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Effect of Genotype, Environment, and Their Interactions on Internal as well as External Egg Quality Traits of Different Chicken Genotypes and Poultry Species in Ethiopia and Beyond: A Review

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ABSTRACT

This review study was conducted to evaluate the effects of management, environment, storage temperature, and durations, breed, generation, selection, species, and the interaction effect of breed by management, and correlations effects of these factors on egg quality traits (internal and external egg quality traits) of different poultry genotypes, and species. The egg quality parameters include but are not limited to shell, albumen, and yolk characteristics, and can be divided grossly into external and internal quality parameters. The internal egg quality parameters are based on the air cell size, albumen, yolk quality, Hauge Unit, etc. The objective of this review study was, therefore, to evaluate different research findings and to give comprehensive and evidence-based information to poultry value chain actors on the effect of different factors on egg quality parameters and nutritional quality of eggs. For this review study, both global and local research outputs and poultry resource materials were reviewed, and a comparative analysis was made and presented. The review study indicated that breed, species, management systems, age of birds, generation, selection, storage temperature, duration, and the interaction and/or correlation effects of these factors do have significant effects on the internal as well as external egg quality traits at different levels. In some of the traits, there are either positive or negative correlations. For example, some global research findings indicated that egg weight does have a positive correlation with most internal egg quality parameters as opposed to external egg quality traits. Management systems including feeding also have a significant positive impact on egg quality parameters. Birds that are assigned under intensive and improved management systems can produce better quality eggs as compared to birds kept under local management systems. Improved feeding, health care, housing, and other management factors do have a significant positive effect on the performance of exotic chickens as compared to local landraces. Storing eggs from day zero to 30 days at room temperature does have a significant effect on the internal egg quality traits compared to the

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external egg quality traits. For example, the albumen weight (g) is reduced by 8% from day zero to 30 days of storage which will have a significant effect on the nutritional quality of the eggs. The Haugh Unit similarly reduced by 22% from day zero to day 30 which has a major effect on the internal egg quality traits and nutritional quality of eggs. On the other hand, the effect of storage days does have a limited impact on external egg quality traits as compared to internal egg quality traits. Similarly, species of birds do affect egg quality parameters. For example, some research findings indicated that the rate of deterioration of guinea fowl eggs' internal qualities was lowest when compared to that of domestic chicken and duck eggs and this could be attributed to its shell thickness. On a unit basis, the Guinea fowl egg has a smaller surface area than the chicken egg which reduces the rate of water loss in Guinea fowl egg. Observations on Guinea fowl and chicken eggs stored at room temperature for 20 days revealed that the yolk and albumen contents of the Guinea fowl egg retained their qualities better and longer than the chicken egg and Duck eggs. Other research findings indicated that as the egg weight increases, the Hauge Unit increases which is a very good indication of the presence of a positive correlation between these two parameters. The value of the Hauge Unit is a measure of internal egg quality traits (protein quality). The higher the value the better the quality of eggs. Therefore, better management including feeding does have a direct impact on egg weight which in turn does influence the Hauge Unit and nutritional quality of eggs. Therefore, for profitable poultry business and delivery of safe and quality eggs to the consumers, and to produce first-class day-old chicks, the farmers should consider the management aspect of their layers, the breed type to be used, the age of birds, generation, storage temperature, and duration. The information also helps in reducing the wastage of eggs during transportation.

Keywords: Breed, Correlation, Egg quality, Hauge Unit, Interaction effect, Management system, Traits.

INTRODUCTION

Poultry production is one of the key and growing livestock subsectors in most parts of the world including Ethiopia. It plays important roles in terms of generating employment opportunities, improving family nutrition, serving as a means of livelihood, and women empowerment. It is a suitable business for poor households due to the small quantity of land needed and the low investment costs required to start up and run the operation. The sub-sector has also minimum environmental effects with limited water requirement and high feed conversion efficiency.

The current poultry population of Ethiopia is estimated to be around 57 million of which the majority (32.9 percent or 18.7 million) are chicks and 34.3 percent (19.5 million) are laying hens [1]. The composition of the breeds indicated that, of the total poultry population, 78.9% are indigenous ecotypes, 12% hybrids and 9.1% of the total is exotic breeds [1]. About 56 percent (9.6 million) of Ethiopian households have poultry holdings with varying ranges of flock size [1]. However, about 80 percent of the households with poultry keep from 1 to 9 chickens [2]. The sub-sector is indeed dominated by extensive scavenging (low-input-low-output husbandry system) and family poultry production systems.

However, Ethiopia has a small (but growing) number of medium, and large-scale intensive broiler and layer farms located in and around Addis Ababa, Bishoftu, Modjo, and Adama. Such poultry farms are also emerging in the growing urban areas of Mekelle, Bahir Dar, Gondar, Hawassa, and Dire Dawa [3]. The composition in terms of chicken type and ownership of the commercial poultry sector in Ethiopia indicated that the majority (74 percent) of the commercial farms are engaged in egg production, 14 percent in dual-purpose chicken farming, 9 percent of the commercial farms are keeping all kinds of commercial chicken as available, and the remaining 3 percent is keeping broilers [3]. The dominant proportion of the national poultry meat and eggs are produced under the scavenging family poultry production systems using low-producing indigenous breeds [3]. However, these days exotic breeds in intensive poultry production systems are contributing to an increasing share of production [3]. The domestic poultry market is constrained by seasonal fluctuations in demand (fasting), the ever-increasing price of inputs including feed, disease challenges, the limited, and unstable supply of energy, quality of the products, and other institutional challenges. The per capita chicken meat consumption in Ethiopia is not more than 0.6kg/head and 0.5kg eggs/head, respectively [3]. However as reported by [4], the per capita egg consumption of Ethiopia is even less than that (0.38 Kg) which is the least from all African countries and even from East Africa average. For example, the consumption of eggs in Kenya, Sudan, and Tanzania is 4 times, 3.6 times, and 2.7 times higher than in Ethiopia, respectively. However, the frequency of consumption for eggs is higher compared to chicken meat in Ethiopia. While Ethiopia's overall egg consumption is low, the case is relatively improving in the main urban areas. For example, residents in the capital, Addis Ababa, are estimated

to consume an average of 3.5 kg of eggs annually, which is 7 times higher than the country's average [4].

The per capita poultry products consumption is also governed by the consumer preference for quality products (eggs and meat) concerning several characteristics including cleanliness, freshness, surface area, mass, and origin (genotype of a hen) [5]. The egg quality also includes several aspects related to the shell, albumen, and yolk, and can be divided into external and internal quality parameters. Both the internal as well as external egg quality traits influence the nutritional content and safety of eggs. The internal quality is based on the air cell size, albumen, yolk quality, Hauge Unit, the presence of blood and meat spots, and others. All egg quality characteristics are affected by several factors including age, generations of birds, the genotype of the hen, nutrition, species, storage duration, temperature, type of rearing system, and the time of oviposition, etc. Maintaining the quality of eggs does have a direct effect on overall market coverage and expansion. updated as per the comment.

