



Hatching, Brooding and Reproductive Characteristics of Indigenous Chickens

Ajibike, A B^{1,2,3*}, Ilori, B. M³, Adebisi, I. A.¹, Adeniyi, O. A.⁴, Adebambo, A. O.³

¹Department of Animal Production Technology, Oyo State College of Agriculture, Igboora, Oyo State, Nigeria;

²Research Center of Animal Breeding, Biotechnology and Transgenesis, Faculty of Animal Science and Food Engineering, University of Sao Paulo, Campus Fernando Costa, Pirassununga-SP, Brazil;

³Department of Animal Breeding and Genetics, Federal University of Agriculture, Abeokuta, Nigeria;

⁴Department of Animal Health Technology, Oyo State College of Agriculture, Igboora, Oyo State, Nigeria

*Corresponding author: abajibike@oyscatech.edu.ng

Abstract

This article reviews the broodiness characteristic of African indigenous chickens (AIC) and their comparative reproductive performances with exotic and crossbred birds. Indigenous chicken is innately endowed with excellent brooding characteristics, distinguishing them from exotic chickens. Their contribution to the socio-economic and socio-cultural development of the African rural community cannot be overlooked. It was discovered that 90% of local farmers who reared indigenous chicken were predominantly women who kept them mainly as a source of income and sacrifice. The average duration for brooding by indigenous chicken is 21 to 23 days. Naked Neck, Frizzle Feather and White Leghorn require an average of 124 days to lay their first egg, whereas local breeds like Potchefstroom Koekoek, Venda and Ovambo require an average of 137 days. On average, indigenous hens lay 4 to 14 eggs per clutch and have 2 to 4 clutches per year with an average of 40 to 80 eggs per hen per year. However, their genetic potential for egg production is about 125 eggs, with a hatchability percentage of 80%. Mortality has been the major factor that compromises the sustainability of chicken production, which results from a lack of good mothering ability, poor nutrition, lack of proper shelter, inadequate health control and predators.

Keywords: Indigenous chickens, hatching, broodiness, reproductive performance, Africa

Introduction

Cunningham (2009) defines broodiness, also known as incubation behaviour, as a condition when laying hens break their egg-laying cycle to set and marshal their behavioural and physiological resources to support the incubation and hatching of their chicks. Broodiness is a sex-linked behavioural trait as it is often associated with females in most breeds of domestic poultry; however, males of some bird species, as well as some non-avian animals, exhibit broodiness (Kumar Sarkar, 2022). Okeno *et al.* (2012) define broodiness as when a hen incubates and raises her chicks until they are weaned.

In poultry, an increase in body temperature, reduced water and food ingestion, frequent clutch occupancy, egg retrieval and spinning, defensive or aggressive behaviour, and egg production cessation are characteristics often associated with broodiness (Jiang *et al.*, 2010; Romanov, 2001). Most avian species, predominantly indigenous chicken breeds, exhibit broodiness with an average duration of

20 days (Jiang *et al.*, 2010). With this, studies have identified broodiness with a reduction in egg production due to the laying cessation and reduced feed consumption during the period of brooding (Iyasere *et al.*, 2019).

Ruscio and Adkins-Regan (2004) reported that the brooding trait of a hen is characterised by crouching down, fluffing its feathers, and allowing its chicks to approach and stay beneath its wings. It was further reported that birds that do not show brooding behaviour actively avoid chicks. Brooding is essential in avian species because young birds are unable to regulate their body temperature. As a result, adequate heat must be provided for the first few weeks, with the number of weeks depending on the species and the current environmental condition.

Characteristic features of a good broody hen

A good brooder bird should be moderately big-sized with a broad chest, big wigs, clean shanks, short legs, clean and in sound health



(i.e. free from worms and parasitic diseases which can cause irritation and disturbance), must have a natural maternal instinct to incubate eggs till hatching and foster the chicks after hatching, protect the chick from predators, should be able to nurture the chicks for over 8 weeks before weaning and back to lay in approximately 12 – 16 weeks post-hatching.

Bushra (2012) describes that a good broody hen possesses the ability to sit for longer periods, usually not less than 3 days, and shows aggressiveness and alertness in protecting her chicks from manageable predators and prey, and the ability to rescue them from unseen dangers by signalling the chicks to hide. Indigenous chickens are known to possess good maternal quality, good sitters, hatch their eggs, high fertility and hatchability and are thus an important genetic resource needed for conservation, utilisation, and genetic improvement to future food security (Guèye, 2019; Ajibike *et al.*, 2017; Bushra, 2012; Dana *et al.*, 2010). Conversely, African Indigenous chicken has invaluable characteristics that are not found in the exotic strains, which include excellent mothering qualities and the ability (Kyarisiima *et al.*, 2004). Local breeds can incubate and brood naturally (Pedersen *et al.*, 2002). According to Kitanyi (1998), small clutch sizes (2 - 10 eggs), an inclination to brood, and long pauses between consecutive clutches are typical characteristics of indigenous chickens.

