Journal of Agriculture Science & Technology JAGST 25 (2) 2026, 207 – 224

REVIEW ARTICLE

Genetic and morphological diversity of indigenous chicken of Kenya: A Review

Mathew G. Gicheha[1], Moses M. Gikunju[2], Ouko, O.V[2], Vincent Mwashi[1]

[1]*Department of Animal Sciences, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya.*
[2]*Department of Animal Sciences, Egerton University, Njoro, Kenya.*

Corresponding author email: gichehag@gmail.com

Abstract

This review was conducted to identify evaluate and characterize genetic diversity of indigenous chicken in Kenya. Indigenous domestic chickens (IC) are often reared under the traditional scavenging system by small-holder farmers in developing countries. In Kenya, IC remains the most popular and contributes towards food security in the rural areas as 90% of the Kenyan farmers are involved in poultry rearing, with IC supplying 40% and 60 % of the marketed eggs and meat respectively. The popularity of IC among the resource poor rural households is attributed to their low production costs, better adaptability to poor quality feeds and harsh scavenging conditions and higher tolerance to parasites and diseases. Their productivity is normally low due to poor feed conversion efficiency, low adoption of modern technologies and genotype. The improvement, utilization, sustainable management and conservation of a particular population of domestic animals necessitate its characterization. The first step for characterization of local genetic resources requires an understanding of various morpho biometrical traits between and within populations. Variations among individuals or groups, provide a basis for breeding and selection. There are several genetic improvement programs in Kenya that are focusing on improvement of a varied range of traits; production, disease resistance among others. Several ecotypes of indigenous chickens exist with a variety of genes that determine their phenotypic and productive traits. There exist a variety of ecotypes in Mombasa County; frizzled feathered, naked neck, barred feathered, mauve feathered, black feathered and dwarf size birds. While Kuchi ecotype has been recorded in Lamu and Marakwet Counties in Kenya. A wide range of phenotypic variations exists between the IC ecotypes. This could be as a result of extreme inbreeding and crossbreeding with exotic ecotypes. There has been a shift from the use of morphological characterization to molecular based approaches for purposes of accuracy. The molecular approaches have the capacity to determine genetic diversity between or within populations and their ancestry. In East Africa, numerous studies have been done to evaluate genetic diversity and relations between populations of indigenous chicken. East African IC are closely related genetically and clearly distinct from their commercial counterparts. Molecular tools like genetic markers especially microsatellite markers have been used to determine the genetic background of indigenous chicken. Most evaluation studies involving indigenous chicken in Kenya have been undertaken. The variations in the indigenous chicken ecotypes are an important aspect for future breeding programs. Therefore, these chickens denote a rich genetic diversity that requires intensive characterization for breeding

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v25i2.11

and conservation purposes.

Keywords: Indigenous chicken (IC), Genetic evaluation, Characterization, Ecotypes.

1.0 Introduction

Indigenous chickens (*Gallus domesticus*) refer to chickens that are adapted to harsh environmental conditions that include free-range, extensive small-scale village and organic production systems. Such chickens are sometimes called backyard, traditional, village, scavenging, local or family chickens (Mahendrah 2016). Indigenous poultry farming involves rearing of chicken (*Gallus domestics*) under a low input production system (Menge et al 2005). Addis et al (2014) also reported that these large populated indigenous chickens are still found in extensive production system. In comparison with the exotic chickens, indigenous chickens are characterized by poor performances (Bogale, 2008). They are among the most abundant and widely spread domestic animals (Lawler 2014). Their uses diversify greatly ranging from anthropometric purposes like ornamentation and entertainment to biomedical research and constitute an important source of protein (both meat and eggs) (Wu and Kaiser 2011). In developing countries, indigenous domestic chicken is often reared under the traditional scavenging system by small-holder farmers (Desta et al 2013). Their popularity emanates from tolerance to common poultry diseases and adaptability to fluctuations in both feed quality and quantity and requirement of minimum or no input (Desta and Wakeyo 2012). They exhibit a wide spectrum of phenotypic and morphologic properties because of the natural and artificial selection (Wragg et al 2012). Therefore, these chickens denote a rich genetic diversity that requires intensive characterization for breeding and conservation purposes (Dessie et al 2011).

In Kenya, indigenous chicken forms an integral part of many households and are a valuable asset in terms of food security, economic and social roles (Magothe et al 2012a, b). They play a significant role in alleviating poverty. However, various challenges face the production of indigenous chicken and these contribute to the low production of the birds. In the region, feed supply varies seasonally and has been identified as a major constraint to productivity (Besbes 2009). Of the total production costs in poultry enterprises, feed accounts for about 60–70%. Hence, there is need for efficient feed use since it directly affects profitability of the production units (Aggrey et al., 2010), by providing the necessary nutrient for eggs and meat production. In the free-range production system, these requirements are not met adequately due to the low inputs associated with the scavenging system. In indigenous chicken production, it is therefore important to evaluate the systems used and extra effort put in the management of the indigenous chickens in terms of supplementary feeding and genetic selection (Kingori et al 2010). Despite the high productivity of exotic breeds, the indigenous chicken (IC) remains popular in Kenya and contributes towards food security in the rural areas (Kingori et al 2010). 90% of the Kenyan farmers are involved in poultry rearing, with indigenous chicken supplying 40% and 60 % of the marketed eggs and meat respectively (Ochieng et al 2013). The popularity of IC among the resource poor rural households is attributed to their low production costs, better adaptability to poor quality feeds and harsh scavenging conditions and higher tolerance to parasites and diseases (Okeno 2013). For the majority of the people living in the rural areas, the indigenous chickens are important source of quality meat and eggs as food and cash income

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v25i2.11

(Njenga 2005). Generally, indigenous chickens are multicolored, long legged and smooth feathered with a few naked necked, fizzled feathered and dwarf birds (Njenga 2005). The challenge of fighting malnutrition and poverty can be effectively met to a large extent by strengthening indigenous chicken production (Sharma 2007) that is practiced in many developing countries. There are about 32.5 million chickens in Kenya with 22 million being indigenous (FAOSTAT 2014) which is about 70% of all the poultry reared in Kenya (King'ori et al 2010). The farming of indigenous poultry contributes up to 1.7% of the country's GDP which is about 30% of the total agricultural GDP (Ochieng et al 2013). In the world, rearing of indigenous chickens (IC) is also estimated to contribute 30% of white meat whereas in Kenya, it accounts for 47% of eggs and 55% of meat respectively (FAO 2012; Kingori et al 2010).