The idea of egg quality is not well understood by poultry producers and traders in most developing countries including Ethiopia. Therefore, this review study is initiated to understand the factors affecting egg quality traits, interaction, and correlations of these factors, and to share the information with the poultry farmers and value chain actors, and to reduce wastage, leverage better markets, and deliver healthy and safe diets. The specific objectives of this review study include.

1. By reviewing the global and national research outputs on egg quality parameters to deliver evidence-based information to poultry value chain actors to produce the best quality eggs for the market, supply quality products, and produce first-class day-old chicks.
2. By sharing the global and local experiences on the effects of different factors that affect the egg quality parameters, to reduce wastage, and increase the income of the poultry farmers.

Egg Production Performance of Different Chicken Genotypes in Ethiopia:

Ethiopia has a huge number of indigenous chickens distributed in different agroecology and regional states. Indigenous chickens that live in different geographical areas of the country have varieties of ecotypes. Chicken population distribution varies with regional states, higher in Oromia followed by Amhara Regional State. Harari Regional State has a lower chicken population [6].

These huge local ecotypes produce not more than 40-60 eggs/year/hen whereas, under intensive poultry production systems, exotic breeds produce an average of 250 eggs/year/hen with an average egg weight of 60 grams in Ethiopia [6]. As Figure [1] below indicates, the share of exotic and hybrid chicken egg production increases over time. Whereas the contribution of the local ecotypes declined from 91.3% in 2010/11 to 63.1% in 2017/18. The contribution of exotic on the other hand, was 0.81% in 2010/11 and increased to 25.3% in 2017/18. The same sources indicated that the contribution of crosses was 7.9% in 2010/11 and increased slightly to 11.6% in 2017/18 [6].

Other sources like [7], similarly indicated that the egg production potential of exotic chicken under intensive management system on average is 250 eggs as the local ecotypes remained at 30-60 eggs/bird/year. A similar source indicated that the egg weight of the exotic breeds is around 60 grams whereas the local ecotypes are not more than 38 grams/egg. The bigger egg weight of the exotic chicken is another advantage (better egg mass) on top of the higher egg number produced by the exotic chicken as compared to the locals. According to [2], the market supply of eggs from domestic production in Ethiopia by 2017 revealed that 55,000 tonnes of eggs were produced. The egg production potentials of different poultry genotypes under the Ethiopian situation are summarized and presented in Figure [1] below.

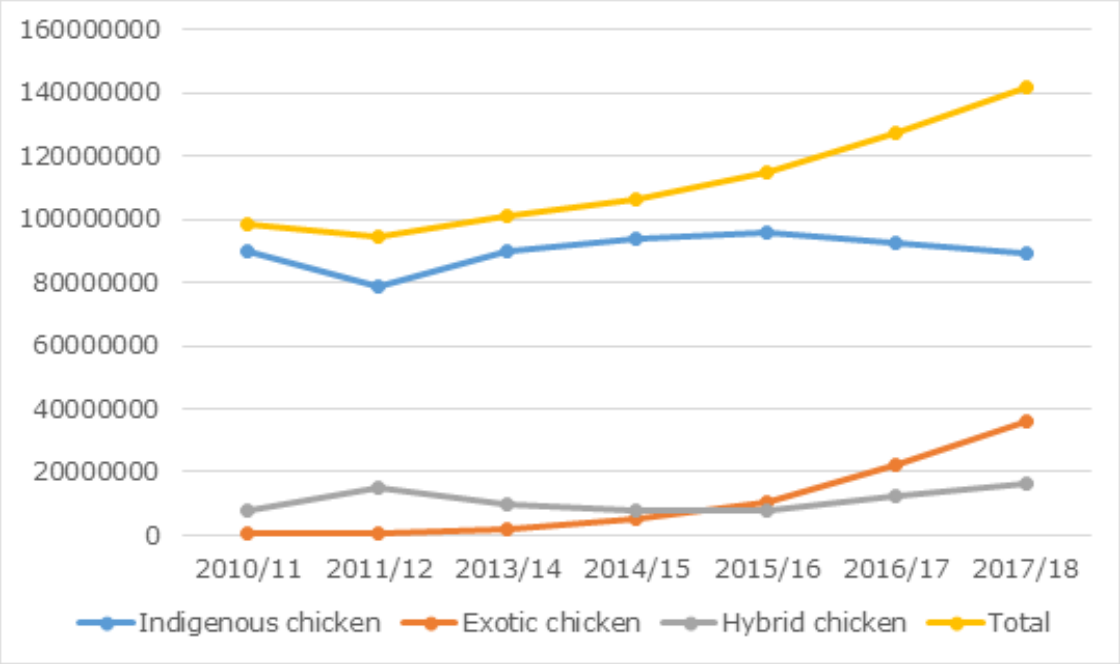

Figure 1. Egg production potentials of different chicken genotypes in Ethiopia the topic is more of for Ethiopia and we want to see the performance of different chicken genotypes under the Ethiopian situation and we want to give a recommendation based on the findings to Ethiopia poultry farmers. But the experience can be used somewhere else as well.

Source: Calculated by the author [6]:

Poultry Products Consumption in Ethiopia

Consumption of poultry products in Ethiopia is more common in urban than in rural areas, and it is high during holiday periods. Recent data showed that consumption of poultry products is one of the lowest, even by Sub-Saharan Africa standards. Per capita, egg consumption in Ethiopia stands at 0.5 kg while neighboring Kenya has an annual per capita consumption rate of 1.9 kg. The African average is 2.3 kgs and for Asia 9.2 kgs, 11.4 kgs for America, and 12.7 kgs for Europe. The world average also stands at 8.9 kg [3].

In urban households, eggs, and chicken meat are becoming part of the normal diet. However, the frequency of consumption for eggs is higher compared to chicken meat. During the survey, 96 percent of participants indicated that they purchase eggs all year round, while the case was the same for chicken meat with only 40 percent of participants [6]. Despite some progress, per capita consumption of eggs and chicken meat is still low in Ethiopia. In 2019, the per capita consumption of eggs in Ethiopia was estimated to be 0.38 kg, which lags its East African peers [4]. Ethiopia is ranked among the lowest consumers of eggs globally at 155th out of 161 countries. The countries with the highest per capita consumption of eggs in Africa include Algeria (7.16 kg), Tunisia (7.15 kg), and South Africa (5.77 kg) [6].

Urban cities are the main market outlet for backyard, small-scale, and commercial poultry producers due to the higher purchasing power and nutrition-consciousness of urban residents. Hence, although still below the FAO recommended intake of 4.5 kg per year, consumption of eggs is significantly higher in urban areas compared to the rural population. Likewise, per capita consumption of chicken meat in Ethiopia is one of the lowest in the world. In 2019, the country ranked 159 places out of 161 countries with an annual consumption of 0.69 kg, only better than Chad and Burundi. African peers such as Kenya, Sudan, Rwanda, and Uganda consume two times or more poultry meat compared to Ethiopia—indicating the poultry meat market in Ethiopia is still at an infant stage [4].