The importance and socio-economic benefits of broodiness

Survival of chicks is dependent on the broodiness of the hen. Controlling the chick's body temperature is one of the paramount importance of brooding in Indigenous chickens (Molenaar, 2012), as the chicks are unable to regulate their body temperature post-hatching. Sonaiya and Swan (2004) reported that broodiness tends to increase the survivability of chicks. Mengesha and Tsega (2011) indicated that local chicken plays a vital role in improving household nutrition, gender equity, food security and income generation, with women and children being the most beneficiaries due to their contribution to the production and marketing. To achieve these, a good household backyard farmstead must maintain optimum production of chicks per season.

Factors affecting brooding and hatching performance.

Several factors have been implicated in affecting chickens' performance in brooding and hatching.

Breed

One of the criteria in selecting a parent stock is the performance record and adaptability of the breed to the production environment. Studies have revealed that the reproductive efficiency of poultry operations is significantly influenced by the reproductive performance of the cock due to the quality and quantity of semen produced, together with the libido and siring capacity of cock (Adedokun and Sonaiya, 2001). Molekwa and Umesiobi (2009) concluded that the Potchefstroom Koekoek breed has a higher fertile and hatchability rate of set eggs than Naked Neck, Ovambo and Venda chickens.

Fayeye *et al.* (2005) reported that Normal feathered chickens have a much higher hatchability percentage (56%) than Fulani ecotypes, which have a fertility rate of 76%. Ajayi and Agaviezor (2016) observed higher hatchability in Naked neck hens (73.1%) and lower in Normal feathered chickens (58%). In addition, he pointed out that the frizzled genotype's superiority in terms of hatchability might be related to the frizzle gene's increased capacity for thermoregulation. Furthermore, Peters (2000) found that Normal feathered hens laid the highest number of eggs compared to exotic, frizzle feathered, and Naked Neck hens.

Peters (2000) believed that genotype by environment interactions determines the performance of any chicken breed. The phenotypic expression of any domestic fowl is always a result of the interaction between the genetic compositions of the bird and the environmental factors exhibited in the offspring's reproductive performance. Hatchability is believed to be a derivation of fertility coupled with the existence of major genes and breed/strain differences that decrease embryonic livability (Peters *et al.*, 2004).

Genotypic differences may likely be caused by variations in hatchability of different breeds or strains of chickens, as Peters *et al.* (2004) concluded that breed and strain variations have a significant impact on egg fertility



because Normal feathered chickens possessed the ability to lay more fertile eggs compared to the exotic, frizzled feathered strains and naked neck strains respectively. Furthermore, he opined that the sire effect accounts for the major effect of fertility as a result of the semen's quality influencing the cock's sperm cell potency as evidenced by the local strain's semen potency favourably influenced by the genotype-environment interaction in Normal-feathered cock compared with the exotic strain's semen potency, which is negatively impacted, thus, indirectly affecting its fertility.

Additionally, Ibe (1993) and Ikeobi *et al.* (1996) reported that fertility is influenced by sire strain. Furthermore, King`ori (2011) reported that the effect of chicken breeds on egg hatchability is insignificant and further reviewed that light breeds have higher hatchability and fertility than heavy breeds. Kugonza *et al.* (2012) concluded that crossbred birds generally performed better than indigenous breeds. Also, Adekunle (2011) found that the percentage hatchability and fertility of crossbred (Frizzle $\times$ Normal feather) were 50% and 45.90%, respectively, while the percentage of hatchability and fertility for reciprocal crosses was found to be 68% and 80.65%, respectively, in Nigerian Indigenous chickens.

Season and time/period of egg lay

Ugwu *et al.* (2009) reported that breeding starts at the on-set of rainy seasons in June when seeds begin to sprout and grasses grow, leading to an increase in the population of young insects and lizards which serve as food for native hens and guinea fowls who live in flocks and can travel up to thirty-two kilometres in a day. FAO (2010) opined that the hatchability of eggs set in spring and autumn was significantly higher. These were explained by the increased availability of fresh eggs and more optimal conditions for egg storage during these seasons of the year. However, summer eggs are held for a shorter period and have a lower hatchability, possibly due to the effect of high storage temperature. Roy *et al.* (2003) reported that season significantly influenced fertility by comparing experiments conducted on white leghorn chickens in Meghalaya over different seasons. Habte *et al.* (2013) opined that natural incubation occurs mainly in the dry season.

Gang and Zhen (1993) discovered that eggs

laid between 5:00 - 11:00hr were more fertile than laid eggs between 11:00hr and 17:00hr, and viable egg hatchability was high for laid eggs between 5:00 - 8:00hr with a progressive reduction in hatchability for subsequent eggs laid after this time.

Age of a hen

Onasanya and Ikeobi (2013) opined that an increasing hen's age reduces hatchability, and hens above 24 months of age show a significant decrease in fertility and hatchability rate. Furthermore, they believed that an increase in sperm accumulation in the hen's oviduct within the first six months of lay increases fertility with age-in-lay.