Due to poor feed conversion efficiency, low adoption of modern technologies and genotype, the productivity of indigenous chicken is normally low (Khobondo et al 2015). Minor considerations have been given to IC by researchers, decision and policymakers in research and development plan (Mahoro et al 2017). The improvement, utilization, sustainable management and conservation of a particular population of domestic animals necessitate its characterization (FAO 2007). For characterization of local genetic resources, the first step requires an understanding of various morpho biometrical traits between and within populations (FAO 2012). Variations among individuals or groups, provide a basis for breeding and selection (Faruque et al 2010). In Kenya, studies on the phenotypic characteristics of IC have been conducted (Ngeno et al 2014), and increased production of IC have been reported (1) mainly due to increase in human population, technology advancement and reduced land resources (Martin 2000). This started in the early 1960's with the introduction of exotic breeds in the country that included the Rhode Island Red, New Hampshire Red, White Leghorn, Black Australorp and White Sussex (FAO 2007). In 1976, a genetic improvement initiative for the IC through the cockerel exchange program, under the National Poultry Development Programme (NPDP) was launched (Trail 1962). The program was terminated in 1994 with no studies to determine its achievements (Ngeno 2014; Magothe et al 2012a; Okeno et al 2013).

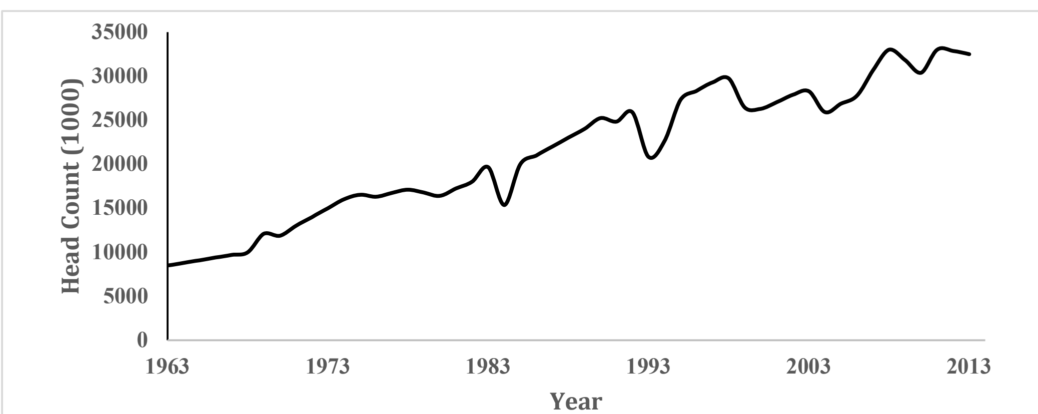

Figure 1: Chicken Production trend in Kenya (FAOSTAT, 2014)

The NPDP program was financed by the Danish International Development Assistance

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v25i2.11

(DANIDA). It however failed due to predestined dilution of indigenous ecotype and the inherent non-broody nature of the progeny (Bebora et al 2005; Magothe et al 2012a). Other factors that contributed to the failure are; in compatibility with low-input systems, lack of clear breeding objectives and operational breeding programs (Ngeno 2014; Okeno et al 2012). It is however a possibility that this program contributed to the growth in IC population in Kenya and also lowered genetic diversity therein (FAO 2007). DANIDA later reintroduced program in two districts in Kenya using the Bangladesh model (Bebora et al 2005). A new model, where crossbreeding takes place on-station and the crossbreds are distributed to the smallholder farmers, was introduced by Danish International Development Agency (DANIDA) in 1999 After the village crossbreeding or upgrading programs failed. This model was implemented in countries such as Kenya, Burkina Faso, Malawi, Benin, Mozambique, Senegal, and South Africa (FAO 2010; Riise et al 2005). This model flopped in 2005 as its predecessors when DANIDA pulled out (Riise et al 2005). Poor planning led to the failures of these upgrading attempts due to inefficient flow of inputs, lack of self-sustainability of the program, and adaptation challenges of the chickens (Ndegwa et al 2012; Okeno 2013).

Currently, there are several ongoing genetic improvement programs at the National Animal Husbandry Research Station (NAHRS) in Naivasha. These programs are focusing on improvement of a varied range of traits; production, disease resistance among others (KARI, 2014). Another critical aspect in improving indigenous chicken in Kenya is the Agricultural Sector Development Strategy. It is therein envisioned improvements in various sectors of animal production including indigenous chicken breeding (GoK, 2010). For the advancement of present-day types of chickens, crossbreeding has been a noteworthy device and could be in like manner be used to enhance the rural chicken. Typically, crossbreeding methodology includes a cross between a local breed and an enhanced exotic with the point of joining the better creation limit of the previous with the later flexibility to a harsh environmental condition Khawaja et al (2013). In their study, Adeleke et al (2011) reported improved performance and viability traits in reciprocal effects in crosses involving exotic broiler breeder and local chickens. Along genetic lines, IC have been characterized for feather (such as frizzled feathered or normal), body structure (such as dwarf types, naked neck) and colour variants (such as black, white, brown, mottled etc.). Some of the major genotypes available include, frizzle, naked-neck, dwarf, crested-head, tailless bearded, normal feathered and feathered-shank (Njenga 2005). An ecotype refers to chicken from one area or agro-ecological zone as distinguished from another. The names are derived from ecological zones and regional names have been used in some areas (Gondwe 2005). There are several ecotypes of indigenous chickens with a variety of genes that determine their phenotypic and productive traits (Eskindier et al 2013). According to Njenga (2005), there exist a variety of ecotypes in Mombasa County; frizzled feathered, naked neck, barred feathered, mauve feathered, black feathered and dwarf size birds. There has also been

recorded Kuchi ecotype in Lamu and Marakwet Counties (Magothe et al 2012a; Chesoo et al 2013). There exists a wide range of phenotypic variations between the IC ecotypes in Kenya (King'ori et al 2010). This could be as a result of extreme inbreeding and crossbreeding with exotic ecotypes (Mwai et al 2005). It is however important to note that these chicken ecotypes are not only found in Kenya. They are also found in other countries in Sub-Saharan Africa

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v25i2.11

(Tadelle et al 2003; Msoffe et al 2001; King'ori et al 2010; Lyimo et al 2012).

A detailed morphological characterization of indigenous chicken in Kenya is given by King'ori et al (2010) and Magothe et al (2012b). Description of some of the major ecotypes is given herein.

2.0 Indigenous chicken genetic resources

2.1 The naked neck

This particular ecotype (Figure) has little or no feather coverage on the lower neck and hence the name 'naked neck'. This enables the birds to tolerate heat stress in tropical environment compared to their feathered counterparts (Nwachukwu et al 2006; Magothe et al 2010). The feather restriction gene results in less feather coverage of 20-30% overall (Islam and Nishibori, 2009). The genotypes are able to withstand high ambient temperatures and to utilize poor quality feeds which is a characteristic of free-range production system. The heat disseminating adaptation reduces the energy partitioned towards thermoregulation (Galal et al 2007). High temperature affects chickens because the feather insulates the bird and hinders internal heat dissipation. High temperature result to changes in metabolic, physiological and cellular levels in chickens. Excessive heat in turn leads to decrease in feed consumption and chicken weight consequently leading to low efficiency and productivity (Coble et al 2014). This is a challenge especially to chicken found in hot environments. To assess their performance in hot environments, several studies have been done on various chicken phenotypes. As indicated in a study by Cahaner et al (2008), the naked neck gene can be used to alleviate heat stress. Interestingly, the naked neck genotype has been shown to affect heat dissipation traits like the rectal and surface temperature measurements and wattle length (Chen et al 2008). Evidence in literature shows that genotypes (both exotic and indigenous) possessing the naked neck and frizzle genes, either singly or in combination have led to increased growth rates, superior body weights, better feed conversion, higher egg production and disease tolerance in tropical environments although little is known about the general characteristics and production, reproduction performances and genetic make-up of available indigenous chicken genotype (N'dri et al 2007; Islam and Nishibori 2009; Gicheha 2021). In such warm and humid or hot and dry regions in Kenya, these genotypes are predominant.

