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Review Article

Additive and Non-additive Genetic Effects on Growth and Egg Production Performance of Crossbred Chicken in Ethiopia

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Abstract

The present review article aims to provide an overview of the additive and non-additive genetic effects of crossbreeding and their contribution to the improvement of growth and egg production traits in chickens. It discusses the advancement in crossbreeding effects and mating design contribution to a significant rate of genetic progress in indigenous chicken. In Ethiopia, crossbreeding practice may be used to enhance the performance of local chicken ecotypes. The article extensively reviews various papers related to crossbreeding trials conducted in Ethiopia, evaluating their effectiveness in improving growth and egg production. It discusses the mating design and breeds used in these programs, such as exotic breeds like Rhode Island Red, Fayoumi, White Leghorn, Koekoek, Sasso, Kuroiler, and local Ethiopian chicken ecotypes. Among the exotic breeds involved in crossbreeding, Rhode Island Red and Sasso are considered more favorable for improving growth rate and color preference, while White Leghorn is preferred for enhancing egg production traits. In opposite to these indigenous chickens are preferred for disease resistance and product quality. Additive genetic effects are typically responsible for the genetic improvement of traits over generations through selection. In egg production, additive genetic effects influence the overall capacity of a chicken to lay eggs, affecting traits like egg number and egg size. Whereas, In growth performance, additive genetic effects influence traits like body weight gain, feed conversion efficiency, and overall growth rate. Non-additive genetic effects include dominance and epistatic interactions between genes. These effects can lead to genetic heterogeneity and can impact traits like egg production and growth performance besides playing a role in hybrid vigor or heterosis. In conclusion, both additive and non-additive genetic effects play a crucial role in determining egg production and growth performance in chickens. Additive effects drive genetic improvement over generations, while non-additive effects provide immediate benefits like hybrid vigor. Understanding and utilizing both types of genetic effects is essential for enhancing these traits in poultry breeding programs. Chicken crossbreeding programs are highly important in the poultry industry as they continuously improve the genetic potential of chickens, leading to more efficient production systems and higher profitability for producers.

Keywords

Additives Effects, Crossbreeding, Heterosis Effect, Maternal Effects

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1. Introduction

The practice of crossbreeding in poultry is highlighted as a method to increase genetic diversity and harness heterosis for traits like growth and egg production. This approach is particularly relevant in countries like Ethiopia to improve local chicken ecotypes. Crossbreeding is extensively employed in poultry breeding programs to enhance the number of heterozygous loci, ultimately resulting in heterosis for traits such as growth and egg production [1]. Crossbreeding between exotic breeds and indigenous chickens has been practiced in Ethiopia and other developing country to generate crossbreds suitable for family poultry production in particularly and in general at different some other tropical countries [2-4]. Genetically, the crossbreeding effect can be divided into two broad components, which are additive and non-additive. In other words, crossbreeding exploits both additive and non-additive gene variance and tends to increase heterozygosity [5, 6]. Additive genetic effects refer to the genetic contribution from both parents that directly influences the phenotype of the offspring. These effects are usually responsible for the gradual, cumulative changes observed in traits over generations in breeding programs. The additive component explains the average effect of the strains/breeds or parental lines involved, weighted according to the level of each parental population in the crossbreds [5]. Additive genetic effects are the sum of the effects of individual genes on a trait. When two different breeds are crossed, if both breeds contribute positively to growth and egg production traits, the offspring may exhibit improved performance due to the additive effects of these genes. This can result in crossbred chickens that grow faster and/or produce more eggs than either of the purebred parents. While the non-additive component explains gene combination (heterosis) effects [7]. A better understanding of additive and non-additive genetic variances and their mode of inheritance is important for developing appropriate breeding programs that aim to improve the desired traits [8]. Non-additive effects, including dominance and epistasis, occur when the combination of alleles at different gene loci influences a trait differently than the individual alleles would suggest. Dominance effects can lead to traits in the offspring that are more similar to one parent than the other, while epistatic effects can result in traits that are different from what would be expected based on the additive effects of the individual genes. The most important crossbreeding effects are heterotic effect, purebred effect, maternal effect, combining ability, and reciprocal effect [11]. Crossbreeding in chickens can have several effects on performance, including growth rate, egg production, and overall health. Some key effects include such as heterosis (Hybrid Vigor), complementation, genetic diversity, adaptation to local conditions, improved feed conversion and better reproductive performance. In crossbred chickens, both additive and non-additive genetic effects contribute to the overall performance of the birds. Understanding these effects is crucial for breeders to design effective crossbreeding programs that maximize desirable traits such as growth rate and egg production. So far different crossbreeding activity and mating design were done elsewhere in Ethiopia as precondition in developing suitable and resilient chicken breed for different production system. The present review article aims to deliver information the on additive and non-additive genetic effects of crossbreeding and their contribution to the improvement of economically important growth and egg production traits in chicken.