Egg Quality (size)

Studies have established the correlation between hatchability and egg weight and shown that to have optimal hatchability in hens, it is beneficial to have eggs with an average size or weight (Onasanya and Ikeobi, 2013). Rashid *et al.* (2013) concluded that, in local chicken breeds, medium-sized eggs are better for higher hatchability rates and decreased embryonic mortality, while large-sized eggs have a higher hatchling weight. Gonzalez *et al.* (1999) reported that ostrich birds with large eggs produced large chicks compared to those with medium and small-sized eggs. However, the hatchability of eggs averaging 46 – 50 g and those within 50 – 77 g varies between 8 - 10.5 %, which is lesser compared to eggs with a mean weight of 50 – 66 g (Shatokhina, 1975).

Management condition

Early separation of chicks from broody hens can shorten the rearing period, boost local chicken productivity, achieve lower chick mortality by providing better biosecurity, nutrition, and management, and resolve lower production coefficient in native chickens, which can be attributed to the high percentage of unproductive layers and insufficient feed in the scavenging feed resource base (Hossen, 2010).

Nwagu (2019) affirmed that the presence of metallic compounds, contaminants, toxins, and mycotoxins in poultry feeds reduces hatchability and fertility. The inclusion of selenium in poultry's diet at 2.5 mg/kg affected hatchability and fertility; however, 5 mg/kg resulted in reduced hatchability with a decline to zero at the 10 mg/kg inclusion level



(Bolton and Blair, 1974).

Onasanya and Ikeobi (2013) opined that a well-balanced diet and access to clean water are necessary for effective poultry breeding to maximise hatchability, fertility, and production efficiency. However, they concluded that feeding, drug administration, and vaccination procedures in an intensive management system can improve reproductive performance and egg production compared to when chickens are kept under an extensive husbandry system.

Furthermore, improved hatchability requires proper maintenance of the incubation environment at a recommended temperature of 50 - 55% for the setter and increased to

75% for the final 2 -3 weeks (Nwagu, 2019). Oluyemi and Roberts (1979) established that nutritional deficiency was the primary identified cause of high embryonic mortality between days 14 and 15 of incubation.

Clutch Size

With an average reproductive cycle of 68 days, weaning increases clutch count from three (3) to six (6), yielding an increase of 4 eggs per clutch and hen's egg output from 45 to 96 per annum (Hossen, 2010). Kwaku (2009) recorded a clutch size of 2 to 3, confirming the value of two or three clutches of eggs in a year recorded by Azharul *et al.* (2005) for broody hen and 3 clutches per year with an average of 12 eggs/clutch established by Lwesya *et al.* (2004).

Table 1: Summary of production parameters of Indigenous chickens in Africa

Country	Egg (per clutch)	Clutches (per year)	Egg production (e/h/y)	Egg weight (g)	Hatchability (%)	Reference
Benin	-	-	50 – 100	40	-	Assan (1990)
Burkina Faso	12 - 18	2.7 – 3.0	-	30 – 40	60 – 90	Bourzat and Saunders (1990)
Cameroon	-	-	50 – 80	30	82	Ngou Ngoupayou (1990)
Ghana	12.9	3	20	41.3	84.5	Hagan <i>et al.</i> (2016)
Mali	8.8	2.1	35	34.4	69.1	Wilson <i>et al.</i> (1987)
Nigeria	10	2 – 3	60 – 80	-	80	Sonaiya (1990); Ibe (1998)
Senegal	8 - 15	4 – 5	40 – 50	40	60 – 95	Sall (1990); Guèye (2003)
Sudan	10.9	4.5	50	40.6	90	Wilson (1979)
Tanzania	12 - 13	3	36	37.9 – 49.5	50 - 100	Katule (1992)
Ethiopia	11 - 13.5	2.1	46	-	68.9 - 70	Tadelle <i>et al.</i> (2003)
Uganda	6 – 20	2.5 – 3.0	20 – 50	40 – 50	40 – 100	Kyarisiima <i>et al.</i> (2004)

e/h/y: eggs/hen/year

Effect of broodiness on egg weight viz a viz hatchability

It is believed that brooding is the primary reason for local hens' low egg production, and different native techniques have been employed to lessen (disrupt) the broody tendency of the chickens, particularly when the eggs are utilised for objectives other than incubation (Bushra, 2012). Studies have shown that the sizes of laid eggs by hens impacted their productivity (Rashid *et al.*, 2013; King`ori, 2011), however, no chicken population combines the capacity for good egg qualities, such as fertility, hatchability,

survival, and high egg output (Alabi *et al.*, 2012). During natural incubation, 80% hatchability is regarded as usual; nevertheless, a range of 75 – 80 % is deemed satisfactory (Sonaiya and Swan, 2004).

One of the important economic traits affecting hatchability is egg weight and the early performance of chicks hatched. The egg quality, lower fertility rate, handling of eggs and management conditions during incubation and hatching, and high embryonic mortality due to poor eggshell quality, influenced by egg weight, are identified factors causing lower



hatchability. Farooq *et al.* (2001) observed a positive correlation between egg weights and chick hatching weight, which was reported to range between 62 - 72% for hatching chick weight and 68.2% of the initial egg weight (Murad *et al.*, 2001; Wilson 1991).