Located on chromosome 3, the naked neck gene (Na), has been linked to growth and differentiation factor 7 (GDF7). In the naked neck mutation, it is partly responsible for the control of feather inhibition (Headon 2013) and is characterized by either a fully featherless neck or featherless neck with a tuft of feather at the base of the neck and a reduction in the entire feather coverage by 20– 40%. Thermoregulatory properties have been found on the gene, Na, and therefore under very high ambient temperature conditions, birds carrying it are able to dissipate heat so that productivity in terms of eggs and meat would not be depressed through the reduced feed intake resulting from the difficulty in dissipating excess body heat as in normally feathered birds (Njenga 2005; Adomako et al 2011). In Kenya, feed quality is a limiting factor in poultry production (Okeno et al 2013). The naked neck ecotype has the ability to utilize low protein diets; a situation common to Kenya and other Sub-Saharan countries (Galal et al 2007). It has been documented to produce heavier eggs, larger clutch sizes and exhibited better feed efficiency compared to other indigenous ecotypes on the same diet (Adomako et al 2011; Fathi et al 2013). This ecotype is common in Narok, Turkana and West

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v25i2.11

Pokot (Okeno et al 2011).

2.2 The frizzled feathered

The feathers of this chicken ecotype do not lie smoothly backwards like in other ecotypes. Instead, they grow outwards and curl (Figure). The curled contour feathers make the bird unable to fly. The frizzling becomes visible as early as four days after hatching (Fathi et al 2013). In chickens exposed to high ambient temperatures, the frizzled genotype has also been studied. In poultry production, this gene has beneficial effects in decreasing heat stress (Zerjal et al 2013). In addition, in some communities, the frizzle genotype is associated with cultural practices (Njenga 2005). Utilizing the naked-neck, frizzle or naked-neck-frizzle genotypes in hot environments for meat, eggs or for dual purpose production, communities would be expected to increase live bird off take and egg yield without additional cost increases. In the cold environments, frizzled feathers inhibit insulation, for this reason, IC with frizzle feathered are disadvantaged relative to the normal feathered chicken (Fayeye et al 2006). Sørensen (2010), reported that in high temperature areas, frizzled IC performs well due to their ability to dissipate high heat as opposed to birds with normal feathers. Compared to other genotypes, frizzled and naked-neck birds have been described as more disease resistant. These genotypes have been revealed to have a higher total antibody titre compared to their normal-feather counterparts (Mahrous et al 2008). Compared to normally feathered genotype, Hamal et al. (2006) demonstrated the phagocytic ability of naked-neck and frizzled birds to be more efficient using Indian-ink. Therefore, the naked-neck and frizzled feathered can withstand some diseases. In Kenya this ecotype is common in; Turkana, West Pokot and Narok (Okeno et al 2011). This is due to the bird's ability to radiate heat through reduced insulation by the feathers (Hagan et al 2011).

2.3 Dwarf

The dwarf compared to frizzled and naked neck gene gene has been shown to have no value with regard to chicken tolerance to chronic heat stress (Deeb and Cahaner 2001). It's gene is known to increase egg mass production and feed efficiency (Yeasmin et al 2003). Due to better reproductive capacity, the dwarf genes are favoured by farmers. As a result of reduced body size, these birds have a lower feed intake and produce more eggs and less meat than their normal counterparts under farm conditions (Rashid et al 2005). This ecotype (Figure) has a smaller size than the other ecotypes in Kenya. Its body size is 20% to 30% smaller (Oke 2011). On productivity, the hens have small sized eggs, their chicks have a small hatching weight.They are also known to grow faster and fatter at the early age though they are surpursed by their conterparts after the growers period in matters of body size (Galal et al 2007). The small adult body size makes results to a reduced feed requirement for maintainance. Emperical research indicate the ecotype is adaptive to thermal stress common in hot and humid tropical environment (Chih-Feng et al 2009). It also has a high feed conversion efficiency and survivability (Rashid et al 2005).

2.4 Kuchi

The *Kuchi* ecotype is superior in terms of mature body weight and related traits. This ecotype (Figure) is a game-type chicken and has a higher body and egg weight in comparison to other

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v25i2.11

indigenous ecotypes (Lwelamira et al 2008; Lyimo et al 2013). It has longer shank and keel (Lyimo et al 2012). Furthermore, the Kuchi genotype is similar to the Kuchi ecotype of Tanzania (Msoffe et al 2001) and would be ideal for meat production in warm and humid low population density areas. The bird has characteristics of game chicken and would thus be better able to evade or fight off predators. In Tanzania, this ecotype has been recommended for meat production (Lwelamira et al 2008). This ecotype has been reported in Elgeyo Marakwet, Uasin Gishu and Lamu Counties in Kenya (Magothe et al 2012b; Chesoo et al 2013). Kuchi ecotype has been proved to be a viable source of income to farmers, in Elgeyo Marakwet County for instance consider this chicken a gateway out of poverty (Wesonga 2013). The disease resistant chicken weighs twice as much as conventional breeds and currently enjoys impressive uptake among poultry farmers for economic empowerment. According to the residents, when fully mature the chicken sells at Shs1500 and Shs2000 for the pullet and cockerel respectively while eggs retail at Sh30 compared to Sh8 to Sh10 of other breeds (Wesonga 2013). Furthermore, improving both the management system and their genetic potential through the selection and line-breeding towards meat traits can enhance performance of these chicken ecotypes. There is a need therefore to develop tailor-made indigenous chicken ecotypes towards the mitigation of the over-reliance to exotic genotypes for meat and egg production which is hitherto a drain of foreign exchange, disease risks and unmanageable costs of production. For further improvement towards meat traits, The Kuchi ecotype serves as a good starting genetic material (Magonka et al 2016; Chesoo et al 2014).

