Review: Heritability, Breeding Value, Environmental Deviation and Repeatability of Chicken Performances

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Abstract: Growth and egg production are economically the most important traits in small holder poultry production systems. These two traits also showed medium to higher level of heritability, relative to their respective trait categories. Heritability of monthly egg numbers ranged from 0.20 to 0.32 which is moderate. Heritability of growth traits ranged from 0.15 (BW6) to 0.40 (BW0). The values were moderate for body weight at 16 weeks of age (0.23) and that of hatch weight but remained low for the rest of the traits. Reproductive traits in chickens have low estimates of heritability and are strongly influenced by the environment and by non-additive effects of genes.

Keyword: Heritability, Repeatability Variance.

1. INTRODUCTION
Genetic parameters are used for setting up breeding objectives, choosing selection criteria’s, for breeding value evaluation and predicting selection response. The performance of birds is determined by its genotype and environmental factors (Boukwampet al., 1973). In animal breeding, it is imperative to determine breeding value with the objective of classifying the best individuals that will be the parents in the next generation, and quantifying its contribution to the genetic gain (Grosso et al., 2010). Selection of better breeds or strains has gone a long way in producing quick and rapid transformation in animal proteins supply (Nawathe and Lamorde, 1987). Some of the genetic parameters used for selection by breeders are repeatability, heritability and genetic and phenotypic correlations.
According to Falconer (1989), fewer records are required to realize a high expected response from selection in traits with high repeatability estimates while those with low repeatability estimates will require larger number of records. Gaya et al. (2006) had shown genetic correlation between body weight at different ages and carcass traits and suggested that direct selection for body weight at 38 and 42 days of age could produce indirect genetic gain for breast muscle, leg and eviscerated body weight. They also indicated that heritability estimates for body weight at different ages for evaluation of genetic variability and considerable direct additive genetic effects seemed to exist in the expression of body composition traits. Kabir et al. (2006) reported that mean values of body weight at various ages showed good performance. They also noted that heritability estimates observed for body weight and shank length decreases with increasing age of birds.

Repeatability measures the degree of association between records on the same animal for traits expressed more than once in animal life. Its estimate indicates the again in accuracy expected from multiple measurements (Falconer, 1989). The advantage of breeding programmers' in the increase the proportion of additive genetic variance and improvement of selection response. Repeatability and heritability estimates reported for reproductive traits (fertility and hatchability) and related to them such as egg number, egg weight, shell thickness and semen quality were generally low (Bennerwitz et al., 2007). The low repeatability and heritability estimated reported for these traits were attributed to the huge influence of non-genetic factors (Falconer. 1989). The improvement of egg production parameter are desirable because of their economic importance. this can be brought about by improvement of both genetic and non-genetic factors influencing egg production, since egg production varies from one period from another, a knowledge of the repeatability estimates will guide the breeder in designing an appropriate breeding plan for their improvement. Therefore, the objective of this paper is to review heritability, repeatability, breeding value and environmental variances of economically important traits of poultry.

2. LITREATURE REVIEW
2.1. Heritability, Repeatability, Breeding Value and Environmental Variances of Monthly Egg Production Traits

In general, the genetic and phenotypic correlations between monthly records decreased as the time interval of the ages increased. Also, later ages indicated higher estimates for these correlations than early ages. According to Luo et al. (2007) estimation of genetic parameters for cumulative egg numbers in a broiler dam line by using a random regression model Poultry who used a random regression model and showed a lower correlation between the initial weeks of production with later stages of production in a broiler dam line.