A better hatchability rate and lower embryonic mortality are recorded in medium-sized eggs compared to large-sized eggs with a better hatchling weight (Rashid *et al.*, 2013). This finding corroborated the report of Kalita (1994) that middle-sized eggs have a higher hatchability than small and large-sized eggs.

Effect of Brooding Length on Production Cycle and Hen Day Production

Hossen (2010) concluded that weaning reduces the length of the hen production cycle, resulting in an increased hen's egg productivity as the number of clutches increases, and creep feeding improves egg production as well as reduces local chicken mortality, thus increasing the clutch size (3 – 6) and an average annual egg laid of 96 eggs. This supports the study of Huque *et al.* (1990) that a 30 - 40g daily supplementary feeding in an improved management system resulted in 27 - 30% increased annual eggs laid by local chickens.

In addition, broody hens are used in increasing indigenous chickens' egg production by reducing the chick's rearing duration, which has been shown to result in the laying of about 36 eggs in 3 clutches (an average of 12 to 13 eggs per clutch) of 16 days (Sonaiya and Swan, 2004).

The importance of broodiness while defining breeding objectives

The necessity to formulate breeding programs tailored for village settings was emphasised by Sölkner *et al.* (1998) as there is a need to delineate production environments, understand breeding practices, production goals, and traits that rural farmers value because an animal's adaptability is typically measured by the traits that affect its ability to survive, reproduce, and be productive in a given production environment (Prayaga and Henshall, 2005). Okeno *et al.* (2012) and Binte Zalal *et al.* (2022) suggested enhancing traditional management systems through cost-effective interventions like artificial brooding of chicks and supplementing chickens with locally available feed resources as a strategy to

decrease early age mortality, improve clutch numbers per hen, increase yearly egg production, and curtail associated feed expenses.

Mallia (1999) opined that the egg-laying capacity of broody chickens can be improved by using artificial incubation in a backyard or semi-intensive management systems, as this will not stop the hens from laying during the incubation period. However, the focus should be on the traits economically important to the farmers, marketers and consumers in developing a breeding goal to improve indigenous chickens (Yakubu *et al.*, 2020) as there is a high chance of the end users rejecting the breeding goal if their needs are not met (Bett *et al.*, 2011).

Abdelqader *et al.* (2007) suggested that production status characterisation, best breeding practices and identification of economically important traits by the farmers are essential to developing an appropriate breeding programme for indigenous chickens' improvement.

The optimal number of eggs needs to be set at a time.

Depending on the size, a hen can successfully hatch between 12 and 15 eggs, e.g. a bantam hen can cover an average of 8 - 10 eggs. Azharul *et al.* (2005) observed that an indigenous chicken can incubate up to 17 eggs weighing an average of 41g in one term; however, the hatchability of more than 10 eggs decreases based on the hen's size (King'ori, 2011). According to Habte *et al.* (2013), the availability of eggs determines the number of eggs laid by a hen, the size of the eggs, and the hen's maternal genotype and instinct, but recorded a mean of 11.32 as the number of eggs set per hen with a range of 6 - 20 eggs per hen, which agrees with the findings of Sonaiya and Swan (2004) that observed a mean of 13 as the number of eggs set per hen.

Good broodiness versus egg production performance

Research has shown that a negative correlation exists between high egg production and broodiness (Tadelle *et al.*, 2003), however, in an observational study where chicks were separated from the hens at 4 weeks of age, Hossain (1993) reported an increase in the number of clutches from 3.5 to 5 clutches/hens, an increase in laying



percentage from 18% to 25%, and an increase in indigenous hen's egg production from 42 eggs/hen to 60 eggs/hen which reduce brooding period to 5 weeks instead of 9 weeks in a traditional management system.

Comparative Analysis between native chickens and their crosses for their broodiness character

A broody hen's maternal traits play a vital role in the success of the hatching and brooding process. According to Peters (2000), the Normal feathered dam has the highest number of fertile eggs set and hatched compared to exotic, frizzle feathered and Naked neck dams respectively. Habte *et al.* (2013) observed an overall hatchability percentage of 82% and 44.36% for local and exotic chickens, with 11, 26 and 31 eggs per clutch per hen per year for indigenous, exotic and crossbred chicken respectively.

In crossbreeding trials, the frizzle-feathered genotype has been shown to enhanced hatchability and fertility, while the naked neck genotype seemed to have a fatal influence on embryonic survival (Adeleke *et al.*, 2012). Research has revealed a negative correlation in crossbred chickens between egg weight and hatchability (Farooq *et al.*, 2001), thus indicating that differences in hatchability are significantly influenced by the genetic composition of native hen (Onasanya and Ikeobi, 2013; Rashid *et al.*, 2013).