However, the average low per capita consumption of eggs and poultry meat is also an indication of the considerable potential for growth that the Ethiopian market holds. Poultry is one of the most affordable nutritious foods and many families in Ethiopia are becoming aware of its impact on health and reducing malnutrition in children. In addition, several initiatives are underway to create demand—both led by the government and development organizations initiatives. The impact of these initiatives, coupled with

increasing awareness, and growing purchasing power of the middle classes, is expected to increase demand for eggs and poultry meat. To satisfy the potential demand growth for eggs and poultry meat, small-scale and commercial farms need to increase their supply [4].

In addition to local supply, Ethiopia has a strategic locational advantage to compete internationally. Ethiopia is centrally located in the global economy and has proximity to the key markets of Africa, the Middle East, and Europe. The East and North African markets alone are estimated to be valued at over USD 3 billion and are largely import-dependent and growing [4]. Ethiopia is a member of the Common Market for Eastern and Southern Africa (COMESA) with preferential access to a regional market of over 400 million people [4]. As Figure [2] indicates to reach African per capita egg consumption, Ethiopian farmers should produce six or more times the African average egg production which is 479% higher than the Ethiopian average (as the figure below indicated). The per capita chicken egg consumption of some selected African countries is summarized and presented in Figure [2].

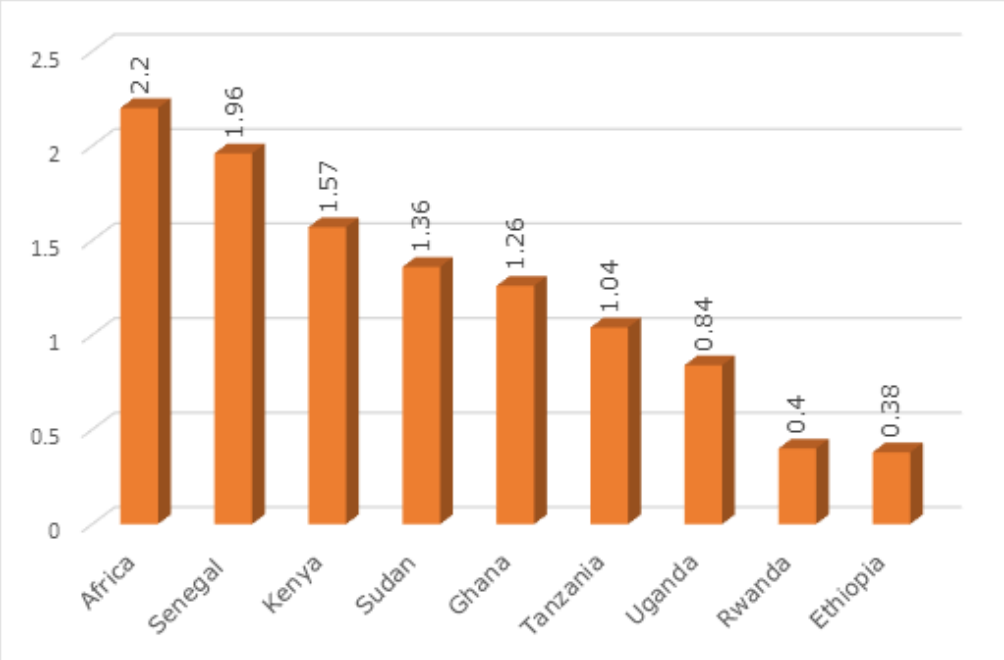

Figure 2. Per capita egg consumption for some selected African countries (kg).

Source [4]

Effect of chicken breed and poultry species on external and internal egg quality parameters

Egg quality is important for both consumers and to produce first-class day-old chicks. In Ethiopia, at Yirgalem and Hawassa towns an experiment was conducted to see the effect of breed on egg quality parameters. Eggs were purchased from local ecotypes, Sasso, and Bovans breeds [8]. The objective of the study was to see the breed and location effect on both internal as well as external egg quality parameters. The results of the study indicated that the weight of the eggs highly varied between the genotypes and within the genotypes (between locations). The eggs of the native chickens weighed (45.20±5.53 and 39.30±4.04 g), while the eggs of Sasso chickens weighed (56.40±7.07 and 56.00±7.2 g), whereas those of Bovans Brown weighed (57.80±7.22 and 60.70±5.98 g) at Hawassa and Yirgalem towns, respectively. The results pertaining to the Haugh Unit of the eggs (from Hawassa and Yirgalem) from the native chickens were (74.91±15.78 and 82.55±3.82), while for Sasso chickens (86.50±11.07 and 87.04±11.10) and Bovans Brown were (94.60±7.74 and 86.29±5.85), respectively. The Haugh Unit of the egg from the native chickens was lower than exotic chicken; this was observed irrespective of the locations. It was concluded that the egg quality of exotic chickens in the study areas performed well [8]. Of the three breeds, Bovans Brown which is usually managed under improved management laid heavy-weight eggs as compared to the other two. Consequently, the Hauge Units are higher than the rest of the two. Therefore, better feed supply and management are important for better egg weight and Hauge Unit [8]. The relationship between the egg weight and the Haige Unit is summarized and presented in Figure [3] below.

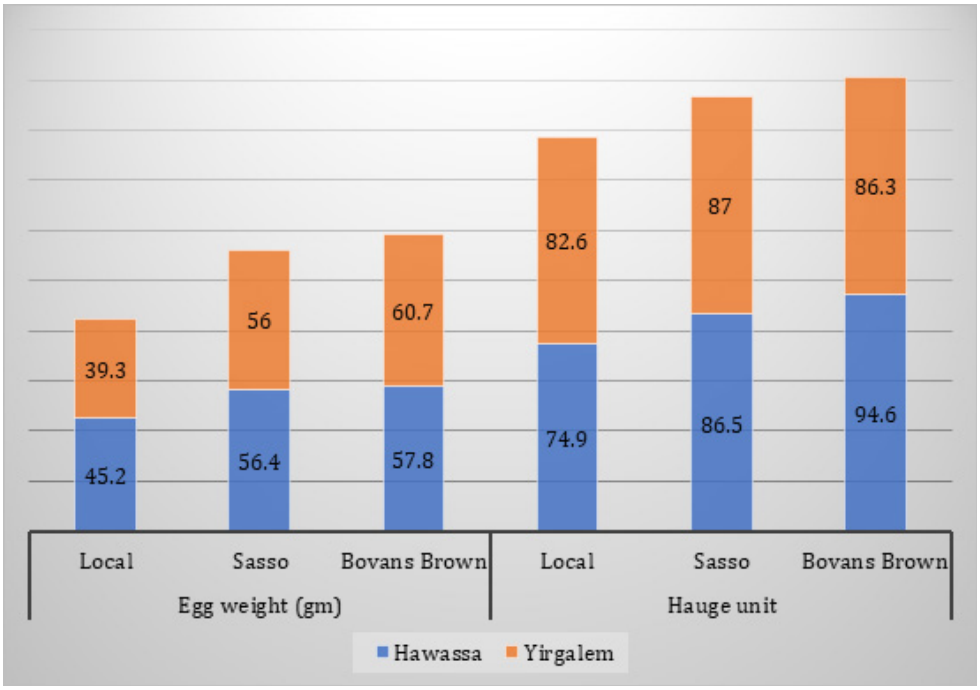

Figure 3. Relationship between egg weight and Hauge Unit of different poultry genotypes.

