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Heterosis and reciprocal effects on productive and reproductive performance in F1 generations of Fayoumi x White leghorn and Koekoek x White leghorn chickens

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ABSTRACT. This study evaluated heterosis and reciprocal effects in across of White Leghorn with Fayoumi, White Leghorn with Koekoek in comparison to their pure line breeds for the productive and reproductive traits. Data were purposively collected from 357 layers based on their genetic groups and each genotype was reared in three replicates on a deep litter system from 20-72 weeks. Results showed that genotype groups were found to have no significant differences ($p > 0.05$) for age at first egg (AFE) and hen- housed egg production (HHEP). Purebred Koekoek and crossbred of male White Leghorn and female Koekoek were superior for body weight at first egg (BWAFE). Purebred Fayoumi has exhibited the least values for egg number. Purebred White Leghorn was the best by their feed conversion ratio. Effects of heterosis were non-significant ($p > 0.05$) for AFE and BWAFE, and hen-housed egg production. A negative heterosis percentage was noted for AFE in all crossbred genotypes. Crossing between male Koekoek and female White Leghorn gave the highest heterosis effect for feed intake while crossing between male White Leghorn and female Fayoumi gave the highest estimates of heterosis for total egg number per hen. The main crossbred between male White Leghorn and female Fayoumi hybrids outperformed in AFE and HHEP while the main crossbred between male White Leghorn and female Koekoek outperformed in BWAFE and HHEP. On the contrary, reciprocal crossbreds between male Fayoumi and female White Leghorn and male Koekoek and female White Leghorn had higher feed intake and better feed conversion ratio.

Keyword: crossbreed; egg; Fayoumi; heterosis; Koekoek; reciprocal; white leghorn.

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Introduction

Genetic progress can be accomplished either by selection or crossbreeding. Cross breeding maximizes the expression of heterosis or hybrid vigour in the cross, normally reflected in improved fitness characteristics (Hoffmann, 2005). The exploitation of heterosis is a major reason for crossbreeding in farm animals (Ibe, Obasi, Ojewola, & Nwachukwu, 2005). The utilization of this phenomenon has led to the development of high-quality breeds in poultry and other farm animals. Usually, characters that suffered a reduction in inbred status are often restored or tend to be restored on crossing. Heterosis has been exploited to genetically improve characters that are subject to little additive gene action (Ndjon & Nwakalor, 1999). A good combining ability resulting from a choice of the best performing crossbred could lead to the production of birds that will be better in growth rate, the efficiency of feed conversion, reproductive traits, and carcass performance, without losing adaptation to the local environment, thereby resulting in reduced costs of production (Khawaja, Khan, Parveen, & Iqbal, 2016). On the other hand, several scholars reported as heterosis is more influenced by the maternal side (Hristakieva, Oblakova, Lalev, & Mincheva, 2014). Thus, in poultry, the presence of the reciprocal effects is important in deciding upon the use of either the sire or dam line in crosses because the male line can help in the production of elite crosses (Prakash, Vipin, Pandey, & Khare, 2020). Many researchers have also detected the manifestation of maternal influence on the live weight of offspring (González & Andrés, 2003).

Many studies conducted on crossbreds and reciprocal crossbreds in poultry were evaluated of growth performance test of chickens up to the age at sexual maturity. Besides, a major problem that limits the supply and availability of chicken meat and eggs in Ethiopia is a lack of alternative chicken breeds for both meat and egg production (Ibrahim, Goshu, Esatu, Bino, & Abebe, 2018). Because of these reasons, after improving the chicken population of Ethiopia for long years, the population of hybrid chickens is still estimated to be below

5% (Itafa, Mohamed, Abate, Derseh, & Woldegiorgiss, 2021). Dual-purpose chicken breeds such as Koekoek and Fayoumi are preferred due to their egg and meat production as well as their disease resistance and better performance in village poultry production systems. Koekoek chickens have the desirable characteristics of free-ranging, adaptability to smallholder production systems, high fertility, and hatchability (Ibrahim, Goshu, Esatu, & Cahaner, 2019). On the other hand, Fayoumi chickens are better disease-resistant and adapted to hot climates but it is not a good meat producer because of their smaller body size (Kebede, 2017). On the contrary, White Leghorn chickens are known for their potential for a higher economic return as layers and fast growers but are more prone to diseases (Javed, Farooq, Mian, Durrani, & Mussawar, 2003; Kebede, 2017). However, there was no study conducted on crossbreeding of White Leghorn with Fayoumi and White Leghorn with Koekoek chicken breeds for the exploitation of heterosis and create crossbred offspring that share the desirable traits of each parental breed. Therefore, the objective of this study was to evaluate heterosis and reciprocal effects of White Leghorn with Fayoumi and White Leghorn with Koekoek crossbreds in comparison to their pure line breeds for the productive and reproductive traits.