Conclusion and recommendation

Indigenous chicken (IC) will continue to be the most common breed of chicken for many years to come as it contributes significantly to the food and nutritional (source of animal protein) and economic (income and poverty alleviation) security of rural communities. Every effort should be made to boost their productivity through better husbandry and nutrition. To prevent the erosion of their important genetic traits (such as feed efficiency, egg production, body weight and average daily gain) and resources, a review of the existing national animal genetic resources and conservation policy must be prioritised by the government, breeders, researchers and farmers to formulate a new broader and comprehensive breeding and genetic improvement programme through selection and adapting a good mating pattern towards meeting the current production needs and future food security. Also, enough financial resources should be given for the establishment of gene banks and molecular characterisation of the IC genes for proper conservation.

Reference

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. *Trop Anim Health Prod*, 39(3): 155-164.
<https://doi.org/10.1007/s11250-007-9000-x>

Adedokun, A. S. and Sonaiya, B. E. 2001. Comparison of the performance of Nigerian indigenous chickens from three agro-ecological zones. *Livestock Research for Rural Development*, 13(2): 1-6.

Adekunle, A. A. 2011. *Fertility and hatchability of crosses of Nigerian Indigenous Chicken* B. Agric. Final Project, Department of Animal Breeding and Genetics, University of Agriculture, Abeokuta, Ogun State, Nigeria.

Adeleke, M. A., Peters, S. O., Ozoje, M. O., Ikeobi, C. O., Bamgbose, A. M. and Adebambo, O. A. 2012. Effect of crossbreeding on fertility, hatchability and embryonic mortality of Nigerian local chickens. *Trop Anim Health Prod*, 44(3): 505-510.
<https://doi.org/10.1007/s11250-011-9926-x>

Ajayi, F. and Agaviezor, B. 2016. Fertility and hatchability performance of pure and crossbred indigenous chicken strains in the high rainforest zone of Nigeria. *International Journal of Livestock Production*, 7(12): 141-144.

Ajibike, A. B., Adeleye, O. O., Ilori, B. M., Osinbowale, D. A., Adeniyi, O. A., Durosaro, S. O., Sanda, A. J., Adebambo, O. A. and Adebambo, A. O. 2017. Genetic diversity, phylogeographic structure and effect of selection at the mitochondrial hypervariable region of Nigerian chicken populations. *Journal of Genetics*, 96(6): 959-968.
<https://doi.org/10.1007/s12041-017-0860-1>

Alabi, O. J., Ng`ambi, J. W. and Norris, D. 2012. Effect of Egg Weight on Physical Egg Parameters and Hatchability of Indigenous Venda Chickens. *Asian Journal of Animal and Veterinary Advances*, 7(2): 166-172.
<https://doi.org/10.3923/ajava.2012.166.172>

Assan, B. E. 1990. *L'élevage villageois de la volaille en République du Bénin: Situation actuelle* CTA – Seminar Proceedings, Smallholder Rural Poultry



- Production, Thessaloniki, Greece. pp. 17 - 26.
- Azharul, I. M., Ranvig, H. and Howlider, M. A. R. 2005. Incubating capacity of broody hens and chick performance in Bangladesh. *Livestock Research for Rural Development*, Vol. 17, Article 19. Retrieved December 5, 2023 from <http://www.lrrd.org/lrrd17/2/azha17019.htm>
- Bett, H., Peters, K. and Bokelmann, W. 2011. Hedonic price analysis to guide in breeding and production of Indigenous chicken in Kenya. *Livestock Research for Rural Development*, 23(6): 11p.
- Binte Zalal, F., Kumar Sarkar, P., Sultana, M., Kawsar, M. H. and Kumar Fouzder, S. 2022. Natural Incubation and Broody Hen Management Practices in Barishal District, Bangladesh. *Advances in Animal and Veterinary Sciences*, 11(2). <https://doi.org/10.17582/journal.aavs/2023/11.2.189.195>
- Bolton, W. and Blair, R. 1974. *Poultry Nutrition* (Fourth Edition ed.). London : H.M.S.O.
- Bourzat, D. and Saunders, M. 1990. *Improvement of traditional methods of poultry production in Burkina Faso*. In Proc CTA seminar, 3rd International Symposium on Poultry Production in Hot Climates, Hameln, Germany. 12 June 1987.
- Bushra, B. (2012). *The Status of Indigenous Village Chicken Production and Marketing System in Ethiopia*. Retrieved 02 December 2023 from https://en.engormix.com/poultry-industry/poultry-industry/the-status-indigenous-village_a35476/
- Cunningham, D. L. (2009). *Controlling Broodiness in Backyard Flocks*. ThePoultrySite.com. Retrieved 01 December 2023 from <https://www.thepoultrysite.com/article/s/controlling-broodiness-in-backyard-flocks>
- Dana, N., van der Waaij, L. H., Dessie, T. and van Arendonk, J. A. 2010. Production objectives and trait preferences of village poultry producers of Ethiopia: implications for designing breeding schemes utilizing indigenous chicken genetic resources. *Trop Anim Health Prod*, 42(7): 1519-1529. <https://doi.org/10.1007/s11250-010-9602-6>
- FAO. 2010. *Chicken genetic resources used in smallholder production systems and opportunities for their development*. FAO Smallholder Poultry Production Paper No. 5. Rome.
- Farooq, M., Mian, M., Ali, M., Durrani, F., Asghar, A. and Murqarrab, A. 2001. Egg traits of Fayoumi birds under subtropical conditions. *Sarhad Journal of Agriculture (Pakistan)*, 17: 141 – 145.
- Fayeye, T. R., Adeshiyan, A. B. and Olugbami, A. A. 2005. Egg traits, hatchability and early growth performance of the Fulani-ecotype chicken. *Livestock Research for Rural Development*, Vol. 17, Article 94. Retrieved December 4, 2023 from <http://www.lrrd.org/lrrd17/8/faye17094.htm>
- Gang, F. Y. and Zhen, Y. S. 1993. The effect of time of lay on fertility and hatchability. *British Poultry Science*, 34(3): 613-614. <https://doi.org/10.1080/00071669308417616>
- Gonzalez, A., Satterlee, D. G., Moharer, F. and Cadd, G. G. 1999. Factors affecting ostrich egg hatchability. *Poult Sci*, 78(9): 1257-1262. <https://doi.org/10.1093/ps/78.9.1257>
- Guèye, E. F. 2003. Information dissemination for family poultry research and development. *Livestock Research for Rural Development*, Vol. 15, Article 17. Retrieved December 6, 2023 from <http://www.lrrd.org/lrrd15/2/guey152.htm>
- Guèye, E. F. 2019. The role of networks in information dissemination to family poultry farmers. *World's Poultry Science Journal*, 65(1): 115-124. <https://doi.org/10.1017/s0043933909000099>
- Habte, M., Ameha, N. and S, D. 2013. Production performance of local and exotic breeds of chicken at rural household level in Nole Kabba Woreda, Western Wollega, Ethiopia. *African Journal of Agricultural Research*, 8(11): 1014 - 1021. <https://doi.org/10.5897/AJAR2013.6933>
- Hagan, M. A. S., Donkoh, A., Awunyo-Vitor, D. and Gonzalez-Redondo, P. 2016.