Source: [8]

Another experiment was conducted in Tanzania using Kuroiler and Sasso chicken to evaluate the egg quality parameters under semi-scavenging (on-farm) and deep litter (on-station) management conditions. The eggs were collected both from, hens raised under on-station and on-farm conditions. The results showed that the mean values of all egg quality traits studied were higher for on-station than on-farm except shell, yolk, and albumen ratios which did not differ between the two management conditions. Concerning breed effects, Kuroiler chickens had higher values for egg weight, egg length, yolk weight, albumen height, and Haugh Unit than Sasso chickens. Significant interaction effect of management system by breed was observed on egg weight and eggshell ratio. Pearson's correlation coefficients showed that egg weight was positively correlated with all external and internal egg quality traits of both Sasso and Kuroiler chickens, except with shape index and yolk ratio for external and internal egg quality, respectively [9]. From these two experiments, one can conclude that location and management do have strong effects on egg quality parameters.

The Haugh Unit (HU) is calculated from the height of the inner thick albumen and the weight of an egg, and it is a typical measure of albumen quality (egg quality trait). It is generally accepted that the higher the Haugh Unit value, the better the nutritional quality of the egg. In this study, the albumen height and Haugh Unit were also affected by the management system with on-station eggs showing higher values (7.58±0.03 mm, albumen height and 86.98±0.17, Haugh Unit) than those of on-farm (6.80±0.05 mm, albumen height and 84.1±0.27, Haugh Unit). The higher score in albumen height and Haugh Unit for eggs from on-station than on-farm could be associated with better management and nutrition of the birds, which have a significant influence on internal egg quality traits [9].

The same source indicated that eggshell quality is associated with levels of resistance to breakages during transportation affected by the management system in Tanzania. The study further reported that the management system significantly affected shell weight, and shell thickness in favor of on-station. The lower values particularly for on-farm eggs for shell quality traits are most likely to be associated with poor feeding the inadequate Calcium (Ca) and other trace minerals intake. Regarding breed effects on external egg quality, results showed that only egg weight and egg length differed between the two breeds. Kuroiler chickens had heavier (57.13±0.33 g) and longer (56.89±0.17 mm) eggs than Sasso chickens (55.80±0.29 g and 56.10±0.15 mm for egg weight and length), respectively which might be due to variations in genetic make-up between the breeds [9].

Regarding breed effects on internal egg quality, it was observed that the albumen height and Haugh Unit differed between the two breeds. Kuroiler had higher mean values for albumen height (7.29±0.45 mm) and Haugh Unit

(85.98±0.24) than Sasso (7.09±0.41 mm, albumen height and 85.12±0.21, Haugh Unit). The correlation between egg weight and the Hauge Unit is supported by several research findings mentioned previously in this review paper. In addition to albumen height and Haugh Unit, the yolk weight was also heavier (18.61 g) for Kuroiler than for Sasso (17.98 g). Like that of egg weight and Hauge Unit correlation, yolk weight and egg weight were positively correlated traits; this might be a reason for heavier yolk for Kuroiler, as the breed had also heavier egg weight than Sasso [9].

There were significant interaction effects between the management system and breed on egg weight and eggshell ratio. This implies that except for egg weight and shell ratio, the response of the two breeds on other evaluated egg quality traits was similar when subjected to different management systems. It was observed that, while the two breeds had comparable egg weight and shell ratio on-farm, these traits differed on-station where Kuroiler outperformed Sasso on egg weight but had a lower shell ratio for Kuroiler. The probable reason for this variation might be due to differences in the strength of correlation coefficients for egg weight and shell ratio between the two breeds. The correlation between egg weight and shell ratio was higher for Sasso than for Kuroiler; therefore, for every increase in egg weight, the percent share of the shell became higher for Sasso than for Kuroiler [9].

The phenotypic correlation coefficients for external egg quality traits indicated that there are significant and positive correlations between egg weight and egg length, egg width, shell weight, shell ratio as well as shell thickness of both Sasso and Kuroiler chickens. The highest correlations were observed between egg weight and egg width for Sasso and Kuroiler chickens (0.80 and 0.66, respectively), while the lowest significant and positive correlation (0.15) was observed between egg weight and shell thickness for both Sasso and Kuroiler chickens [9]. On the contrary, a significant but negative correlation (-0.12) was observed between egg weight and shape index for Sasso chickens, while for Kuroiler the relationship was non-significant but still negative (-0.01) [9]. The interaction effect of the breed and management system of these two breeds on egg weight is summarized and presented in Figure [4] below.

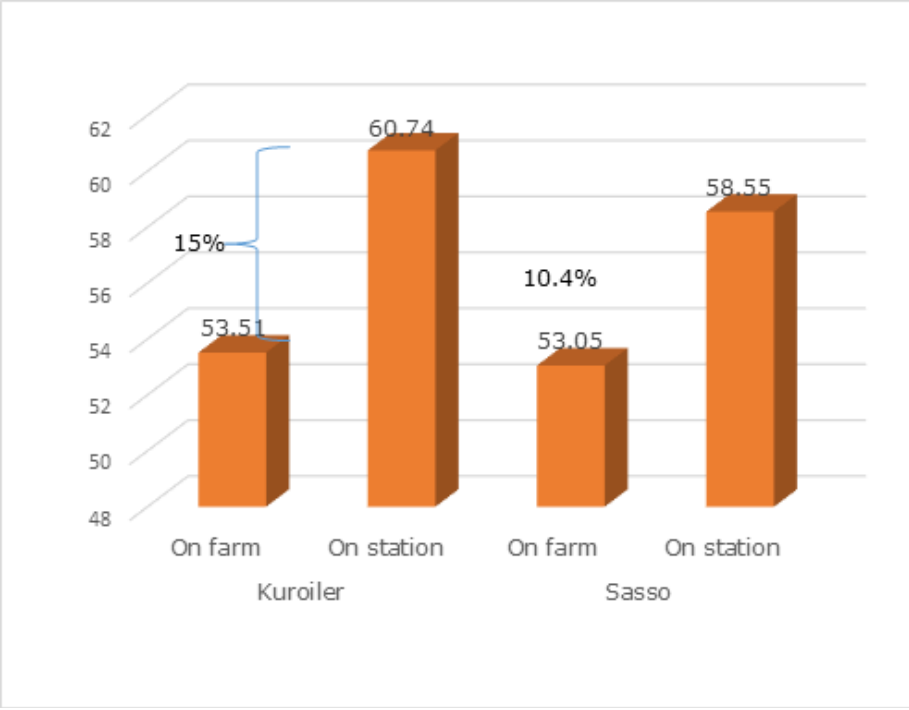

Figure 4. On-station and on-farm egg weight performance of the two breeds.

