous chickens among rural communities"? I also think the last three paragraphs on this page are more like repetition, or can fit well in previous sections.

- Page 5, paragraph 1 - What is the difference between this section and the proceeding one?

- Some of the references used on the production statistics are too old. Surely production statistics reported in 1989 and 1984 would have changed by now? Authors should use mostly young literature throughout the document. Some of the sections, e.g. paragraph 4, lines 7- 9, do not add value to the review and should be deleted.

- The last paragraph on page 6 can be summarised into one sentence.

- Page 7, paragraph 2 - The subtopic is incomplete. In Zambia? SSA? How does the last

sentence fit into the paragraph? Any link with the preceding sentence?

- Page 7, paragraph 7 - The sentence "…. there are beneficial adaptability and genetic gains…" contradicts sentences in the preceding paragraph. If the chickens are adapted, then why is the mortality rate high?

- Page 7, paragraph 8 - Isn't this repetition? The preceding section also includes nutritional challenges (at least according to the section heading). Southern Africa is rich in supplements for indigenous chickens. Communal farmers grow crops such as sorghum, finger millet sunflower and millet which can be used to feed chickens. Some of these crops are drought resilient. Is nutrition really a big problem for indigenous chickens under communal systems in Sub Saharan Africa? Maybe when it comes to commercialization of the indigenous chickens.

- Page 8

  Revise subtopic "Low policy for…."

  Some of the prices quoted were reported 5 years ago? Are the prices still the same now?

  Authors may also comment on the issue of market linkages

- Page 9 - What is the link between the section on "research applications" and preceding linkages? The subtopic is also not clear. Does it reflect on the contents of the section?

Is the topic of the review discussed comprehensively in the context of the current literature?
Partly

Are all factual statements correct and adequately supported by citations?
Partly

Is the review written in accessible language?
Yes

Are the conclusions drawn appropriate in the context of the current research literature?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Sustainable livestock production

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Author Response 09 Apr 2022

Christopher Kanyama

RESPONSE TO REVIEWERS REPORT

This is the response to the reviewers report and guidance provided by Zindove T.J (2022) with reference to our review article entitled: Strategies of enhancing rural livelihoods and promoting sustainable use and conservation of indigenous chickens in Zambia [version 1].

On behalf of my fellow authors, I acknowledge receipt of the report and appreciate the valuable guidance provided by the reviewer.

We shall definitely consider the suggestions and guidance given with the aim of improving the quality of content to the required scientific standard.

Looking forward to future engagements.

Kanyama C.M

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(09/04/2022)

Competing Interests: No competing interests disclosed