- Growth performance and economic evaluation of broiler Chicken fed with rain tree (*Samanea saman*) seed meal. *Cogent Food & Agriculture*, 2(1). <https://doi.org/10.1080/23311932.2016.1277445>
- Hossain, S. M. 1993. Manipulation of the broody period to increase egg production of indigenous hens under rural conditions in Bangladesh. *Livestock Research for Rural Development*, Vol. 5, Article 13. Retrieved December 11, 2023 from <http://www.lrrd.org/lrrd5/2/bangla2.htm>
- Hossen, M. J. 2010. Effect of management intervention on the productivity and profitability of indigenous chickens under rural condition in Bangladesh. *Livestock Research for Rural Development*, Vol. 22, Article 192. Retrieved December 4, 2023 from <http://www.lrrd.org/lrrd22/10/hoss22192.htm>
- Huque, Q. M. E., Ebadul, M. H. and Rigor, E. M. 1990. The effect of chick separation on productivity of the hen and chick. *Asian-Australasian Journal of Animal Sciences*, 3(2): 121-123. <https://doi.org/10.5713/ajas.1990.121>
- Ibe, S. N. 1993. Growth Performance Of Normal, Frizzle And Naked-neck Chickens In A Tropical Environment. *Nigerian Journal of Animal Production*, 20: 25-31. <https://doi.org/10.51791/njap.v20i.2098>
- Ibe, S. N. 1998. Improving productive adaptability of local chicken in a tropical environment. *Nigerian Journal of Animal Production*, 20: 25 - 31.
- Ikeobi, C. O. N., Ebozoje, M. O., Adebambo, O. A., Adenowo, J. A. and Osinowo, O. A. 1996. Genetic difference in the performance of the local chicken in the South Western Nigeria. *Nig. J. Genetic*, 11: 55 - 60.
- Iyasere, O. S., Ajayi, O. D., Alade, S. O. and Akinbode, V. O. 2019. Behaviour, physiology and body mass of Nigerian indigenous hens during brooding. *Agricultura Tropica et Subtropica*, 52(2): 43-47. <https://doi.org/10.2478/ats-2019-0005>
- Jiang, R. S., Chen, X. Y. and Geng, Z. Y. 2010. Broodiness, egg production, and correlations between broody traits in an indigenous chicken breed. *Poult Sci*, 89(6): 1094-1096. <https://doi.org/10.3382/ps.2009-00621>
- Kalita, N. 1994. Effect of egg weight, storage period and position of egg on hatchability. *Indian Journal of Poultry Science*, 29(3): 281 - 283.
- Katule, A. M. 1992. Crossbreeding as a tool for genetic improvement of chickens in sub-optimum environments. *Bulletin of Animal Production in Africa*, 41: 71 - 80. <https://pubmed.ncbi.nlm.nih.gov/2403332/>
- King`ori, A. M. 2011. Review of the Factors That Influence Egg Fertility and Hatchability in Poultry. *International Journal of Poultry Science*, 10(6): 483-492. <https://doi.org/10.3923/ijps.2011.483.492>
- Kitalyi, A. J. 1998. *Village chicken production systems in rural Africa: Household food security and gender issues*. FAO Animal Production and Health Paper 142. Food and Agriculture Organization of the United Nations. Rome. <https://www.fao.org/3/W8989E/W8989E00.htm>
- Kugonza, D. R., Kirembe, G., Tomusange-Nvule, E., Lutalo, R. and Drani, E. 2012. Experimental validation of farmer innovations in incubation and brooding management of chickens. *Livestock Research for Rural Development*, Vol. 24, Article 91. Retrieved December 4, 2023 from <http://www.lrrd.org/lrrd24/5/kugo24091.htm>
- Kumar Sarkar, P. 2022. Broodiness and Broody Hen Management During Egg Incubation. *Reviews in Agricultural Science*, 10: 337-343. https://doi.org/10.7831/ras.10.0_337
- Kwaku, A. 2009. *Local Domestic Chicken: Their Potential and Improvement*. Ph.D. Thesis, Department of Animal Science, Kwame Nkrumah University of Science and Technology, Ghana.
- Kyarisiima, C. C., Kugonza, D. R. and Twesigye, C. 2004. The potential role of Ugandan indigenous chicken in poverty alleviation. *The Uganda Journal*, 50: 85-90.