Source: calculated by the author [9].

Research conducted on local Sakini chicken [10] revealed that the egg weight was increased across the generation of selection by 8.3% in G1, 11.8% in G2, and 17.2% in G3 with respect to G0. The finding indicated that through selection egg weight significantly improved which helps for a better egg market. The egg weight of free-range normal feathered Nigerian indigenous chicken was 40.83 g and Sudanese indigenous chicken eco-types was 38.46 g. Egg weight is

largely affected by environmental factors like feed supply, and parental average body weight of the birds.

To evaluate the effect of the age of the birds on the internal egg quality parameters, research was conducted using 85-week-old laying birds [11]. The result indicated that the egg quality characteristics of old laying hens have a negative impact on shell and albumen quality but do not affect yolk quality characteristics. Old laying hens may diminish shell quality characteristics, such as shell weight, shell thickness, and shell ratio, because of the increasing egg weight and size (a well-known egg characteristic in old laying hens). In addition, a clear reduction in albumen quality characteristics was observed in the advanced age of hens. Both Haugh Unit and albumen height (key egg quality characteristics) decreased their measurements as the birds' age progressed. The albumen quality deteriorated as the bird progressed which is the best indicator of egg quality parameters. But, as the age of laying birds advanced, the yolk quality characteristics were not affected. This study helps to understand that raising laying hens above 80 weeks would reduce the egg quality characteristics; compromising both the quality and efficiency of egg production and increasing wastage during transportation [11].

A study was conducted to evaluate the effect of breed type on the egg quality parameters using white and brown egg layers [12]. The result indicated that the average egg weight of brown egg layers is heavier than their white counterparts. Similarly, the albumen percentage is higher for brown egg layers. But the yolk percentage is higher for white egg layers than the brown egg layers. The difference between the shell percentage of the two chicken types does not show any significant difference [12]. The findings will help to determine the type of chicken breed to use based on their background.

A study was conducted to compare external and internal egg quality attributes and some functional traits of eggs from five different poultry types/species namely, Sri Lankan village chicken and commercial chicken (Shaver Brown), Duck (Vigoa), Quail (Japanese quail), and Turkey (Turkey white) [13]. Yolk color, shape index, egg weight, and shell thickness values of the freshly laid eggs showed significant differences among the four species. The Yolk color of the village chicken egg was 7.30 which is significantly higher than that of other species. Quail eggs had the highest shape index value (80.90±0.01) and the lowest egg weight (9.47±5.64 g). Whereas Turkey eggs had the lowest shape index value (69.20±0.02) and the highest egg weight (71.48±5.21 g). Village chicken eggs and Quail eggs had significantly lower eggshell thickness than that of other poultry species. The result indicated that egg quality characteristics showed a significant difference among the different poultry species related to the chicken genotypes, the environment where these species are kept, and the possible interaction effect between the breed by environment. The shape index and the HU were the highest in Quail eggs. Whereas the Duck eggs had the highest viscosity and gel strength among the different poultry species. Moreover, Sri Lankan village chicken eggs showed excellent egg yolk color compared with eggs from other poultry species used in this study. The relationship between egg weights and the Hauge Unit (HU) of different poultry species is summarized and presented in Figure [5]. From the figure, the HU is the highest for Quail eggs as compared to the other poultry species which implies the highest egg quality parameters of all the internal egg quality parameters. Therefore, based on the available market and the interest of the customers, the poultry farmers can select the species used to meet their business objectives. The positive correlation between egg weight and HU applies within breeds not between breeds as can be seen from Quail birds' eggs and the HU.

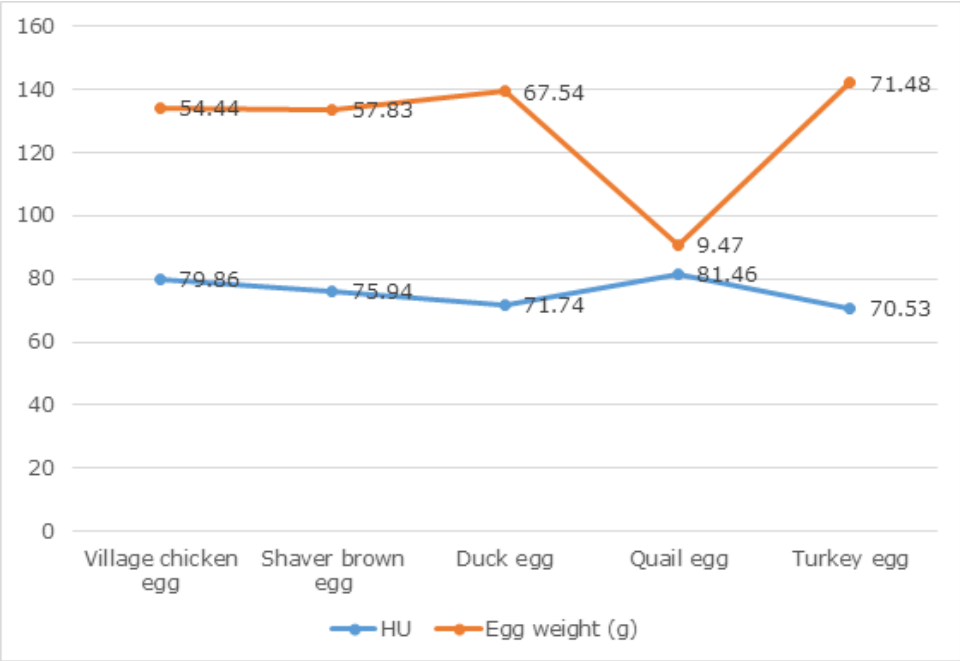

Figure 5. Comparison of the egg quality parameters of different poultry species.

Source: [13]

The study was conducted in Nigeria to determine the effect of egg weight on the internal and external egg quality characteristics of Isa Brown egg layer chickens [14]. Eggs were collected in 24 hours' time and were categorized into three weight categories (light, medium and heavy weights). The egg quality traits evaluated were internal egg quality characteristics (yolk height, albumen height, albumen length, albumen width, Haugh Unit, yolk index, albumen index, and yolk diameter) and external egg quality characteristics (egg length, egg width, oblong circumference, eggshell weight, egg shape index, and eggshell thickness). The result of the study indicated that egg weight had a significant effect on egg length, egg width, oblong circumference, eggshell weight, and eggshell thickness. Egg weight did not significantly affect the Haugh Unit as opposed to the previous studies which revealed that egg weight has a positive correlation with the Hauge Unit. The weight of the eggs also does not influence the yolk index, albumen index, and albumen length of the three egg weight groups. However, significant differences were observed among the light, medium, and heavy egg weight groups in terms of yolk height, yolk diameter, and albumen height and albumen width. Positive correlations were observed between egg weight and egg length, egg width, oblong circumference, eggshell weight, and eggshell thickness. Egg weight also correlated positively with yolk height, yolk diameter, albumen height, and width [14].