Material and methods

Study site

The study was carried out at the Poultry Research Center, Haramaya University, located 505 km east of Addis Ababa. The site is placed at an altitude of 1980 meters above sea level, 9° 26' N latitude, and 42° 3' E longitude. The area has an average annual rainfall of 741.6 mm. The mean annual minimum and maximum temperatures are 8.25 and 23.4°C, respectively.

Parental lines and mating design

Seven (7) chicken genotypes of three purebreds (White Leghorn male × White Leghorn female, Fayoumi male × Fayoumi female, Koekoek male × Koekoek female), three main crossbreds (White Leghorn male × Fayoumi female, White Leghorn male × Koekoek female), and two reciprocal crossbreds (Fayoumi male × White Leghorn female, Koekoek male × White Leghorn female) chickens were purposively crossed and grown to the age of sexual maturity (20 weeks).

Sampling methods and study design

A total of 357 female chickens which consists of 51 from each genotype at 20 weeks of age were purposively selected based on their genetic group and simultaneously considered. The chicken of each breed was divided into three pens as replicates under a completely randomized design so that there were 17 chickens in each replicate.

Management of experimental birds

Experimental genotypes were maintained on a deep litter system for 52 weeks under the same management condition. They were raised in separate pens according to genotype. Feed and water were offered for all genetic groups *ad libitum*. The chickens were fed on identical layer ration formulated with locally available ingredients such as wheat short, soybean meal, noug seed cake, peanut cake, ground maize, layer premix, salt, and limestone at 16% CP and 2579 kcal kg^{-1}. The lighting program was set to 16 hours of brightness throughout the experiment.

Data collection

Ages at sexual maturity was estimated in days from hatching up to the day at which each breed group of pullets reached 5% of egg production (Shafik, El-Bayomi, Sosa, & Osman, 2013). Body weight at sexual maturity was recorded when chickens reached egg production at 5% by weighing layers according to their genetic makeup. Eggs were daily collected, counted, summed up, and registered for each genetic group starting from age at sexual maturity to the end of the experimental period (72 weeks) and the total number of egg produced per hen, and hen-housed egg production were calculated according to Shafik et al. (2013). A weighed amount of feed was offered every day and the refusal was collected the next morning and weighed. The feed offer and refusal were recorded for each replicate and daily feed intake was calculated by subtracting feed refusal from offer. Feed conversion ratio (FCR) was estimated as a ratio between the feed consumed and the egg mass.

Evaluation of heterosis effects

The heterosis effect for all studied parameters was calculated as follows:

H%= [F1-(P1+P2)/2] x 100 (Hristakieva et al., 2014)

[(P1+P2)/2]

Where:
H% – Heterosis (%),
F1– average values of traits of crossbreds,
P1, 2 –average values of traits of parental lines.

Evaluation of reciprocal effects

The reciprocal effects for all studied parameters were evaluated as the difference between reciprocal F1 performances, i.e:

$$RE = \left[PF1\left(WLm * Fay(f)\right) - PF1\left(Fay(f) * WLf\right)\right]/2$$

$$RE = \left[PF1\left(KKm * WL(f)\right) - PF1WL(m) * KK(f)\right]/2$$

where:
RE - reciprocal effect,
PF1 (WL_m X Fay$_{(f)}$) - the mean performance of the F1 from a White Leghorn males and Fayoumi hens crossings,
PF1 (Fay(m) X WL_f) - the mean performance of the F1 from a Fayoumi male and White Leghorn hens crossings,
PF1 (KK_m X WL_f) - the mean performance of the F1 from a White Leghorn males and Fayoumi hens crossings,
PF1 (WL_m X KK_f) - the mean performance of the F1 from a White leghorn males and Koekoek hens crossings.