- Lwesya, H., Phoya, R. K. D., Safalaoh, A. C. L. and Gondwe, T. N. P. 2004. Rearing chicks in enclosures under village conditions: effect on chick growth and reproductive performance of mother hens. *Livestock Research for Rural Development*, Vol. 16, Article 89. Retrieved December 14, 2023 from <http://www.lrrd.org/lrrd16/11/wesr16089.htm>
- Mallia, J. G. 1999. Observations on family poultry units in parts of Central America and sustainable development opportunities. *Livestock Research for Rural Development*, Vol. 11, Article 29. Retrieved December 9, 2023 from <http://www.lrrd.org/lrrd11/3/mal113.htm>
- Mengesha, M. and Tsega, W. 2011. Phenotypic and genotypic characteristics of indigenous chickens in Ethiopia: A review. *African Journal of Agricultural Research*, 6(24): 5398-5404.
<https://doi.org/10.5897/Ajar11.434>
- Molekwa, J. T. and Umesiobi, D. O. 2009. Relationships between cock semen viability and the fertility of artificially inseminated South African indigenous chicken breeds. *South African Journal of Animal Science*, 39(5): 24-28.
- Molenaar, R. 2012. The importance of brooding period. In: XXIV World's Poultry Congress, 5th - 9th August, 2012, Salvador, Brazil.
- Murad, A., Farooq, M., Mian, M. A. and Muqarrab, A. K. 2001. Hatching performance of Fayumi eggs. *Sarhad. J. Agric.*, 17(1): 1 - 6.
- Ngou Ngoupayou, J. D. 1990 *Country report on small holder rural poultry production in Cameroon*. In: CTA Seminar proceedings on Small holder Rural Poultry production, 9-13 october 1990, Thessaloniki, Greece. pp. 39-41.
- Nwagu, B. I. 2019. Factors affecting fertility and hatchability of guinea fowl eggs in Nigeria. *World's Poultry Science Journal*, 53(3): 279-286.
<https://doi.org/10.1079/wps19970022>
- Okeno, T. O., Magothe, T. M., Kahi, A. K. and Peters, K. J. 2012. Application of risk-rated profit model functions in estimation of economic values for indigenous chicken breeding. *Trop Anim Health Prod*, 44(6): 1279-1287.
<https://doi.org/10.1007/s11250-011-0069-x>
- Oluyemi, J. A. and Roberts, F. A. 1979. *Poultry production in warm climates* (1st edition ed.). Macmillan Press, Nigeria.
- Onasanya, G. O. and Ikeobi, C. O. N. 2013. Egg physical traits, performance, fertility and hatchability in exotic and Nigerian indigenous chickens. *Standard Research Journal of Agricultural Sciences*, 1(1): 1 - 8.
- Pedersen, C. V., Kristensen, A. R. and Madsen, J. 2002. *On-farm research leading to a dynamic model of a traditional chicken production system* In: Proceedings of the joint 17th Scientific Conference of the Tanzania Society for Animal Production and the 20th Scientific Conference of the Tanzania Veterinary Association, Arusha, Tanzania. pp. 237 - 247.
- Peters, S. O. 2000. *Genetic Variation in the reproductive performance of indigenous chicken and growth of pure- and half-bred progeny*. M. Agric Dissertation, Department of Animal Breeding and Genetics, University of Agriculture, Abeokuta, Ogun State, Nigeria.
- Peters, S. O., Omidiji, E. A., Ikeobi, C. O. N., M.O., O. and Adebambo, O. A. 2004. Effect of Naked neck and frizzled genes on egg traits, fertility and hatchability in local chickens. In: J.O. Ogunji, I.I. Osakwe, V.U. Ewa, S.O. Alaku, M.O. Otuna and B.O. Nweze (eds). Proceeding of the 9th Annual conference of Animal Science Association of Nigeria, Ebonyi State University, Beaklike, Nigeria. pp. 262 - 264
- Prayaga, K. C. and Henshall, J. M. 2005. Adaptability in tropical beef cattle: genetic parameters of growth, adaptive and temperament traits in a crossbred population. *Australian Journal of Experimental Agriculture*, 45(8).
<https://doi.org/10.1071/ea05045>
- Rashid, A., Khan, S., Abbas, G., Amer, M., Khan, M. and Iftikhar, N. 2013. Effect of egg weight on hatchability and hatchling weight in Fayoumi, Desi and crossbred (Rhode Island Red X Fayoumi) chickens. *Veterinary World*, 6(9).