2. Heterosis Effect on Growth and Egg Production Performance of Crossbred Chicken

Crossbreeding can result in chickens that grow faster, reaching market weight more quickly. Heterosis, also known as hybrid vigor, refers to the phenomenon where the offspring of two different breeds or strains exhibit traits that are superior to those of both parents. Positive heterosis, or hybrid vigor, refers to the phenomenon where crossbred offspring outperform the average of their parent breeds. This enhanced performance is largely due to the beneficial interactions of alleles inherited from both the sire and dam, resulting in effects like dominance and epistasis [9]. In chickens, heterosis can significantly impact important traits such as growth rate, egg production, and overall performance. However, predicting the extent of heterosis, particularly from epistatic interactions, is challenging due to the complex and often unknown relationships among various genetic loci [10]. This unpredictability can complicate breeding strategies aimed at maximizing desirable traits in poultry**.** Heterosis has long been utilized in poultry breeding programs to produce progenies that exhibit higher performances than the average of their parental breeds [15]. When two genetically distinct chicken breeds are crossed, the resulting offspring may benefit from heterosis, leading to improved growth and egg production compared to purebred birds. Heterosis is the result of non-additive gene action. That is, it is a result of dominance (interaction within loci) and epistasis (interactions between loci), or both [5, 7]. The positive effects of dominance are due to increased levels of heterozygosity [5]. Due to increased heterozygosity, the crossbreds would have uniformity and are influenced the least by environmental factors compared to their parent lines [6]. As cited by Galukande et al. [5], epistasis interactions can have a negative effect because of a breakdown of favorable interactions between loci in purebred animals developed by both natural and artificial selection within breeds before crossbreeding. The fact that heterosis is a result of non-additive gene action means that it is difficult to predict the amount of heterosis to expect when particular breeds are crossed. The degree of heterosis can vary depending on the specific traits being evaluated and the genetic distance between the parental breeds. For example, crossing two breeds with complementary traits, such as one breed known for its fast growth and another for its high egg production, can result in offspring that exhibit both traits to a greater extent than either parent. This can be particularly beneficial in commercial poultry production, where maximizing growth and egg production are key goals. Some crosses result in substantial heterosis, and others do not [14]. Although it is difficult to predict the level of heterosis that will arise from crossing any two breeds, it is usually greater for crosses between genetically diverse breeds.

Heterosis is measured by crossing populations to produce an F_1 generation and comparing them with the parental breeds [15]. Although F_1 has the highest level of individual heterosis, the level decreases in subsequent generations, partly due to recombination loss [14]. Heterosis is halved in the second generation (F2) and continues to be half in subsequent generations of backcrossing to the parent breeds. However, it remains constant in subsequently-produced two-breed hybrids. The levels of heterosis are presented as percentage values and can be used to calculate the expected performance of crossbreds [7]. The same author noted that heterosis is measured as the superiority of the crosses over the average of the parent breeds but not as the superiority of the crosses over the best parent line. When a particular cross produces a large amount of heterosis, the parent breeds are sometimes said to nick well or show good combining ability [14]. Overall, the heterotic effect on growth and egg production performance of crossbred chickens can be significant and is an important consideration for poultry breeders and producers looking to optimize the performance of their flocks.