Statistical methods and experimental design

Completely randomized designs with three replications were used. Data were subjected to one-way ANOVA by using SAS software (Statistics Analysis System [SAS}, 2016). When the analysis of variance indicates the existence of a significant effect, then Fishery's test method was used to locate the means that are significantly different from each other at 95%. The following statistical model was used:

$Y_{ik}= \mu + G_i + e_{ik}$

where:
Y_{ik}= the observed value of i^{th} genotype,
μ = overall mean,
G_i = effect of the i^{th} genotype (i= White leghorn, Fayoumi, Koekoek, and their crosses),
e_{ik} = random error.

Results

Comparative performance of Fayoumi, Koekoek, White Leghorn, and their crossbreeds

The comparative performance evaluation of Fayoumi, Koekoek, White Leghorn, and their crossbreeds are shown in Table 1. There was a non-significant difference ($p > 0.05$) among the genetic groups for age at first egg (AFE) and hen-housed egg production (HHEP). The crossbred of male White Leghorn and female Koekoek started laying at the earliest among studied genotypes. The body weight at the age at first egg-lay was strongly significant among the breeds ($p < 0.05$) and the heaviest weight was recorded in Koekoek and crossbreds of WLH * KK. The hens of the Fayoumi breed were laid the lowest total number of eggs with the lightest weight among hens of other breeds ($p < 0.05$). The White Leghorn and Fayoumi breeds were significantly ($p < 0.05$) exhibited minimum feed intake whereas the main and reciprocal crossbreds of White Leghorn with Koekoek breeds consumed more feed than others. The lowest ($p < 0.05$) feed conversion (g feed: g egg mass) was observed in Fayoumi, WLH * KK, and KK * WLH, and the best feed conversion was recorded in White Leghorn. The crossbred of male White Leghorn and female Fayoumi (WLH * Fay) was produced the highest hen-housed egg production (66.72%) which is not significant among the genotypes ($p > 0.05$).

Table 1. Comparative performance of Fayoumi, Koekoek, White Leghorn, and their crossbreeds during the production phase (22-72 weeks) (Mean).

Variables	Genetic groups (sire breed given first)							*PV*
	Purebreds			Main Crosses		Reciprocals		
	WLH * WLH	Fay * Fay	KK * KK	WLH * Fay	WLH * KK	Fay * WLH	KK * WLH	
AFE (days)	166.67	166.67	160.33	163.33	155.00	156.33	156.67	0.3096^{ns}
BWAFE (g)	1349.38^{c}	1178.36^{d}	1701.46^{a}	1357.22^{c}	1677.87^{a}	1364.89^{c}	1501.13^{b}	0.0002***
TEN/hen	242.48^{a}	180.77^{b}	236.05^{a}	237.14^{a}	214.02^{ab}	203.36^{ab}	222.74^{ab}	0.02553*
HHEP (%)	65.07	66.17	59.99	66.72	59.46	60.93	55.49	0.7216^{ns}
FI (g hen^{-1} day^{-1})	129.80^{c}	125.24^{c}	138.47^{ab}	131.51^{bc}	139.62^{a}	131.91^{bc}	143.56^{a}	< .0001***
FCR	2.43^{c}	2.66^{a}	2.56^{b}	2.51^{bc}	2.70^{a}	2.53^{b}	2.75^{a}	< .0001***

^{abc}Means with the same letter in rows are not significantly different. AFE = Age at first egg, BWAFE = Body weight at first egg, TEN-Total egg number per hen per life cycle, HHEP = Hen-housed egg production, FI = Feed intake, FCR = Feed conversion ratio, PV-P-value, WLH * Fay = male White Leghorn crossed with female Fayoumi, Fay *WLH = male Fayoumi crossed with female White Leghorn, WLH * KK = male White Leghorn crossed with female Koekoek, KK * WLH = male Koekoek crossed with female White Leghorn, YH = Yolk height.

Heterosis effects on productive and reproductive performance

Table 2 describes the percentage heterosis of main and reciprocal crossbreds of White Leghorn with Fayoumi and Koekoek considering parameters like age at first egg, bodyweight at first egg, average feed intake, feed conversion ratio, total egg number, and HHEP.