- <https://doi.org/10.5455/vetworld.2013.592-595>
- Romanov, M. N. 2001. Genetics of Broodiness in Poultry - A Review. *Asian-Australasian Journal of Animal Sciences*, 14(11): 1647-1654. <https://doi.org/10.5713/ajas.2001.1647>
- Roy, T. C., Rahman, M., Kalita, N. and Das, B. 2003. Effect of season and year on the fertility and hatchability in White Leghorn chickens of Meghalaya. *The Indian Veterinary Journal*, 80(10): 1026 - 1029.
- Ruscio, M. G. and Adkins-Regan, E. 2004. Immediate early gene expression associated with induction of brooding behavior in Japanese quail. *Horm Behav*, 46(1): 19-29. <https://doi.org/10.1016/j.yhbeh.2004.02.002>
- Sall, B. 1990. *Contribution a l'etude des possibilites d'amelioration de la production en aviculture traditionnelle: mesure du potentiel de la race locale et des produits d'un croisement ameliorateur*. MSc thesis, Institut National de Developpement Rural, St. Louis, Senegal.
- Shatokhina, S. 1975. *Relationship of morphological traits of eggs with embryonic and post-embryonic development of different lines of laying hens* Cand. Agric. Sci. Thesis of Candidate of Agricultural Sciences,, Kuban Agricultural University, Krasnodar, Russia.
- Sölkner, J., Nakimbugwe, H. and Valle Zarate, A. 1998. Analysis of Determinants for Success and Failure of Village Breeding Programmes. Proceedings of the 6th World Congress on Genetics Applied to Livestock Production, Armidale. pp. 273-280
- Sonaiya, E. B. 1990. The system approach to rural poultry development. In Proceedings of an International workshop on Rural Poultry Development in Africa, Obafemi Awolowo University, Ile Ife. 13-16 Nov. 1989. pp. 243-247
- Sonaiya, E. B. and Swan, S. E. J. 2004. *Small-Scale Poultry Production, Technical Guide Manual*. Food and Agriculture Organization of the United Nations (FAO), Rome.
- <https://www.fao.org/3/y5169e/y5169e00.htm>
- Tadelle, D., Million, T., Alemu, Y. and Peters, K. J. 2003. Village chicken production systems in Ethiopia: 2. Use patterns and performance valuation and chicken products and socio-economic functions of chicken. *Livestock Research for Rural Development*, Vol. 15, Article 10. Retrieved December 10, 2023 from <http://www.lrrd.org/lrrd15/1/tadeb151.htm>
- Ugwu, S., Onyimonyi, A. E., Nicholas, O. and Mkpado, M. 2009. Economics of Alternative Incubation Technology in the Development of Subsistence Poultry Enterprise: Evidence Involving Indigenous Knowledge in Katsina State, Nigeria. *International Journal of Poultry Science*, 8(3): 277 - 282.
- Wilson, H. R. 1991. *Effects of egg size on hatchability, chick size and posthatching growth*. In: "Avian Incubation" Poultry Science Symposium No. 22, Buitenvoort-Heinemann Ltd., Surrey, UK. Pp. 279-283.
- Wilson, R. T. 1979. Studies on the livestock of Southern Darfur, Sudan, VII. Production of poultry under simulated traditional conditions. *Trop Anim Health Prod*, 11(3): 143-150. <https://doi.org/10.1007/BF02237790>
- Wilson, R. T., Traore, A., Traore, A., Kuit, H. G. and Slingerland, M. 1987. Livestock production in central Mali: reproduction, growth and mortality of domestic fowl under traditional management. *Trop Anim Health Prod*, 19(4): 229-236. <https://doi.org/10.1007/BF02242121>
- Yakubu, A., Bamidele, O., Hassan, W. A., Ajayi, F. O., Ogundu, U. E., Alabi, O., Sonaiya, E. B. and Adebambo, O. A. 2020. Farmers' choice of genotypes and trait preferences in tropically adapted chickens in five agro-ecological zones in Nigeria. *Trop Anim Health Prod*, 52(1): 95-107. <https://doi.org/10.1007/s11250-019-01993-0>