3. Maternal Effects on Growth and Egg Production Performance of Crossbred Chicken

Crossbreeding can increase the number of eggs laid by hens, leading to higher egg production and potentially greater profits for egg producers. Maternal effects play a significant role in the growth and egg production performance of crossbred chickens. These effects are related to the influence of the hen (mother) on the phenotype (physical characteristics) of her offspring beyond the direct contribution of the genes she passes on to them. Some key maternal effects include such as maternal genetic effects, maternal environmental effects and, maternal care effects. The genetic makeup of the mother can influence the growth and egg production performance of her offspring. For example, if the mother comes from a breed known for high egg production, her offspring may inherit genes that contribute to better egg-laying ability. Maternal effect is extra result of additive gene action, which reflects the contribution of maternal additive and dominance gene effects as well as differences in allele frequency [12]. It is the influence of the dam's genes on the performance of its progeny through the environment provided by the mother rather than her direct additive genetic contribution [13]. The environment in which the mother is raised can also impact the performance of her offspring. Factors such as nutrition, health, and stress levels during the mother's development and egg-laying period can affect the growth and development of her chicks. This effect on the performance of the progeny can be a function of the genetic or environmental differences between mothers (i. e., maternal variability) or a combination of the two [16]. The maternal effects measure the pre- and post-natal mothering ability of a breed/line [17]. However, this effect in birds is distinct from mammals because any maternal effect on artificially incubated chicks must be the residual effect of dam reflected in egg characteristics at laying [13]. The level of care provided by the mother, including incubation behavior, brooding, and feeding, can influence the growth and survival of her offspring. Adequate maternal care can lead to better growth and health outcomes for the chicks. The transfer of antibodies from the mother to her offspring through the egg yolk can provide passive immunity, protecting the chicks from diseases early in life and impacting their overall health and growth. According to different authors [18, 4, 19] the significant variation in maternal effect suggests the influence of maternal additive and dominance gene effects. The higher maternal effect observed in parental crosses for different traits would suggest that using these breeds as a dam in a crossbreeding program aiming to improve egg production traits for which the breeds showed a higher maternal effect is appropriate. Factors that can determine maternal effect are egg size, incubation environment, egg composition, maternal antibodies, and cytoplasmic or mitochondrial inheritance. As artificially hatched chicks are raised independently of their mothers; however, the maternal effect is considered less significant beyond hatching [16].

4. Combining Ability Effect on Growth and Egg Production Performance of Crossbred Chicken

Crossbreeding can be help in the improving disease resistance, which can reduce the need for costly medications and treatments, as well as reduce the risk of disease-related losses which can result in chickens that are better adapted to local environmental conditions. Combining ability refers to the ability of two parental lines to combine favorably in their offspring for specific traits. In the context of growth and egg production performance of crossbred chickens, combining ability plays a crucial role in determining the performance of the progeny. In crossbred chicken breeding programs, breeders often use a combination of both general combining ability (GCA) and specific combining ability (SCA) to select parental lines and develop new crossbred strains with improved growth and egg production performance. Evaluating the combining ability of different parental lines, breeders can make informed decisions about which crosses are likely to produce the best-performing offspring.

General combining ability (GCA) refers to the average performance of a breed, line, or strain when crossed with other breeds. It assesses the mean performance of all F1 crossbreds that include this breed as a parent, expressed as a deviation from the overall mean of those crosses [20]. Essentially, GCA quantifies the influence a breed has on its offspring. Significant differences in GCA can arise among breeds due to factors like line heterosis and the additive effects of parental gametes, which correlate to an individual's breeding value [12, 21, 22]. GCA represents a parent's average performance across various crosses. A high GCA indicates that a parent reliably passes on favorable genes for a specific trait to its offspring. In chicken breeding, a parent with a high GCA for traits such as growth or egg production would consistently yield offspring that perform well in those areas. Generally, a higher GCA in any breed is likely linked to greater differences in gene frequencies at each genetic locus [23].

Every cross has an expected value, which is determined by the sum of the general combining abilities (GCA) of its two parental breeds [20]. Specific combining ability (SCA) reflects how much a particular cross deviates from this expected value, indicating the average inferiority or superiority of specific crosses compared to the average performance of their parents [24, 17, 20]. The variation in SCA arises from the non-additive effects of combining gametes to form F1 crosses, which can involve dominance or epistatic interactions such as additive by dominance and dominance by dominance effects or a combination of both [23, 18, 26]. This interaction is often described as the interaction between a strain of sire and a strain of dam. Therefore, SCA measures how the average performance of a cross diverges from the expected additive effects [12]. SCA indicates whether two parents possess complementary genetic factors that lead to enhanced performance in their offspring. For instance, if one parent provides genes for rapid growth while the other offers genes for high egg production, their offspring may demonstrate superior performance in both traits due to SCA.