Another research was conducted in Nigeria using normal feathered and naked neck local chicken ecotypes [15] to evaluate the influence of strain and production cycle on egg quality traits. This study indicated that strain type and production cycle influenced most of the egg traits studied, with the normal feather showing in general a superiority over the naked neck. It also suggests that the best internal egg quality with respect to the yolk and albumen traits was obtained from eggs produced between 31-60 days of lay. The external egg quality traits of the naked neck and normal feather Nigerian indigenous chickens were influenced by the strain type and laying period. Variations due to strain effect were observed in egg weight, egg length, and egg breadth, whereas the egg shape index was similar for the two strains. The information obtained from this study would be relevant when considering selection criteria for traits used for breeding programs aimed at developing different layer lines of the Nigerian indigenous chicken with egg quality traits.

In Nepal, an experiment was conducted using indigenous Sakini chicken [16] to compare external and internal egg quality traits of four different generations (G0, G1, G2, and G3) of Sakini chicken and determine relationships among these traits across all generations. The experiment focused on both the external as well as internal egg quality traits, like egg weight, egg length, egg breadth, shell thickness, and shell weight, and internal egg traits like yolk weight, yolk height, yolk diameter, albumen weight, albumen height, albumen

diameter. The result of the experiment indicated that there was a significant difference in almost all traits of external and internal traits of eggs except eggshell quality, yolk-to-albumin ratio, and yolk percentage across generations. Encouragingly, it was observed that an increasing trend for each trait especially the Haugh Unit, a measure for better quality of egg protein in every generation indicated that selection should continue till uniform performance in HU and other traits is demonstrated in the population. Positive and significant correlations were observed between egg quality traits under study. This finding suggested that selection brings genetic improvement in most of the egg quality traits of indigenous Sakini chicken. However, continuous selection practices are to be employed in successive generations to exploit the maximum genetic potential in Sakini chicken [16]. The details of the relationship between egg weight, yolk weight, and albumen weight are summarised and presented in Figure [6].

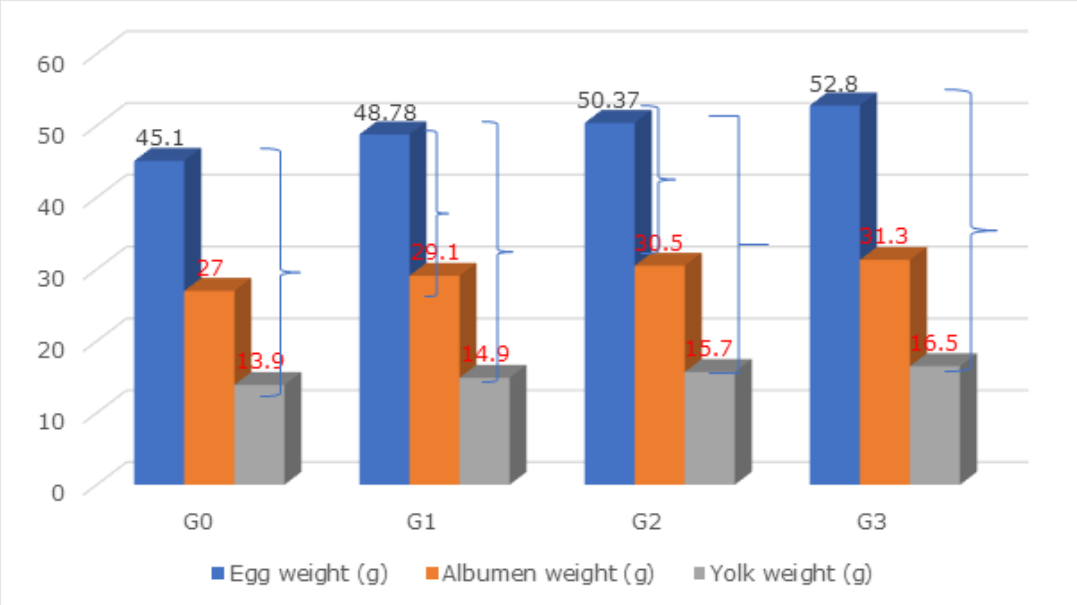

Figure 6. Effect of selection on egg quality traits on indigenous Sakini chicken.

Source [16]

Effects of Management System and Agroecology on Egg Quality Parameters of Different Chicken Genotypes

A study was conducted [17] in Ethiopia at two agroecology (lowland and midland) to evaluate the egg production potential and quality traits of different poultry genotypes. The breeds considered for this research work were Bovans Brown, Koekoeck, Sasso, and Local chicken ecotypes under a traditional management system. The results indicated that the number of eggs per hen per year was 49.1, 134, 117, and 138 for local, Sasso, Bovans, and Koekoeck breeds, respectively. As it is well known, Bovans Brown is an egg-type breed but under a traditional production system, it's egg production is less than the two dual-purpose breeds (Sasso and Koekoek) as a result of breed-by-management system interaction (feed and other management). But the Sasso breed reared in the lowland produced the highest egg number followed by Bovans being higher than Koekeock and local chickens. In most cases for rural farmers without improved feed, dual-purpose breeds like Sasso are recommended because of their foraging ability, resistance to the environment, and their docile nature. The result of this experiment indicated that, the egg production performance of these breeds, which are kept in mid-altitude areas performed better than the other two agroecology may be the good weather situation favorable for better feed availability at the mid-altitude areas compared to the other two extreme agroecologies. In addition to the potential of agroecology, the interaction effect of agroecology by breeds may be the reason for better egg production at the mid-altitude areas for all the breeds as indicated in Figure [7]. The egg weight and yolk index values for the Sasso breed reared in the lowland agroecology were higher than those of other chicken breeds. Koekoeck and Sasso's chicken breeds kept in the midland had higher shape index and shell thickness values than those of the lowland. All internal egg quality traits of Koekoeck chickens reared in the midland agroecology were superior to those of lowland. In conclusion, the Sasso chickens in the lowland agroecology were superior in most performance

traits even though lower than the midaltitude performance. Therefore, it is always good to see the performance of each breed at each agroecology before recommendation. In general, the findings of this study indicated that the external egg quality traits of the different chicken genotypes studied were influenced by agroecology, which could be attributed to the quality and quantity of feed available and the interaction effect of the breed by agroecology. The annual egg production potential per hen under different agroecology is summarized and presented in Figure [7] whereas the external as well as internal egg quality traits of these chicken breeds are summarized and presented in Figure [8].