There was no significant difference ($p > 0.05$) in the percentage of heterosis for age at first egg, bodyweight at first egg, and HHEP among the genotypes. The negative heterosis for age at first egg is an indication of an earlier maturity of progenies due to crossbreeding. There was no significant difference ($p > 0.05$) in percentage heterosis (PH) for body weight at first egg (BWAFE). However, the PH (10.15%) for BWAFE was higher in main crossbred (WLH * KK) than in their reciprocal crossbred whereas the PH (7.47%) for BWAFE was lower in main crossbred of WLH * Fay than in their reciprocal crossbred. The daily feed intake PH was significantly ($p < 0.05$) different among genotypes and the highest PH (7.24%) was recorded in the reciprocal crossbred of KK * WLH. The PH was positive for feed intake in both main and reciprocal crossbreds which is an indication of higher feed intake in crossbred than purebred. The PH for FCR was significantly ($p < 0.05$) influenced by the genotype. Positive and significantly higher PH was recorded in the main and reciprocal crossbreds of WLH and Koekoek while negative and significantly lower PH results were noted in main and reciprocal crossbreds of WHL and Fayoumi. Positive and significantly higher PH for total egg production was recorded in main crossbred of WLH * Fay but the negative and significantly lower result was recorded in main crossbred of WLH * KK. Positive and negative values of PH were noted for HHEP in progenies of the main crossbred of WLH and Fayoumi.

Reciprocal effects on productive and reproductive performance

Effects of reciprocal on the performance of offspring's produced from a crossbreed between White Leghorn and Fayoumi, White leghorn and Koekoek are shown in Table 3. Offspring's which mothered by White leghorn were superior to those mothered by Fayoumi by their body weight at first egg, feed intake, and feed conversion ratio. Likewise, offspring's mothered by White leghorn were superior to those mothered by Koekoek by their age at first egg, egg number, feed intake, and feed conversion ratio.

Discussion

Comparative performance of Fayoumi, Koekoek, White Leghorn, and their crossbreeds

This study result discovered a non-significant difference ($p > 0.05$) among the genetic groups in terms of age at first egg and hen housed egg production (Table 1). This is consistent with Khawaja, Khan, Mukhtar, Parveen, and Fareed (2013) study that found a non-significant ($p > 0.05$) difference in age at sexual maturity amongst crossbred chickens. On contrary, Bekele, Gjøen, Kathle, Ådnøy, and Abebe (2009) noted variations in sexual maturity of the same breed due to feeding regime, intensity and duration of light, and temperature. All pure lines were started egg-laying a few days later than crosses (Table 1). Numerically, early age at first egg-lay was observed in main crossbred of WLH * KK (155 days) and followed by reciprocal crossbred (156 days) in Fay * WLH and KK * WLH chickens. The main and reciprocal crossbreds were advanced in age at first egg. This indicated that crossbreeding had improved age at first egg-lay in the crossbred compared to the purebred chickens. It is therefore of no great surprise that crossbreeding has served to decrease the time taken to reach sexual maturation that is the start of an animal's reproductive life or age at first egg. This could be attributed to the fact that crossbreeds often exhibit heterosis, which often shows non-additive effects (Falconer & Mackay, 1996).

There was a significant difference (p < 0.05) in the body weights at the first egg of the genotypic groups with Koekoek and crossbred of WLH * KK having the highest values (Table 1). The difference is attributed to variation in genotype as opined by Nwoye, Mbuka, and Iheanacho (2010). Besides, the performance differences in body weight among different chicken genotypes under a similar management milieu are widely reported in the literature (Ogbu, Tule, & Nwosu, 2015). However, WLH, main and reciprocal crossbreds of WLH and Fayoumi did not differ significantly. The highest body weight at the first egg in Koekoek and its crossbred (WLH * KK) indicates the potential of breed for fast growth than their counterparts.

There was a strong significant (p < 0.5) difference among genotypes in terms of feed intake and feed conversion ratio or FCR (Table 1). The crossbred between WLH * KK and their reciprocals have resulted in genotypes with the highest feed intake whereas WLH and Fayoumi breeds were revealed the least feed intake. This result was in the same line with Khawaja et al. (2013) who found that Fayoumi purebred chickens had poorer feed utilization than their crossbreds. The best FCR was noted for White Leghorn while the poorest was recorded for Fayoumi, WHL * KK, and KK * WLH. The variations in feed intake could be associated with the differences in layers body weight and egg production while the FCR could be related to the variations in feed intake and egg production. In agreement with this result, Nwachukwu, Ibe, and Ejekwu (2006) indicated more feed consumption in heavier birds than lighter ones. Correspondingly, significant differences in FCR among Koekoek, Sasso, and their reciprocal crosses were noted by Tolasa, Seid, Hassen, and Aliy (2020). Likewise, Amao (2017) was reported significant effects of genotype on feed intake and feed conversion ratio among Rhode Island Red, naked neck breed, and their crosses. Furthermore, Salo-Ojo and Ayorinde (2011) noted significant effects of genotype on feed intake and FCR among Fulani Ecotype, dominant black chicken in Nigeria, and their crossbreds. Hussen, Goshu, Esatu, and Abegaz (2018) also reported significant feed conversion differences among different genotypes. This difference in feed intake and FCR among the genotype shows the importance of crossbreeding program.