The estimates of genetic and phenotypic correlations between M1 and all other monthly records decreased largely (ranging from −0.024 to 0.137 and 0.073 to 0.101, respectively) when ASM was included in the model. These changes among all M2 to M8 records were minor, suggesting that ASM is a main source of variation for the first month’s egg production record. However, no studies have been found to confirm the influence of ASM on genetic and phenotypic correlations.
Table 1. Variance components and heritability of monthly and cumulative egg numbers during early part laying period in Horro chickens

<table>
<thead>
<tr>
<th>Trait</th>
<th>$\sigma^2_a$</th>
<th>$\sigma^2_e$</th>
<th>$h^2$ (±SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>0.1</td>
<td>0.2</td>
<td>0.32 (0.13)</td>
</tr>
<tr>
<td>M2</td>
<td>2.6</td>
<td>10.2</td>
<td>0.20 (0.16)</td>
</tr>
<tr>
<td>M3</td>
<td>15.5</td>
<td>12.2</td>
<td>0.56 (0.15)</td>
</tr>
<tr>
<td>M4</td>
<td>7.1</td>
<td>21.8</td>
<td>0.25 (0.14)</td>
</tr>
<tr>
<td>EP12</td>
<td>3.8</td>
<td>11.9</td>
<td>0.24 (0.16)</td>
</tr>
<tr>
<td>EP36</td>
<td>67.6</td>
<td>174.3</td>
<td>0.28 (0.15)</td>
</tr>
<tr>
<td>EP16</td>
<td>115.9</td>
<td>216.5</td>
<td>0.35 (0.16)</td>
</tr>
<tr>
<td>AFE</td>
<td>31.5</td>
<td>458.5</td>
<td>0.06 (0.15)</td>
</tr>
</tbody>
</table>

Source: Nigussie et al., 2011

AFE-Age at first egg (in days); $\sigma a^2$, $\sigma c^2$, and $\sigma e^2$, additive genetic, common environmental, and residual variances, respectively; $h^2$, heritability of direct genetic and common environmental effects, respectively; M1, M2, M3, and M4, egg numbers in the first, second, third, and fourth months, respectively; EP12, EP36, and EP16, cumulative number of eggs produced from months 1 to 2, 3 to 6, and 1 to 6, respectively

Heritability of monthly egg numbers ranged from 0.20 to 0.32, except for M3 for which heritability was 0.56. Heritabilities of cumulative part record egg numbers were from 0.24 (EP12) to 0.35 (EP16) (Nigussie et al., 2011). Heritabilities of monthly egg productions decreased from 0.32 in month 1 to 0.25 at peak egg production in month 4, except for month 3 which was exceptionally high ($h^2 = 0.56$). A comparable pattern of heritability changes in monthly egg numbers has also been reported by Anang et al. (2002) and Wolc and Szwaczkowski (2009). Heritability of cumulative part period egg numbers (0.24–0.35) were within the range reported by Sang et al. (2006) who found moderate values (0.24–0.37) in five Korean native chicken strains for total egg numbers from start to 270 days of lay and the figures (0.31–0.32) reported by Lwelamirae et al. (2009) for cumulative number of eggs produced in the first 90 days of laying in indigenous Tanzanian chickens. Sabri et al. (1999) also reported heritabilities of 0.27, 0.19, and 0.30 for egg numbers produced between 26 and 30, 50 and 54, and 26 and 54 weeks period, respectively, for White Leghorn hens in a subtropical environment. Higher values were reported by Anang et al. (2000) for cumulative egg production of the first 5 months in White Leghorn chickens ($h^2 = 0.46$) and by Kamali et al. (2007) for the first 12 weeks of egg production ($h^2 = 0.49$) in Iranian indigenous fowls compared to our results.

Part period egg numbers were relatively more heritable and consistent than monthly egg productions. Most of the monthly egg production traits were poorly related with each other and with cumulative egg production while the correlations among the latter traits remained quite high. Particularly, the total number of eggs produced to 44 weeks of age (EP3) was found to be the most heritable trait ($h^2 = 0.35$) having a strong positive correlation with BW16 ($r = 0.73$). These two traits seemed to have common genes and utilizing them as selection traits would be expected to improve both egg production and growth performance of local chicken. The standard errors of estimates in this study were mostly high indicating that the estimates have low precision and parameter estimations based on more data are needed before applying the current results in breeding programs.