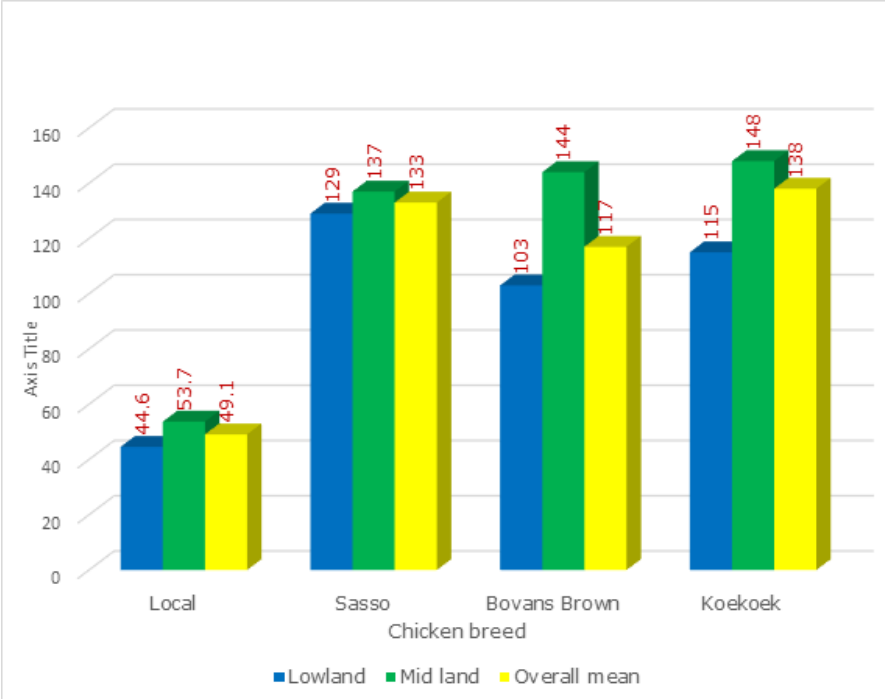

Figure 7. Annual egg production potential of a laying hen of different chicken genotypes under different agroecology.

Source: [17]

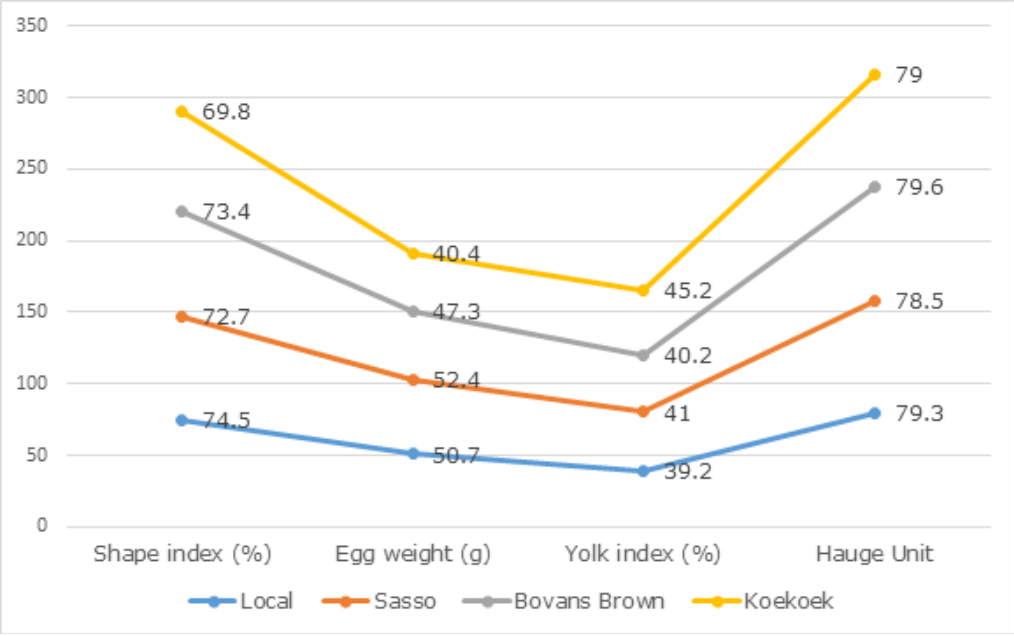

Figure 8. Some external and internal egg quality traits of different chicken genotypes.

Source: [17]

A study was conducted to assess egg fertility, hatchability, and egg quality parameters of indigenous chickens in the Hulla, Aleta Wondo, and Dale districts, representing highland, midland, and lowland agroecology, respectively in Sidama Region, Ethiopia [18]. Six kebeles (localities) (two kebeles from each district) were purposively selected for the experiment. The results indicated that agroecology has no significant effect on fertility (78.17%), hatchability on a total egg basis (63.1%), and hatchability on a fertile egg basis (84.1%) of indigenous chicken eggs. The present research finding is contrary to other findings, which say as altitude increases chick hatchability is reduced and needs further investigation. Naturally, as altitude increases Oxygen concentration reduces which in turn affects the hatchability of chicks. On the other hand, the values of egg weight, egg length, shell weight, yolk weight, and yolk diameter, and albumen weight of eggs collected from midland were higher than those of eggs from highland and lowland areas. However, the highest values for albumen height, yolk height, and Haugh Unit were observed on eggs collected from highland agroecology as compared to the other two agroecologies. Agroecology significantly affects the internal as well as the external egg quality parameters of indigenous chicken eggs compared to fertility and hatchability traits. Therefore, the weather conditions at each agroecology should be taken into consideration when we are dealing with the egg quality parameters [18].

A study was conducted in Peru using 288 eggs from Hy-Line Brown laying hens [19]. The eggs collected were evaluated using various egg quality tests for both external and internal characteristics. The study was conducted to analyze the phenotypic correlations between some internal and external egg quality characteristics in old laying hens. The result indicated that phenotypic correlations between egg quality characteristics in old laying hens have a negative impact on shell and albumen quality but do not affect yolk quality characteristics. This study helps to understand that raising laying hens above 80 weeks would reduce egg quality characteristics [19].

A study was carried out in Ethiopia using improved indigenous chicken (Horro), their crosses, and Koekoek genotypes [20]. The objective was to compare the sensory characteristics and egg quality variabilities among different chicken genotypes. The results of the present study indicated that significantly highest crude protein values were observed in the local genotype, followed by Horro crosses. The egg quality was affected across traits except for eggshell indices. The genotypes with a negative significant correlation with crude protein and had a positive significant correlation with almost all composition traits and external egg quality traits. The genotypes with positive significant correlations of egg weight had positive significant correlations with most internal egg quality traits except that of yolk weight ratio, yolk albumen ratio, and yolk color. In general, the eggs of local, and improved Horro crosses, were best favored followed by the Koekoek genotype, and these differences were deemed due to genetic variations [20]. In the current study, it was noted that sensory characteristics, nutritional composition, and egg quality traits significantly varied among hens. There had been a significant effect on the appearance and acceptance of scrambled and boiled eggs of hens. The moisture, crude protein, crude fat, crude ash, and crude fiber contents of eggs were significantly affected among chickens. External and internal egg equality traits significantly varied among hens. Egg weight had significantly and positively correlated with nutritional composition and egg quality except for yolk color, yolk weight ratio, yolk albumen ratio, and crude protein across hens. Genetic manipulation could have compromised sensory characteristics, nutritional composition, and quality of hens' eggs. The chickens with lower egg weight notified higher crude protein and lower crude fat and are better preferred.