Figure 2: Some indigenous ecotypes in Kenya

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v25i2.11

Other chicken ecotypes including; Barred feathered, Mauve feathered, Feathered shank black feathered, Giant, Bearded and Crested head, have been described (Njenga 2005; King'ori et al 2010; Magothe et al 2012b; Okeno et al 2013). A recent study by Magothe et al (2010) showed that the crested-head , naked-neck and frizzle genes influenced growth patterns and body weights of indigenous chickens. As noted by the authors, the crested-head genotype had a lower growth rate and was lighter than the normal-feather genotype when subjected to the same level of management. The authors speculated that the crested-head genotype could be a superior egg producer Given that growth rate and egg production are negatively correlated. Utilizing these genotypes would therefore increase egg production without additional cost increases. Under all production systems, introducing the naked-neck, frizzle and crested genes into the dwarf genotype would be expected to improve egg production. The feathered-shank (ptilopody) and beard (ear tufts) are adaptations to cold environments (Bartels 2003). The ptilopody gene has been shown to increase body weight and egg mass although information on the bearded genotype is scarce in literature (Fayeye et al 2006). In very cold environments of the country, these genotypes would therefore increase egg and meat productivity. In environments where they are best adapted, utilising these genotypes would not only be in tandem with the socio-cultural uses of the birds but would also increase productivity and conservation (Nimbkar et al 2008). In Kenya, farmers have developed varried preference on the IC ecotypes. This preference is region dependant as illustrated in Table1.

Table 1: Mean ranking of importance in different counties in Kenya (1:4 = most important: least important)

Ecotypes	Counties						
	Siaya	Kakamega	Bomet	Narok	West Pokot	Turkana	Mean
Necked neck	2.15	1.95	2.19	2.15	2.27	2.06	2.13
Frizzled feathered	2.13	2.45	2.00	2.25	3.50	-	2.36
Crest head	1.95	1.94	1.89	1.88	1.73	1.80	1.87
Normal feathered	1.38	1.44	1.40	1.30	1.10	1.39	1.34
Shank feathered	2.25	1.92	2.25	3.25	2.50	2.50	2.31
Dwarf	2.83	2.17	2.67	2.33	2.50	3.00	2.55
Giant	2.10	2.15	2.38	2.29	2.00	2.05	2.16

Source: (Okeno et al., 2011)

3.0 Molecular characterization

The first step to be undertaken for the purpose of identifying threats and opportunities for holistic improvement is characterization of production systems (Mtileni et al. 2009). Characterization helps in understanding the production and management practices of farmers and the associated factors which are essential in developing improvement strategies. Rather than on-station experimental studies characterization studies should be conducted under on-farm conditions through baseline data collection (Abdelqader et al 2007). Molecular or genetic characterization can be defined as the procedures used to investigate relationships between

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v25i2.11

breeds, levels of variability and within-breed genetic structure, the genetic pattern of phenotypes and their mode of inheritance from generation to the next generation (Agarwal et al 2020). Molecular characterization of indigenous chickens helps to assess their origin and the geographic distribution of their diversity, provides new information to guide and prioritize conservation decisions for poultry (Agarwal et al 2020). There has been a shift from the use of morphological characterization to molecular based approaches for purposes of accuracy (Kios et al 2011; Ndegwa et al 2012; Mwacharo et al 2013b). The molecular approaches have the capacity to determine genetic diversity between or within populations and their ancestry (Subbiah et al 2010; Mwacharo et al 2011; Mwacharo et al 2013a). Despite this potential, very little has been done with respect to indigenous chicken in Kenya (Mwacharo et al 2011).

Molecular genetic characterization occurs either as microsatellite loci or mitochondrial DNA-loop sequences depending on the interests of the study (Mwacharo et al 2013b). In contrast to using morphological traits/measurements for characterization, DNA-based methods provide useful information about genetic diversity and are independent of environmental factors (Halima 2007). This holds particularly true for DNA-profiling methods, which are based on the microsatellite markers and polymerase Chain Reaction (PCR) (Tadelle, 2003 and Halima 2007). A number of studies have used microsatellites to address the biodiversity in commercial as well as rare breeds. The PCR technique is a primer extension reaction for amplifying specific nucleic acids in vitro (Besbes 2009). In PCR reaction, the sources of DNA used can be genomic DNA from whole blood or tissue, or forensic specimens and ancient biological sample. PCR is a powerful technique that allows amplifying DNA sequence millions of times in just a few hours (Meseret 2010).

In East Africa, numerous studies have been done to evaluate genetic diversity and relations between populations of indigenous chicken (Mwacharo et al 2007; Hassen et al 2009; Lyimo et al 2013; Mwacharo et al 2013a). East African indigenous chicken are closely related genetically and clearly distinct from their commercial counterparts (Mwacharo et al 2013a). Within the evaluated populations Marsabit Indigenous chicken exhibited significant uniqueness and could be categorized as an important genetic resource (Mwacharo et al 2007). Mwacharo et al (2007) described the Kenyan indigenous chicken as being grouped into four clusters; Coastal, Central, Northern and Western Kenya groups. Other studies have been done using mitochondrial DNA-loop and clustered village poultry into three distinct gene pools (Mwacharo et al 2013a).

4.0 Genetic evaluation

To determine the genetic background of indigenous chicken, molecular tools like genetic markers especially microsatellite markers have been used (Ngeno et al 2014). The genetic diversity of IC has been assessed using molecular markers including microsatellites in various parts of the world (Huo et al 2014). In the evaluation of genetic diversity in chicken, use of thirty (30) microsatellite markers has been suggested by the Food and Agriculture Organization (Pandey et al 2002). Since the early 1990s, studies of genetic diversity and population structure have utilized microsatellite markers for a wide range of applications and have remained the most commonly used markers (Li et al 2002) due to their high degree of polymorphism,

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v25i2.11

codominance, random distribution across the genome and neutrality with respect to selection (Putman and Carbone 2014). Additionally, they offer more population genetic information per marker and are relatively cheaper to genotype than single nucleotide polymorphisms (SNPs) known as biallelic markers. Microsatellites can successfully amplify low-quality DNA samples or low DNA concentration (Gärke et al 2012).

Most evaluation studies involving indigenous chicken in Kenya have been undertaken Egerton University and The University of Nairobi (Magothe et al 2010; Okeno et al 2011; Chesoo et al 2013). This has been in collaboration with other research institutions including; Kenya Agricultural Research Institute (KARI), Agricultural Development Corporation (ADC) and International Livestock Research Institute (ILRI) (Mwai et al 2005; FAO 2007). A detailed description of indigenous chicken traits in Kenya is given by King'ori et al (2010) and Magothe et al (2012b).

5.0 Conclusions

Several achievements have been made in Kenya in characterization and genetic evaluation (Kahi et al 2000; Gicheha et al 2007; Okeno et al 2012). However, there exist weak characterization and evaluation of indigenous chicken (FAO 2007; Magothe et al 2012a). Despite this, the variations in the indigenous chicken ecotypes are an important aspect for future breeding programs (Bebora et al., 2005). Future prospects for this industry include; supportive policy, extension services, feeding and general husbandry, disease control and genetic improvement (Magothe et al 2012a).