The number of eggs per hen per laying in 52 weeks was significantly lower for Fayoumi breeds while other genotypes were almost the same (Table 1). This is consistent with Mmereole, Bratte, and Omeje (2007) who reported a significant effect of genotype on egg production among four genotypes. However, the finding contradicts with Oguntunji and Salako (2012) who noted a non-significant effect of genotype on egg production. The lower egg production performance of Fayoumi was associated with the genotype and lower feed intake of the breed.

Table 2. Percentage heterosis (PH) based on the mean performance of main and reciprocal progenies of WLH, Fayoumi, and Koekoek chicken crosses.

Variables	Genetic groups				*p-value*
	WLH * Fay	WLH * KK	Fay *WLH	KK * WLH	
AFE	-2.03	-8.50	-6.22	-4.20	0.2292[ns]
BWAFE	7.47	10.15	8.13	-1.50	0.227[ns]
DFI	3.19[b]	4.17[b]	3.64[b]	7.24[a]	0.0014[**]
FCR	-1.30[b]	8.29[a]	-0.48[b]	10.58[a]	< .0001[***]
TEN	12.26[a]	-9.28[b]	-5.27[ab]	-5.97[ab]	0.01482[*]
HHEP	2.63[a]	-8.36[a]	-7.01[a]	-15.45[a]	0.4265[ns]

[abc]Means with the same letter in rows are not significantly different. AFE = Age at first egg, BWAFE = Body weight at first egg, TEN-Total egg number; HHEP = Hen housed egg production; DFI = Daily Feed intake, FCR = Feed conversion ratio, WLH * Fay = male White Leghorn crossed with female Fayoumi, Fay *WLH = male Fayoumi crossed with female White Leghorn, WLH * KK = male White Leghorn crossed with female Koekoek, KK * WLH = male Koekoek crossed with female White Leghorn.

Table 3. Reciprocal effects on the performance of crossbred of WLH, Fayoumi, and Koekoek chicken crosses.

Variables	Genetic groups			
	WLH * Fay	Fay *WLH	WLH * KK	KK * WLH
Age at first egg	3.50	-3.50	-0.84	0.84
BWAFE	-3.83	3.83	88.37	-88.37
TEN hen^{-1}	16.89	-16.89	-4.36	4.36
HHEP	2.89	-2.89	1.98	-1.98
Feed intake	-0.20	0.20	-1.97	1.97
Feed conversion ratio	-0.01	0.01	-0.03	0.03

WLH * Fay = male White Leghorn crossed with female Fayoumi, Fay *WLH = male Fayoumi crossed with female White Leghorn, WLH * KK = male White Leghorn crossed with female Koekoek, KK * WLH = male Koekoek crossed with female White Leghorn, HHEP = Hen-housed egg production, BWAFE = Body weight at first egg, TEN-Total egg number.

Heterosis effects on productive and reproductive performance

The PH value for age at first egg was varied from -8.50 to -2.03. Several authors also outlined that heterosis estimates for the age of sexual maturity varied between -25 and 11.5% as reported by Williams et al. (2002). The crossbreeding did improve body weight at sexual maturity except for the reciprocal crossbred between Koekoek and WLH. On contrary, Sharaf, Mandour, and Taha (2006) recorded that crossbreeding did not improve body weight at sexual maturity.