High heritability estimates of 0.853, 0.503 and 0.629 for egg length, egg breadth and egg shape index respectively using data from overall ages for egg traits when the age of the bird was included indicate higher role of additive genetic variance in phenotypic expression of these traits and the low standard error for different age groups and overall mean age group indicates greater precision. These high estimates generally agreed with the report in literature. Pradeepeta et al. (2015) recorded values of 0.679, 0.868 and 0.685 for heritability estimates of egg length, egg breadth and shape index respectively at 50 weeks of age for white leghorns using half-sib correlation analysis.
However, low estimates of 0.136 and 0.040 were recorded for egg length and egg breadth respectively when the age variance was excluded from the computation except egg shape index that registered moderate estimates of 0.243. This variation could be attributed to the removal of age variance which determines its developmental processes and hence robust the non-additive gene actions thereby culminating into low and more accurate estimates of heritability of the traits compared to the report recorded in the literature (Blanco et al., 2014; Begli et al., 2010; Pradeepeta et al., 2015). At 25 weeks of age, high estimates of heritability of 0.850, 0.545 and 0.806 were recorded for egg length, egg breadth and egg shape index. Theoretically, heritability estimates should decline in magnitude when the age variance was excluded from the computation due to decrease in additive genetic variance. Practically, this trend was not observed in this study suggesting minimal influence of non-genetic and permanent environmental variance on heritability estimates of the traits of 25 weeks of age and hence higher to the estimates of egg shape index obtained by several researchers (Blanco et al., 2014; Begli et al., 2010; Pradeepeta et al., 2015) and egg length recorded by Pradeepeta et al. (2015) but lower to the estimates of egg breadth reported by Pradeepeta et al. (2015).

However, there was a decline in the heritability estimates from high to low as registered for egg shape index and from high to moderate as observed for egg length and egg breadth at 51 weeks of age. These indicate that excluding the age variance from the computation weakens the additive genetic variance as genetic potential reduces with advancing age and hence increasing the non-additive genetic and permanent environmental effects thereby reducing the heritability estimates of those traits compared to the estimates reported by other researchers (Begli et al., 2010; Pradeepeta et al., 2015) for these traits. Conversely, Blanco et al. (2014) observed a decline in the estimates of heritability of egg shape index from 0.58 at 32–36 weeks of age to 0.47 at 67–70 weeks of age but the estimates were still higher than those reported in the study. This indicates that the genetic potential of egg shape index, age length and egg breadth is most enhanced at earlier period of egg production leading to minimal influence of environmental factors and thereby culminating into peak egg production compared to the later period of egg laying year thereby enhancing the environmental factors and as a result, reducing the heritability estimates in spite of excluding the age variance in the computation.

The heritability estimates enhanced from moderate to high as observed for egg breadth and egg shape index recorded 0.851 and 0.767 while egg length experienced a further decline to 0.087 at 72 weeks of age. The result obtained from egg breadth and egg shape index agrees favourably with the report of Pradeepeta et al. (2015) while the low estimates registered for egg length were lower than the report of Begli et al. (2010); Pradeepeta et al. (2015). However, the value recorded for egg shape index in this study was higher than the report of Blanco et al. (2014); Belgiet al. (2010). This indicates that the genetic potential of egg length at 72 weeks of age was not fully expressed hence enhancing the non-additive genetic and permanent environmental effects compared to egg breadth and egg shape index.

Estimation of genetic parameters based on individual and group mean records in laying hens Brit; in which the early part of the record tended to have a negative genetic correlation with production in later periods, they were consistent in direction and somewhat in magnitude with those reported by Ananget al (2000) in which genetic and phenotypic parameters for monthly egg production in White Leghorn hens Luo et al. (2007); Estimation of genetic parameters for cumulative egg numbers in a broiler dam line by using a random regression model. The relatively low estimates of genetic correlations between M1, M2 and, to some extent, M3 and all other monthly records indicates that these performances are not influenced by the same genes and, therefore, considering each performance as the same record and fitting a repeatability animal model, seem to be invalid.
2.2. Heritability, Repeatability, Breeding Value and Environmental Variances of Growth Traits