6.0 Acknowledgments

6.1 Conflict of interest

The authors declare that there is no conflict of interest.

7.0 References

Abdelqader A, Wollny C B and Gauly M 2007 Characterization of local chicken production systems and their potential under different levels of management practice in Jordan, Tropical Animal Health and Production, volume 39, pages, 155–164. doi.org/10.1007/s11250-007-9000-x

Adeleke M A, Peters S O, Ozoje M O, Ikeobi C O, Bamgbose A M and Adebambo O A 2011 Growth performance of Nigerian local chickens in crosses involving an exotic broiler breeder. Tropical Animal Health Production, Volume 43, pages, 643–650. doi.org/10.1007/s11250-010-9747-3

Addis H, Zewdu W and Hailu M 2014 Breeding practice and objective of indigenous chicken in North Wollo, Amhara, Ethiopia. International Journal of Livestock Production, volume 5, pages 15-22. doi.org/10.5897/IJLP12.0002

Adomako K, Hagan J K and Olympio S O 2011 Egg production performance of first and second filial generation naked neck (NaNa, Nana) and normal feathered (nana) birds of a cross between indigenous naked neck (NaNa, Nana) males and exotic commercial females (nana). Livestock Research for Rural Development. Volume 22, Article #223. Retrieved

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v25i2.11

February 23, 2022, from http://www.lrrd.org/lrrd22/12/adom22223.htm

Agarwal S, Prasad S, Kumar R and Chandra S 2020. Molecular characterization of native chicken: prospects and challenges. Journal of Entomology and Zoology Studies volume 8, pages 103-106. www.entomoljournal.com

Aggrey S, Karnuah A, Sebastian B, and Anthony N 2010. Genetic properties of feed efficiency parameters in meat-type chickens. Genetics, selection, evolution. Volume 42 pages 25. doi.org/10.1186/1297-9686-42-25

Bartels Thomas 2003. Variations in the morphology, distribution, and arrangement of feathers in domesticated birds. Journal of Experimental Zoology Part B: Molecular and Developmental Evolution. Volume 15, pages 91-108. doi.org/10.1002/jez.b.28.

Bebora L C, Mbuthia P C, Macharia J N, Mwaniki G, Njagi L W and Nyaga P 2005. Appraisal of Village Chicken's Potential in Egg Production. A Journal of The Kenyan Veterinarian, pages, 10-13. doi.org/10.4314/kenvet.v29i1.39587

Besbes B 2009 Genotype evaluation and breeding of poultry for performance under suboptimal village conditions. World's Poultry Sciences Journal, volume 65, pages, 260-271. doi.org/10.1017/S0043933909000221

Bogale K 2008 *In situ* characterization of local chicken ecotypes for functional traits and productions stems in Fogera Woreda, Amhara regional state. A Thesis submitted to Haramaya University. Ethiopia, pages, 123. Retrieved February 23, 2022, from https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.565.2736&rep=rep1&type=pdf

Cahaner A, Ajuh J A, Siegmund Schultze M, Azoulay Y, Druyan S and Valle Zarate 2008 Effects of the Genetically Reduced Feather Coverage in Naked Neck and Featherless Broilers on Their Performance Under Hot Conditions. Poultry Science, volume 87, pages, 2517–2527. doi.org/10.3382/ps.2008-00284

Chen C F, Huang N Z, Gourichon D, Lee Y P, TixierBoichard M and Bordas A 2008 Effect Introducing the Naked Neck Gene in a Line Selected for Low Residual Feed Consumption on Performance in Temperate or Subtropical Environments. Poultry Science, volume 87, pages, 1320–1327. doi.org/10.3382/ps.2008-00002

Chesoo B K, Oduho G W, Kios D K and Rachuonyo H A 2013 Evaluation of three management systems on growth performance of Kuchi indigenous chicken ecotype of Kenya. African Journal of Education, Science and Technology, volume 4, pages, 170-174. http://erepository.uoeld.ac.ke/bitstream/handle/123456789/1511/CHESOO%20BENJAMIN%20KIPROP.pdf?sequence=1&isAllowed=y

Chih-Feng C, David G, Nein-Zu H, Yen-Pai L, André B and Michèle T B 2009 Performance comparison of dwarf laying hens segregating for the naked neck gene in temperate and subtropical environments. Genetics Selection Evolution, volume 41, pages, 1-11.

Coble D J, Fleming D, Persia M E, Ashwell C M, Rothschild M F, Schmidt C J and Lamont S J 2014 RNASeq analysis of broiler liver transcriptome reveals novel responses to heat stress. The Effects of Biotic and Abiotic Stressors on Gene Expression in Chickens, volume 15. https://doi.org/10.1186/1471-2164-15-1084

Deeb N and Cahaner A 2001 Genotype by environment Interaction with Broiler Genotypes Differing in Growth Rate: 2. The Effects of High Ambient Temperature on Dwarf Versus

Normal Broilers. Poultry Science, volume 80, pages 541–548. doi.org/10.1093/ps/80.6.695

Dessie T, Taye T, Dana N, Ayalew W and Hanotte O 2011 Current state of knowledge on phenotypic characteristics of indigenous chickens in the tropics. Worlds Poultry Science Journal, volume 67, pages, 507–516. doi.org/10.1017/S0043933911000559

Desta T T, Dessie T, Bettridge J, Lynch S E, Melese K, Collins M, Christley R M, Wigley P, Kaiser P, Terfa Z, Mwacharo J M and Hanotte O 2013 Signature of artificial selection and ecological landscape on morphological structures of Ethiopian village chickens. Animal Genetic Resources Information, volume 52, pages, 17–29. doi.org/10.1017/S2078633613000064

Desta T T and Wakeyo O 2012 Uses and flock management practices of scavenging chickens inWolaita Zone of southern Ethiopia. Tropical Animal Health Production, volume 44, pages, 537–544. doi.org/10.1007/s11250-011-9933-y

Eskindier Aklilu (2013). On-farm phenotypic characterizationof indigenous chicken and chicken production systems in Horro and Jarso districts, Oromia regional state. Msc Thesis. Submitted to the Department of Animal and Range Science. Haramaya University. Ethiopia. Pages 94. https://www.researchgate.net/publication/290475704.