5. Reciprocal Effects on Growth and Egg Production Performance of Crossbred Chicken

Reciprocal effects refer to the performance differences seen in reciprocal crosses, where two parental lines are crossed, but the sexes of the parents are swapped. In the context of growth and egg production in crossbred chickens, these effects can shed light on how maternal and paternal genetic traits influence offspring performance. Thus, it's essential to manage these effects within breeding programs. Selecting hens with advantageous maternal traits and creating optimal conditions can enhance the benefits of maternal influences in crossbred populations. Achieving high general combining ability (GCA) in parent lines and strong specific combining ability (SCA) in the crosses is crucial for developing chickens that excel in growth and egg production. By studying reciprocal effects, breeders can gain valuable insights into the factors that affect performance, enabling them to make informed crossbreeding decisions. Overall, the impact of crossbreeding on chicken performance can be substantial and is shaped by various elements, including the specific breeds used, breeding goals, and management practices. By carefully selecting parental breeds and implementing effective breeding strategies, poultry producers can leverage crossbreeding to enhance the performance of their flocks.

Reciprocal effects (i. e., differences between reciprocal crosses) reflect differences in gene frequencies between sire and dam lines/breeds in the presence of additive maternal and/or dominance maternal effects [23]. These effects are partitioned into two components, namely general and specific (residual) reciprocal effects. Function of maternal effects and the latter as a variance due to sex-linked effects [24]. On the contrary, [23, 25] interpreted the general reciprocal effect as a variance that contains additive sex-linked and maternal effects. In chickens, maternal effects can have a significant impact on growth and egg production performance. When comparing reciprocal crosses, differences in performance may be observed due to the influence of the maternal genetic and environmental factors. For example, if the mother's breed contributes significantly to egg production traits, the reciprocal crosses may show differences in egg production performance. Reciprocal effects can also reveal interaction effects between maternal and paternal genetic contributions. Certain combinations of maternal and paternal genes may result in superior performance for growth and egg production traits, leading to differences in performance between reciprocal crosses.

Residual reciprocal effect (RRE) is interpreted as a variance due to cytoplasmic inheritance. As RRE measures the difference between the means of each pair of reciprocal crosses after an account has been taken of the average maternal difference between sire and dam lines/breeds [24, 17, 23, 27], this latter interpretation seems more relevant than the former one. This is also supported by [9], who defined RRE as an effect free of any general maternal and sex-linked variances. However, it may contain complex interactions between autosomal and maternal or sex-linked effects [23, 9]. Despite these interpretations, some authors have been using RRE and sex-linked effects interchangeably [12, 18].

Paternal genetic contributions can also influence the performance of offspring. Reciprocal crosses can help determine if there are any specific paternal effects on growth and egg production traits. For example, if the sire's breed contributes to faster growth rates, the reciprocal crosses may exhibit differences in growth performance. Epigenetic factors, such as DNA methylation and histone modification, can also contribute to reciprocal effects. These factors can influence gene expression patterns in the offspring, leading to differences in phenotype between reciprocal crosses.

6. Conclusion and Recommendation

In Ethiopia, utilizing crossbreeding programs with diverse native chicken breeds can enhance growth and egg production by harnessing genetic resources. Selecting parent breeds with desirable traits and understanding genetic mechanisms, breeders can optimize crossbreeding strategies for improved performance in local conditions. Maternal effects from parent.

Abbreviations

SCA	Specific Combining Ability
GCA	General Combining Ability
RRE	Residual Reciprocal Effect

Author Contributions

Shambel Taye: Conceptualization, Methodology, Writing – original draft, Writing – review & editing

Mahilet Dawit: Supervision, Writing – review & editing

Data Availability Statement

This article does not involve any creation or analysis of new data. Therefore, data sharing is not applicable.

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Fields

Shambel Taye: Animal breeding, Animal production, animal physiology, poultry crossbreeding and selection, poultry nutrition

Mahilet Dawit: Animal breeding, Animal biotechnology, Genomics and genetics, Animal physiology, Bioinformatics