Table 2. Variance components and heritability of body weights in Horro chickens

<table>
<thead>
<tr>
<th>Trait</th>
<th>$\sigma^2_a$</th>
<th>$\sigma^2_c$</th>
<th>$\sigma^2_e$</th>
<th>$h^2$ (±SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW0</td>
<td>3.9</td>
<td>3.7</td>
<td>2</td>
<td>0.40 (0.23)</td>
</tr>
<tr>
<td>BW2</td>
<td>19.1</td>
<td>11.4</td>
<td>71.7</td>
<td>0.19 (0.11)</td>
</tr>
<tr>
<td>BW6</td>
<td>197.4</td>
<td>43.8</td>
<td>1,073.30</td>
<td>0.15 (0.08)</td>
</tr>
<tr>
<td>BW8</td>
<td>516.9</td>
<td>36.6</td>
<td>2,643.20</td>
<td>0.16 (0.08)</td>
</tr>
<tr>
<td>BW12</td>
<td>2,399.00</td>
<td>12,410.00</td>
<td>0.16 (0.05)</td>
<td></td>
</tr>
<tr>
<td>BW16</td>
<td>9,673.00</td>
<td>33,220.00</td>
<td>0.23 (0.06)</td>
<td></td>
</tr>
</tbody>
</table>

Source: Nigussie et al., 2011

$\sigma^2_a$, $\sigma^2_c$, $\sigma^2_e$ and $h^2$, additive genetic, common environmental, and residual variances, heritabilities of direct genetic, respectively; BW0, hatch weight; BW2, BW6, BW8, BW12, BW16, body weights at 2, 6, 8, 12, and 16 weeks of age, respectively.

Estimates of direct heritability of growth traits ranged from 0.15 (BW6) to 0.40 (BW0). The values were moderate for body weight at 16 weeks of age (0.23) and that of hatch weight but remained low for the rest of the traits. Common environmental effect was moderate for hatch weight (0.39) but almost nonexistent for the remaining traits. Age at first egg showed a very low heritability (0.06) (Nigussie et al., 2011).

The mean body weights of Horro chicken were generally within the ranges reported for unselected indigenous populations in northwestern Ethiopia (Halima et al. 2007) and many other countries of Africa (Gueye, 1998). The average number of eggs as well as the rate of lay to 44 weeks of age was quite low. Comparative data on early part period egg production of other Ethiopian local chickens is not available. The peak production was attained in the fourth month of lay on the level of 32% (9 eggs/hen). Similar reports showing that indigenous chickens of Ethiopia and of many other African countries are poor egg layers (Gueye 1998; Dana and Ogle 2002).

Body weights to 16 weeks of age were used to characterize the growth of chicken in this study. Selection for rapid early growth at a market age (40–50 days) has been the most common approach in broiler chicken breeding programs (Emmerson, 2003). Our results showed that body weight at 16 weeks of age has a positive correlation to growth from 2 to 12 weeks of age. The correlations were particularly strong with certain growth traits (r = 0.82 with BW8, and 0.99 with BW12). Body weight at 16 weeks was also relatively the most heritable among the other growth traits measured. Therefore, since chickens in Ethiopia are kept for both meat and egg production attaining mature body size at earlier ages is not the target of the production system, and thus, selection at 16 weeks of age could be the most suitable approach to improve growth.

2.3. Heritability, Repeatability, Breeding Value and Environmental Variances of Reproductive Traits

Fertility a sub-trait of hatchability is a complex trait comprising of several sub-traits that are susceptible to genetic and non-genetic factors arising from various sources (Wolc et al., 2010). The genetic components of sire and dam are important in fertility sub-trait of hatchability. The fertility of an egg is affected by factors originating from the hen (ability to mate successfully, store sperm, ovulate an egg cell and provide a suitable environment for the formation and development of the embryo) (Brillard, 2003). Fertility also depends on the hens sire (ability to mate successfully, quantity and quality of semen deposited) (Wilson et al., 1997). In other studies, fertility had been reported as entirely a dam trait or female fertility (Szwaczkowskiet al., 2000; Sapp et al., 2005 and Bennevitzet al., 2007). Estimates of heritability of fertility for both maternal and paternal components varied across ages and breeds, suggesting that fertility may also vary genetically across breeds and ages (Wolc et al., 2009). These diverse positions and information poses a challenge on how best to explore the genetic mechanism that control fertility and to
examine how best to model hatchability and its sub-traits for adequate genetic evaluation and selection. Selection for genetic improvement of hatchability would yield the desired result, if information on the dam and the sire genetic components of hatchability are examined, this information can be used to model the fertility trait for genetic evaluation. It is only then that, the genetic mechanism controlling hatchability can be properly evaluated. Applying the desired selection criteria based on this to the flock sizes will lead to genetic improvement.