FAO 2007 The first report on the state of world's- Animal Genetic Resources for Food and Agriculture. Agriculture. http://www.fao.org/3/a-i4787e/index.html

FAO 2012 Phenotypic characterization of animal genetic resources. FAO Animal Production and Health Guidelines. Volume 11. https://www.fao.org/publications/card/en/c/0fe9d7e8-8dcf-5c94-a051-9977a5853671/

FAO 2010 Chicken Genetic Resources Used in Smallholder Production Systems and Opportunities for Their Development. In P. Sørensen (Ed.), Smallholder Poultry Production. Rome, Italy volume 5, pages 61. https://www.fao.org/publications/card/en/c/43fd958d-1698-59af-8d1b

FAOSTAT 2014 FAOSTAT. Rome, Italy. https://www.fao.org/faostat/en/

Faruque S, Siddiquee N, Afroz M and Islam M 2010 Phenotypic characterization of native chicken reared under intensive management system. Journal of the Bangladesh Agricultural University, 8: 79–82. doi.org/10.3329/jbau.v8i1.6402

Fathi M M, Galal A, El-safty S and Mahrous M 2013 Naked neck and frizzle genes for improving chickens raised under high ambient temperature: I. Growth performance and egg production. World's Poultry Science Journal, volume 64, pages, 813-832. doi.org/10.1017/S0043933913000834

Fayeye T R, Ayorinde K L, Ojo V and Adesina O M 2006. Frequency and influence of some major genes on body weight and body size parameters of Nigerian local chickens. Livestock Research for Rural Development, Volume 18, Article #37. Retrieved February 23, 2022, from http://www.lrrd.org/lrrd18/3/faye18037.htm

Galal A, Ahmed A M, Ali U M and Younis H H 2007 Influence of Naked Neck Gene on Laying Performance and Some Hematological Parameters of Dwarfing Hens. International Journal of Poultry Science, volume 6, pages, 807-813. doi.org/10.3923/ijps.2007.807.813

Gärke C., Ytournel F, Bed'hom B, Gut I, Lathrop M, Weigend S and Simianer H 2012 Comparison

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v25i2.11

of SNPs and microsatellites for assessing the genetic structure of chicken populations. Animal Genetics, volume 43, pages, 419–428. doi.org/10.1111/j.1365-2052.2011.02284.x

Gicheha M G 2021 The effects of heat stress on production, reproduction, health in chicken and its dietary amelioration. In: Patra AK (ed) Advances in Poultry Nutrition Research, IntechOpen, Rijeka, chap 12, https://doi.org/10.5772/intechopen.97284

Gicheha M G, Kosgey I S, Bebe B O and Kahi A K 2007 Efficiency of alternative schemes breeding for resistance to gastrointestinal helminths in meat sheep. Small Ruminant Research, pages, 167-179. doi.org/10.1016/j.smallrumres.2006.01.009

GoK 2010 Agricultural Sector Development Strategy 2010-2020. Nairobi: Government of Kenya. http://www.kenyagreece.com/sites/default/files/agricultural-sector-ds-2020.pdf

Gondwe T N 2005 Characterization of local chicken in low input-low output production systems: Is there scope for appropriate production and breeding strategies in Malawi, Ph.D. Thesis, Universität Gottingen. https://www.semanticscholar.org/paper/Characterisation-of-local-chicken-in-low-input-low-Gondwe/3971b62cbb15a7074c74784503b60059acb5b755

Halima H M 2007 Phenotypic and genetic characterization of indigenous chicken populations in Northwest Ethiopia. PhD thesis. Bloemfontein, South Africa, University of Free State. http://scholar.ufs.ac.za:8080/bitstream/handle/11660/2207/MogesseHH.pdf?sequence=1&isAllowed=y

Hagan J K, Adomako K and Olympio O S 2011 Effects of Naked-Neck and Frizzle Genes on Growth Performance and Carcass Characteristics of Crossbred Cockerels. Journal of Science and Technology, pages, 42-47. Journal of Science and Technology, Vol. 31, No. 3 (2011), p p 4 2- 4 7. 10.4314/just.v31i3.5

Hamal, K., Burgess S., Pevzner, I. and Erf G 2006. Maternal antibody transfer from dams to their egg-yolk, egg-white and chicks in two meat lines of chickens. Poultry Science, Volume 85, pages 1364-1372.

Hassen H, Neser F W, de Kock A and Evan M K 2009 Study on the Genetic Diversity of Native Chickens in Northwest Ethiopia Using Microsatellite Markers. African Journal of Biotechnology, 1347-1353. http://www.academicjournals.org/AJB

Headon D 2013 Systems biology and livestock production. Animal, 7: 1959–1963. https://doi.org/10.1017/S1751731113000980

Huo J, Wu G, Chen T, Huo H, Yuan F and Liu L 2014 Genetic diversity of local Yunnan chicken breeds and their relationships with Red Junglefowl. Genet Mol Res Mol Res.13: 3371–3383. http://dx.doi.org/10.4238/2014.April.29.16

Islam M A and Nishibori M 2009 Indigenous naked neck chicken: a valuable genetic resource for Bangladesh. World's Poultry Science Journal 65: 125-138. https://doi.org/10.1017/S0043933909000105

Kahi A K, Nitter G, Thorpe W and Gall C F 2000 Crossbreeding for dairy production in the lowland tropics of Kenya: II. Prediction of performance of alternative crossbreeding strategies. Livestock Produciton Science, 55-63. https://doi.org/10.1016/S0301-6226(99)00132-3

KARI 2014 KARI Naivasha Research Programmes. Retrieved from KARI Web site:

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v25i2.11

http://www.kari.org/KARI_Naivasha_Research_Programmes.

Khawaja T, Khan S H, Mukhtar N, Parveen A and Ahmed T 2013 Comparative study of growth performance, meat quality and haematological parameters of three-way crossbred chickens with reciprocal F1 crossbred chickens in a subtropical environment. J. Appl. Anim. Res. 41:300–308. https://doi.org/10.1080/09712119.2013.782869

Khobondo J O, Muasya T K, Miyumo S, Okeno T O, Wasike C B, Mwakubambanya R, Kingori A M and Kahi A K 2015 Genetic and nutrition development of indigenous chicken in Africa. Livestock Research for Rural Development, 27: 7. http://www.lrrd.org/lrrd27/7/khob27122.html.

Kingori A M, Wachira A M and Tuitoek J K 2010 Indigenous Chicken Production in Kenya: A Review. International Journal of Poultry Science 9(4): 309–316 http://www.pjbs.org/ijps/fin1669.pdf.

Kios D, Estè V M and Carina V 2011 Application of DNA markers in parentage verification of Boran cattle in Kenya. Tropical Animal Health Production, 1-6. https://doi.org/10.1007/s11250-011-9921-2

KNBS 2010 Kenya National Bureau of Statistics: Population, Housing and Livestock Census Report. Nairobi, Kenya. https://s3-eu-west-1.amazonaws.com/s3.sourceafrica.net/documents/21195/Census-2009.pdf

Lawler A 2014 Why Did the Chicken Cross the World? The Epic Saga of the Bird That Powers Civilization. Atria Books. New York. https://books.google.com/books?hl=en&lr=&id=LE8ADAAAQBAJ&oi=fnd&pg=PA1&dq=Why+Did+The+Chicken+Cross+The+World+The+Epic+Saga+Of+The+Bird+That+Powers+Civilization&ots=E5uCsBdmBW&sig=dF0Mg27fRPx9X8DE-Gh86SMrP1E.