The PH for age at first egg was negative and insignificant for both main and reciprocal crossbred. This indicates the hybrid vigor concerning the age of sexual maturity was improved, as the time for attaining sexual maturity of crosses decreased. The lack of difference observed between the crosses (cross and reciprocal cross) could be attributed to the absence of sex-linked or maternal effect in intercrossing of the strains involved (Singh, Chaudhary, Brah, & Sandhu, 1992). The negative value of heterosis is indicating an advantage of the F1 upon the mean parental performance and is also an indication of greater genetic distance between the tested breeds (Keambou et al., 2010). In line with this, Lalev, Mincheva, Oblakova, Hristakieva, and Ivanova (2014) noted negative PH for age at sexual maturity (-8.32%). Besides, Yahaya, Oni, Akpa, and Adeyinka (2009) reported negative heterosis for age at sexual maturity both in the cross and in the reciprocal crossbreed chickens. The PH values of age of sexual maturity in this study fell within the range (-25 and 11.5%) reported by several authors (Williams et al., 2002). The main and reciprocal crossbred improved age at the first egg. Correspondingly, Soliman, Khalil, El-Sabrout, and Shebl (2020) noted improved age at sexual maturity in the hybrids crossing between the local strain and the commercial strain. This study revealed negative heterosis for age at sexual maturity in all crossbred offsprings which were in the desirable direction. This is consistent with Munisi, Katule, and Mbaga (2015) who noted crossbreds with negative heterosis had lower values of age at sexual maturity than the mid-parents.

This study revealed an insignificant ($p > 0.05$) effect of heterosis for body weight at sexual maturity. However, the crossbreeding did improve body weight at sexual maturity except for the reciprocal crossbred between Koekoek and WLH. On contrary, Sharaf et al. (2006) recorded that crossbreeding did not improve body weight at sexual maturity. Positive PH values (i.e., the value of the crosses was higher than the average of the parental strains) were observed in body weight at the first egg of the main crossbred (WLH * Fay and WLH * KK) and reciprocal crossbred (Fay * WLH) while negative PH value was recorded for body weight at sexual maturity (i.e., the crosses were less in body weight at sexual maturity than the average of the parental breeds). On contrary, Soliman et al. (2020) reported positive (5.58%) and negative (-8.15%) PH values for body weight at sexual maturity. Correspondingly, El Salamony et al. (2002) reported positive heterosis for bodyweight at first egg. However, positive heterosis for bodyweight is not desirable in layers because it will reduce feed conversion by increasing the maintenance requirement.

The study revealed significantly different PH for average daily feed intake among the genotypes and the PH for feed intake was positive in all four hybrids (Table 2). This supported the superiority of hybrids over original breeder lines about feed intake. This coincides with Nwenya, Nwakpu, Nwose, and Ogbuagu (2017) who noted positive PH for feed intake of F1 main and reciprocal progenies of naked neck and frizzle feather chicken crosses. On contrary, Keambou et al. (2010) noted the negative value of the heterosis of a cross between Cameroon local and Hubbard genotype and concluded advantage of the F1 upon the mean parental performance because of the less feed intaken than the pure mean parents. The PH for feed conversion ratio (FCR) was negative and significantly lower in main and reciprocal crossbreds of White Leghorn and Fayoumi whereas it was positive and significantly higher in main and reciprocal crossbred of White Leghorn and Koekeok. This study was revealed an appreciable heterotic improvement of FCR in both the main and reciprocal crossbreds of White Leghorn and Fayoumi. The negative PH indicates the possibility of better economic benefit that may result from genetic improvement by crossbreeding. Correspondingly, Sola-Ojo, Ayorinde, Fayeye, and Toye (2012) reported negative values of heterosis for feed efficiency in the crossbred genotypes which showed the superiority of the parental mean to the crosses in both genotypes.

The PH was significantly higher and positive for the number of eggs per hen and hen day egg production in the main crossbreed of WLH * Fayoumi that is indicating an advantage of the F1 over the mean parental performance. This is consistent with Sola-Ojo et al. (2012) who noted positive PH for egg number and hen day production. Similarly, positive heterosis was noted for egg number for the cross between Iraq Brown line and New Hampshire (Razuki & Al-Shaheen, 2011) and Egyptian local chicken (Sinai) and Rhode Island Red as well as Sinai and White Leghorn (Munisi et al., 2015). On contrary, negative heterosis values for egg number were recorded in the crossbreds of WLH * KK, Fay * WLH, and KK * WLH. This is consistent with Yahaya et al. (2009) who noted negative heterosis for egg number in reciprocal crossbreds.