Reproductive traits in chickens have low estimates of heritability and are strongly influenced by the environment and by non-additive effects of genes. Selection for fertility and hatchability is based on a hypothesis of selection against segregation of deleterious recessive genes, probably at low frequencies, with a presumption that the heritability are low (Gowe et al., 1993). Thus, phenotypes are not good indicators of the best breeding values for reproductive traits; in this case, family selection is more recommended than individual selection (Rishell, 1997).

### Table 3. Estimate of variance components for additive genetic, environmental and phenotypic effects and heritability for fertility, hatchability of fertile eggs and hatchability of total eggs

<table>
<thead>
<tr>
<th>Trait</th>
<th>$\sigma^2_a$</th>
<th>$\sigma^2_c$</th>
<th>$\sigma^2_p$</th>
<th>$h^2 \pm SE$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertility</td>
<td>0.01</td>
<td>0.09</td>
<td>0.10</td>
<td>0.12 ± 0.04</td>
</tr>
<tr>
<td>Hatchability of fertile eggs</td>
<td>0.05</td>
<td>0.13</td>
<td>0.18</td>
<td>0.27 ± 0.04</td>
</tr>
<tr>
<td>Hatchability of total eggs</td>
<td>0.06</td>
<td>0.15</td>
<td>0.21</td>
<td>0.28 ± 0.04</td>
</tr>
</tbody>
</table>

Source: Savegnago R.P et al., 2011

The relationships between productive traits (body weight, egg size and egg production) and reproductive traits (fertility and hatchability) are of interest because if the relationships are strong, they may affect progress of selection. Selection for productive traits could affect the performance of reproductive traits and might directly affect commercial performance, as in the case of meat chickens, for which hatchability is one of the most important attributes of parent stock performance (Hunton, 1971).

Fertility is defined as the interaction between maternal and paternal gametes to produce a viable zygote and can be expressed as the number of fertile eggs per chicken. Chicken selection for rapid growth can affect fertility by increasing the frequency of defective sperms and ova. Such defects are attributed to neuroendocrine imbalances, disruption of gametogenesis synchrony, dysfunctions of ovulation-oviposition patterns, and reduced libido (Barbato et al., 1984).

The hatchability of fertile eggs is the ratio between fertile eggs that produce a viable chicken and all fertilized eggs. Hatchability is the composite of the embryos’ ability to survive and the maternal contribution towards embryo survival (Custódio, 1997). The hatchability of eggs that are laid is another important commercial reproductive trait; it is defined as the ratio between the total number of chickens born and the total number of eggs incubated.

### 3. CONCLUSION

Growth and egg production are economically the most important traits in small holder poultry production systems. These two traits also showed medium to higher level of heritability, relative to their respective trait categories. Improvement in the production environment and non-genetic factors influencing egg production will improve the accuracy of estimating the inherent transmitting ability of the layers in the lowly heritable traits observed for egg shape index and egg length at 51 and 72 weeks and moderately heritable traits reported for egg length and egg breadth at 51 weeks under the influence of age variance. Differences obtained in the heritability estimate ($h^2$) with respect to all the lines are indication of genetic influence on these parameters. Low ($h^2$) obtained for body weight and linear body measurements imply that high environmental effects could be attributed and it implies that selection based on individual performance alone may not be advisable. Likewise, low repeatability estimates (R) implies that chicken lines used in this study have lower ability to repeat their present performance in the future and also high numbers of records are required to realize high expected response for selection. Reproductive traits in
chickens have low estimates of heritability and are strongly influenced by the environment and by non-additive effects of genes. Selection for fertility and hatchability is based on a hypothesis of selection against segregation of deleterious recessive genes, probably at low frequencies, with a presumption that the heritability are low.

4. REFERENCES