Li Y C, Korol A B, Fahima T, Beiles A and Nevo E 2002 Microsatellites: Genomic distribution, putative functions and mutational mechanisms: A review. Molecular Ecology.pp. 2453–2465. https://doi.org/10.1046/j.1365-294X.2002.01643.x

Lwelamira J, Kifaro G C and Gwakisa P S 2008 On station and on-farm evaluation of two Tanzania chicken ecotypes for body weights at different ages and for egg production. African Journal of Agricultural Research, 843-851. http://www.academicjournals.org/AJAR

Lyimo C M, Weigend A, Janßen-Tapken U, Msoffe P L, Simianer H and Weigend A 2012 Assessing Genetic Diversity of Five Tanzanian Chicken Ecotypes Using Microsatellite Markers and Mitochondrial DNA D-loop Sequencing. Conference on International Research on Food Security, Natural Resource Management and Rural Development (pp. 1-4). Göttingen: Georg-August Universität Göttingen and University of Kassel-Witzenhausen. https://www.researchgate.net/publication/260531164

Lyimo C M, Weigend A, Janßen-Tapken U, Msoffe P L, Simianer H and Weigend S 2013 Assessing the genetic diversity of five Tanzanian chicken ecotypes using molecular tools. South African Journal of Animal Science, 499-511. http://dx.doi.org/10.4314/sajas.v43i4.7

Magonka J M, Sendalo D S, Goromela E H, Malingila P B and Daniel E 2016 Production performance of indigenous chicken under semi-intensive management conditions in Central Tanzania. *Journal of the Open University of Tanzania.Vol.22*. (1). DOI:10.4314/HURIA.V22I1

Magothe T M, Muhuyi W B and Kahi A K 2010 Influence of major genes for crested head, frizzle-

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v25i2.11

feather and naked-neck on body weights and growth patterns of indigenous chickens reared intensively in Kenya. Tropical Animal Health and Production 42: 173-183. https://doi.org/10.1007/s11250-009-9403-y

Magothe T M, Okeno T O, Muhuyi W B and Kahi A K 2012a Indigenous Chicken Production in Kenya: In Prospects for Research and Development. World's Poultry Science Journal, 68, 133-144. https://doi.org/10.1017/S004393391200013X

Magothe T M, Okeno T O, Muhuyi W B and Kahi A K 2012b Indigenous population in Kenya: I. Current Status. World's Poultry Science Journal, 119-132. https://doi.org/10.1017/S0043933912000128

Mahendra K P 2016 Importance of indigenous breeds of chicken for rural economy and their improvements for higher production performance. Scientifica 9. https://doi.org/10.1155/2016/2604685

Mahoro J, Muasya T K, Mbuza F, Mbuthia J and Kahi A K 2017 Farmers' breeding practices and traits of economic importance for indigenous chicken in Rwanda. Tropical Animal Health and Production, 50: 121–128. https://doi.org/10.1007/s11250-017-1411-8

Mahrous M, Galal A, Fathi M M and Zein El-Dein A 2008 Impact of naked neck and frizzle genes on growth performance and immunocompetence in chickens. International Journal of Poultry Science 7: 45-54. Doi:10.3923/ijps.2008.45.54

Martin U 2000 The Livestock Revolution- Implications for Smallholder Agriculture: A case study of Milk and Poultry in Kenya. Rome: Food and Agriculture Organization. Livestock Policy Discussion Paper No. 1. http://www.fao.org/ag/againfo/resources/en/publications/sector_discuss/PP_Nr1_Final.pdf.

Menge E O, Kosgey I S and Kahi A K 2005 Bio-Economic Model to Support Breeding of Indigenous Chicken in Different Production Systems. International Journal of Poultry Science, 827-839. doi:10.3923/ijps.2005.827.839

Meseret M 2010 Characterization of village chicken production and marketing system in Gomma woreda, Jimma zone, Ethopia. MSc Thesis. Jimma University, Ethiopia, p110. https://hdl.handle.net/10568/3024

Msoffe P M, Minga U M, Olsen J E, Yongolo M G, Juul-Madsen H R, Gwakisa P S and Mtambo, M M 2001 Phenotypes including immune-competence in scavenging local chicken ecotypes in Tanzania. Tropical Animal Health and Production 33: 341-354. doi: 10.1023/a:1010544221028

Mtileni B J, Muchadeyi F C, Maiwashe A, Phitsane P M, Halimani T E, Chimonyo M, and Dzama K 2009 Characterisation of production systems for indigenous chicken genetic resources of South Africa. *Applied Animal Husbandry & Rural Development*, *2*(1), 18-22. https://www.researchgate.net/profile/TinyikoHalimani/publication/268421439_Characterisation_of_production_systems_for_indigenous_chicken_genetic_resources_of_South_Africa/links/555b9b6608ae8f66f3ad7bda/Characterisation-of-production-systems-for-indigenous-chicken-genetic-resources-of-South-Africa.pdf

Mwacharo J, Bjørnstad G, Han J and Hanotte O 2013b The History of African Village Chickens: An Archaeological and Molecular Perspective. African Archaeological Review, 30, 97-114. https://doi.org/10.1007/s10437-013-9128-1

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v25i2.11

Mwacharo J M, Nomura K, Hanada H, Han J L, Amano T and Hanotte O 2013a Reconstructing the origin and dispersal patterns of village chickens across East Africa: insights from autosomal markers. Mol. Ecol. 22:2683–2697. https://doi.org/10.1111/mec.12294Mwacharo J M, Nomura K, Hanada H J, Hanotte O and Amano T 2007 Genetic Relationships among Kenyan and Other East African Indigenous Chickens. International Society for Animal Genetics, 485-490. https://doi.org/10.1111/j.1365-2052.2007.01641.x

Mwacharo J M, Bjørnstad G, Mobegi V, Nomura K, Hanada H, Amano T and Hanotte O 2011 Mitochondrial DNA reveals multiple introductions of domestic chicken in East Africa. Molecular phylogenetics and evolution, 374-382. https://doi.org/10.1016/j.ympev.2010.11.027

Mwai O, Malmfors B, Andersson-Eklund L, Philipsson J, Rege J E, Hanotte O and Fulss R 2005 Capacity building for sustainable use of animal genetic resources in developing countries. ILRI–SLU Project progress report for the period 1999–2003. SLU (Swedish University of Agricultural Sciences), Uppsala, Sweden and ILRI. Nairobi, Kenya: ILRI (International Livestock Research Institute). http://agtr.ilri.cgiar.org/sites/all/files/library/docs/ILRISLU%20Report/Capacity_BuildingFinal.pdf

Ndegwa J, Mead R, Norrish P, Shephered D, Kimani C and Wachiri A 2012 Growth Characteristics of Six Reciprocal Crosses of Kenyan Indigenous Chicken. Agricultural Science, 1: 160-170. http://dx.doi.org/10.5539/jas.v4n6p160