Reciprocal effects on productive and reproductive performance

The positive trait values for crossbred of both Fay * WLH and KK * WLH show strong evidence of the maternal effects from the White Leghorn dam. This finding is in agreement with the findings of Custodio (2000) who revealed higher maternal effects of the progenies from the White Leghorn dams compared to Rubronegra (Black Australorp x New Hampshire) dams. The reciprocal negative effects for age at sexual maturity were recorded for progenies mothered and fathered by the White Leghorn in the crossbred of Fay * WLH and WLH * KK, respectively. The positive reciprocal values for age at sexual maturity are an indication of an earlier maturity of progenies due to crossbreeding. Verma, Pani, and Mohapatra (1987) also observed a significant maternal effect on age at sexual maturity in reciprocal crosses of White Leghorn strains. The positive reciprocal values were noted for body weight at sexual maturity in the crossbred of Fay * WLH and WLH * KK. This implies the fast growth potential of the breed than their counterparts. Similarly, the reciprocal positive effects for body weight at sexual maturity were reported in the diallel crossing of Saso, Italian, and Mandarah chickens at different ages by Amin (2015). However, Soliman et al. (2020) noted a negative reciprocal effect on age sexual maturity for the F1 of Alexandria male × Lohmann female (AL) chickens. On the other hand, Soliman et al. (2020) noted non-significant reciprocal effects for age at sexual maturity, egg number, egg weight, and egg mass in local and commercial chicken strains and concluded that both could be used as the strain of dam. Besides, Egahi, Dim, and Momoh (2013) reported as egg weight is not influenced by the genotype of the dam.

The crossing of White leghorn male with female Fayoumi has revealed a positive reciprocal effect in age at first egg while the crossing White leghorn male with female Koeokoek was exhibited a negative reciprocal effect in age at first egg. This shows that the reciprocal effects are unique and mainly depend upon the genetic group or breed or line used to develop the particular cross which concurs to the study reported by Haunshi and Sharma (2006). This study showed negative reciprocal effects on egg number in the crossbreds of Fay * WLH and WLH * KK. This concurs with Soliman et al. (2020) who reported a negative reciprocal effect on egg number for the F1 of Alexandria male × Lohmann female (AL) chickens. A negative reciprocal effect recorded for feed intake and feed conversion ratio in both crossbreds of WLH * Fay and WLH * KK were attributed to lower feed consumption and higher feed conversion ratio of the breeds. This result was aligned with the report of Balcha, Mengesha, Senbeta, and Zeleke (2021) who noted a negative reciprocal effect on feed conversion ratio. On contrary, several researchers have reported positive reciprocal effects for feed intake at various ages (Nwachukwu et al., 2006). Darwati and Maulana (2017) also observed a positive reciprocal effect on feed intake and feed conversion ratio. Moreover, Soliman et al. (2020) noted a positive and negative reciprocal effect on body weight at the first egg for the F1 of Alexandria male × Lohmann female chickens. A positive reciprocal effect was recorded on HHEP for the crossbred of WLH * Fay and KK * WLH. Similarly, Rahman, Das, and Chowdhury (2019) also observed positive reciprocal effects of HHEP in crossing White leghorn x indigenous chickens, RIR x indigenous and Fayoumi x indigenous. However, Munisi et al. (2015) reported a positive and negative reciprocal effect on egg number and body weight at first egg while crossing between Black Australorp and indigenous chicken's ecotype.

Conclusion and recommendation

This study showed significant differences among the studied genotypes in both productive and reproductive traits except for the age of a first egg and hen-housed egg production. Significantly higher body weight at first egg was recorded for Koekoek and crossbred of Koekoek and White Leghorn. The White Leghorn breed was the best feed efficient among other genotypes. Negative heterosis was noted for age at sexual maturity in all crossbred genotypes which are desirable and an indication of an earlier maturity of hybrids. The positive heterosis was noted for feed intake in both main and reciprocal crossbreds which is an indication of higher feed intake in crossbreds than purebreds. Positive and significantly higher heterosis percentage of total egg production resulted in the hybrid of White Leghorn and Fayoumi. The positive heterosis percentage value for egg production was noted only for the hybrid of White Leghorn and Fayoumi. This confirmed the high efficacy of crossbreeding between male White Leghorn and female Fayoumi for the production of egg-laying. The reciprocal crossbreds of female Fayoumi and male White Leghorn outperformed their main cross counterparts in the age at first egg and body weight at first egg. This seems to indicate that the Fayoumi gene in the reciprocal crossbred may be advantageous in producing early maturing and fast-growing egg-type chickens. Finally, this study concludes that main and reciprocal crossbreeds between WHL and Fayoumi and WLH and Koekoek have resulted in earlier maturity and a better feed conversion ratio. It is therefore recommended that crossing of White Leghorn cock with hens of Fayoumi and Koekoek should be used to improve the feed conversion ratio.

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