Research was conducted in Turkey to investigate the impact of the egg shape index on egg quality characteristics [21]. The eggs used in this study were laid by layers of the ATAK-S strain. The eggs were classified based on shape index (SI), namely sharp eggs (SI < 72), normal (standard) eggs (SI = 72–76), and round eggs (SI > 76). A total of 166 eggs were analyzed to determine egg quality characteristics. Effects of egg shape on specific gravity, albumen index, and Haugh Unit were statistically significant. However, the effects of the egg Shape Index on egg weight, breaking strength, shell thickness, shell weight, surface area, yolk index, yolk color, albumen pH, and albumen and yolk blood spots were not significant. Statistically significant correlations between egg shape index and egg weight, specific gravity, egg surface area, albumen index, and Haugh Unit were determined. However, the shape index did not correlate with values like breaking strength, shell thickness, shell weight, yolk index, yolk color, and albumen pH. In conclusion, the shape index affects some egg quality characteristics. Therefore, the shape index should be considered when breeding programs are implemented [21]. The relationship between egg weight and some internal egg qualities of indigenous chickens is summarized and presented in Figure [9].

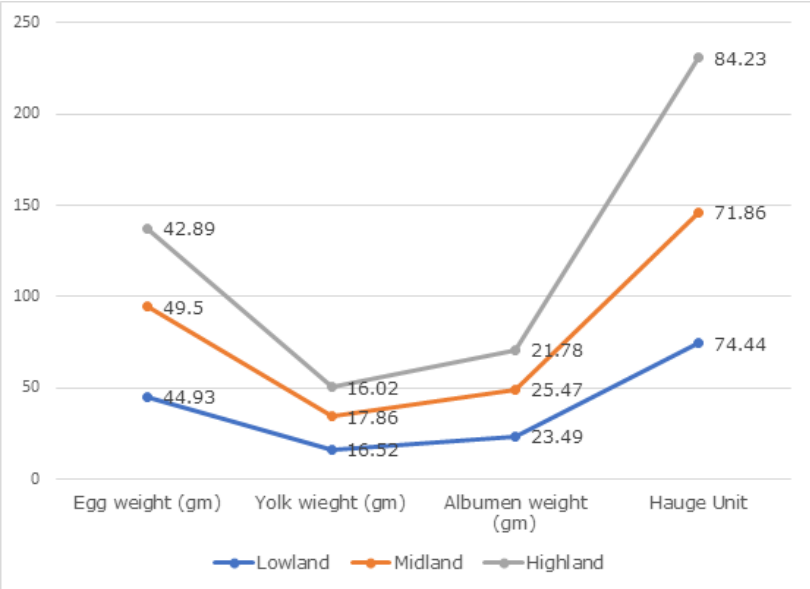

Figure 9. Relationship between egg weight and some internal egg qualities of indigenous chickens

Source [21]

CONCLUSION

Analysing egg quality characteristics is so important to meet consumers' preferences, leverage a better market for their eggs, supply a nutritious and healthy diet, and produce first-class chicks. This review study revealed that breed, generation, and management systems including feeding and health care, agroecology, and species of birds do have effects on both the internal as well as external egg quality traits. In addition to the effect of these individual factors, there are also interactions and/or correlations of some of these factors. It was observed that there is a significant breed difference for both traits, and birds kept under an intensive management system do have better egg quality parameters compared to those kept under traditional management systems. There are also correlations between some of the egg quality traits which will help to improve if we select a breed for one it will positively affect other traits. For example, if we select a breed for better egg weight, it will have a positive impact on the Hauge Unit because these two traits do have strong positive correlations. Most research findings indicated that, as the egg weight increases, the Hauge Unit increases. The value of the Hauge Unit is one of a measure of egg quality traits. The higher the value the better the quality of eggs. Positive and significant correlations were also observed between egg weight and other egg quality traits such as egg length, breadth, shell weight, yolk weight, albumen weight, albumen height, albumen weight, shape index, and surface area. Therefore, better feed supply and management are important for better egg weight and Hauge Unit.

There are also significant differences among breeds on egg quality traits like egg weights, Hauge Unit, Yolk, albumin weights, and other internal as well as external egg quality traits between breeds. The exotic chicken very well responded to the change in management as compared to local landraces. Storage and level of temperature also have a significant effect on egg quality parameters. For example, as we go on storing eggs from day zero to 30 days at room temperature, the internal egg quality traits were significantly affected as compared to the external egg quality traits. For example, the albumen weight is reduced by 8% from day zero to 30 days of storage which will have a significant effect on the nutritional quality of the eggs. The Haugh Unit similarly reduced by 22% from day zero to day 30. On the other hand, the effect of storage days on external egg quality traits is not as significant as that of the effect on internal egg quality traits. On the other hand, the rate of deterioration of Guinea fowl egg internal qualities was lowest when compared to that of domestic chicken and Duck eggs and this could be attributed to its shell thickness. On a unit basis, the Guinea fowl egg has a smaller surface area than the chicken egg, reducing the water loss rate in the Guinea fowl egg. Observations on Guinea fowl and chicken eggs stored at room temperature for 20 days revealed that the yolk and albumen of the Guinea fowl egg retained their qualities better and longer than the chicken egg and Duck egg.

The egg quality characteristics of old laying hens have a negative impact on shell and albumen quality but do not affect yolk quality characteristics. Old laying hens may

diminish shell quality characteristics, such as shell weight, shell thickness, and shell ratio, because of the increasing egg weight and size (a well-known egg characteristic in old laying hens). In addition, a clear reduction in albumen quality characteristics was observed in the advanced age of hens. Both Haugh Unit and albumen height (key egg quality characteristics) decreased their measurements, which are indicators of poor albumen quality.

Therefore, it is concluded that poultry farmers should consider the quality of their eggs to meet the customers' preferences, market, health, nutrition, and for better quality first-class chicks. Factors related to breed, generation, management, storage temperature, duration, species of birds, and their interaction effect and/or correlation are among the traits to be considered when involved in egg production businesses.

RECOMMENDATION

Based on the findings of this review study the following recommendations are made:

- A poultry farmer when planning layers farm should not consider only breed type for egg production. Most research outputs indicated that it is management (feed, health care, housing, and environmental factors) that plays a major role compared to breed alone effect.
- The poultry egg farmers should follow properly the required temperature and storage before marketing eggs.
- When selecting a breed for egg production and egg weight, other correlated traits should also be considered.
- The Hauge Unit, as one of the best egg quality parameters should be considered during selection and genetic improvement of a breed.
- The farmers should also understand the breed, generation, and species effects on egg quality parameters and their interaction and/or correlation effect on egg quality traits since they have a significant effect on egg quality traits.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to this study.

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