N'dri A I, Mignon-Grasteau S, Sellier N, Beaumont C and Tixier-Boichard M 2007 Interactions between the naked neck gene, sex, and fluctuating ambient temperature on heat tolerance, growth, body composition, meat quality, and sensory analysis of slow growing meat-type broilers. Livestock Science 110: 33-45. https://doi.org/10.1016/j.livsci.2006.09.025

Ngeno K, Vander Waaij E H, and Kahi A K 2014 Indigenous chicken genetic resources in Kenya: their unique attributes and conservation options for improved use. *World's Poultry Science Journal*, 70(1), 173–184. https://doi.org/10.1017/S0043933914000154

Nimbkar C, Gibson J, Okeyo M, Boettcher P and Soelkner J 2008 Sustainable use and genetic improvement. Animal Genetic Resources Information 42: 49-66. . https://doi.org/10.1017/S1014233900002558

Njenga S K 2005 Production and socio-cultural aspects of local poultry phenotypes in coastal Kenya. MSc Thesis, Danish Institute of Agricultural Sciences, Tjele, Denmark. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.506.5263&rep=rep1&type=pdf

Nwachukwu E N, Ibe S N, Ejekwu K and Oke U K 2006 Evaluation of Growth Parameters of Main and Reciprocal Normal, Naked Necked and Frizzle Chicken in a Humid Tropical Environment. Journal of Animal and Veterinary advances., 542-546. https://agris.fao.org/agris-search/search.do?recordID=DJ2012071602

Ochieng J, George O and Bockline O B 2013 Management practices and challenges in smallholder indigenous chicken production in Western Kenya. Journal of Agriculture and Rural Development in the Tropics and Subtropics, 51-58.

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v25i2.11

https://www.jarts.info/index.php/jarts/article/view/2013030542607

Oke U K 2011 Influence of some major genes on growth traits of local pullets in humid tropical environment. Agriculture and Biology Journal of North America, 570-576. 10.5251/abjna.2011.2.4.570-576

Okeno O T, Kahi A K and Peters K J 2012 Genetic and Economic Evaluation of Alternative Breeding Objectives for Adoption in the Smallholder Indigenous Chicken Improvement Program. I: University of Göttingen. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1067.263&rep=rep1&type=pdf

Okeno T O, Kahi A K and Peters K J 2011 Breed Selection Practices and Traits of Economic Importance for Indigenous Chicken in Kenya. Livestock Research for Rural Development, 11-20. http://pure.au.dk/portal/da/publications-research/productionsystems-breeding-objectives-and-selection-schemes-for-indigenous-chicken-geneticresources-in-kenya%28ce971fa9-6ec5-489c-b2d3-8fd961ab34fa%29.html

Okeno T O, Kahi A K and Peters K J 2013 Evaluation of breeding objectives for purebred and crossbred selection schemes for adoption in indigenous chicken breeding programmes. British Poultry Science, 62-75. https://doi.org/10.1080/00071668.2013.764492

Pandey A K, Tantia M S, Kumar D, Mishra B, Chaudhary P and Vijh R K 2002 Microsatellite Analysis of Three Poultry Breeds of India. Asian-Australasian Journal of Animal Sciences, 15: 1536–1542. https://doi.org/10.5713/ajas.2002.1536

Putman A I and Carbone I 2014 Challenges in analysis and interpretation of microsatellite data for population genetic studies. Ecol Evol 4: 4399–4428. https://doi.org/10.1002/ece3.1305 PMID: 25540699

Rashid M A, Howlider M A, Alam J, Rashid M D, Kawsar M H and Azmal S 2005 Effect of dwarfism on reproductive and meat yield parameters of crossbred chicken. International Journal of Poultry Science 4: 372-377. https://agris.fao.org/agris-search/search.do?recordID=DJ2012051514

Riise J, Kryger K, Seeberg D and Christensen P 2005 Impact of Smallholder Poultry Production in Bangladesh—12 Years' Experience with DANIDA Supported Livestock Projects in Bangladesh. Paper Presented at The Proceedings of the Workshop Does Poultry Reduce Poverty and Assure Food Security. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.553.5501&rep=rep1&type=pdf

Sharma R K 2007 Role and relevance of traditional family poultry in development countries with special reference to India. World's Poultry Science Journal, 63, 491. https://www.fao.org/3/aq611e/aq611e.pdf#page=37

Sørensen P 2010 Chicken genetic resources used in smallholder production systems and opportunities for their development. FAO. Retrieved from http://www.fao.org/ag/againfo/themes/documents/poultry/SPP5.pdf

Subbiah M, Nayak S, Collins P L and Samal S K 2010 Complete genome sequences of avian paramyxovirus serotype 2 (APMV-2) strains Bangor, England and Kenya: evidence for the existence of subgroups within serotype 2. Virus Research, 85-95. https://doi.org/10.1016/j.virusres.2010.06.009

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v25i2.11

Tadelle D 2003 Phenotypic and genetic characterization of local chicken ecotypes in Ethiopia. PhD Thesis, Humboldt University of Berlin, Germany, 209PP. https://cgspace.cgiar.org/bitstream/handle/10568/3930/pheno_gen_char.pdf?...1

Trail J 1962. The indigenous poultry of Uganda. The fertility, hatchability and chick mortality compared with European breeds. Poultry Science, volume 41, pages 1271-1276. https://doi.org/10.3382/ps.0411271

Wesonga M 2013 Standard Digital News: Business Kuchi chicken offers solution to Marakwet poultry farmers. Page No3. Retrieved February 17, 2015, from https://www.standardmedia.co.ke/business/business/article/2000091693/kuchi-chicken-offers-

Wragg D, Mwacharo J M, Alcalde J A, Hocking P M and Hanotte O 2012 Analysis of genome-wide structure, diversity and fine mapping of Mendelian traits in traditional and village chickens. Heredity 109:6–18. https://doi.org/10.1038/hdy.2012.9

Wu Z and Kaiser P 2011 Antigen presenting cells in a non-mammalian model system, the chicken. Immunobiology 216:1177–1183.Yeasmin, T., Howlider, M.A.R. and Ahammad, M.U. (2003). Effect of introgressing dwarf gene from Bangladeshi indigenous to exotic breeds on egg production. International Journal of Poultry Science 2: 264-266. https://doi.org/10.1016/j.imbio.2011.05.012

Yeasmin T, Howlider M, and Ahammad M U 2003. Effect of introgressing dwarf gene from Bangladeshi indigenous to exotic breeds on egg production. International Journal of Poultry Science, Volume 2, pages 264-266.

Zerjal T, Gourichon D, Rivet B and Bordas A 2013 Performance Comparison of Laying Hens Segregating for the Frizzle Gene Under Thermoneutral and High Ambient Temperatures. Poultry Science 92: 1474–1485. https://doi.org/10.3382/ps.2012-02840

ISSN 1561-7645 (online)
doi: 10.4314/jagst.v25i2.11