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Growth Performance, Carcass Yield, and Humoral Immune Response in Three Broiler Crosses

F. S. Nassar[1*], H. R. Elsherif[1], E. M. EL-Komy[2], and F. K. R. Stino[1]

[1]Department of Animal Production, Faculty of Agriculture, Cairo University, Giza 12613, **Egypt.**
[2]Animal Production Department, Agriculture and Biology Research Division, National Research Centre, El Buhouth St., 12311 Dokki, Cairo, **Egypt**.

***Correspondence:** Fidsaber_nassar@agr.cu.edu.eg **Accepted:** 11Jan. 2018 **Published online:** 19 Feb. 2019

Live body weight (LBW) and carcass traits are the most important factors in the poultry industry to evaluate broiler crosses. The current study was conducted to compare 3 crosses of broiler male line males (Cobb, Arbor Acers, and Hubbard) with Bandarah chicken as a local Egyptian breed on their productive and immune performance of the crosses at 5 weeks. A total of 900 sexed birds from the 3 broiler crosses were raised to study LBW from hatch until 5 weeks of age (LBW5) and carcass traits at 5 weeks of age. Also, Immune responses were analyzed for each cross at 4 and 5 weeks of age. Results indicated that the CB cross had higher carcass, breast muscles, and leg muscles percentages compared to the AB and HB crosses. Also, the CB cross had lower heart, gizzard, liver, spleen, and thymus percentages compared to the AB and HB crosses. However, the HB cross had higher antibody response against Newcastle Disease virus (NDV) than other crosses at 4 and 5 weeks of age. There were significant genotypes by sex interactions on growth and carcass traits between different crosses at different ages. Males and females from the CB cross had the highest LBW5 and relative values of the carcass parts compared to AB and HB crosses. It was concluded that, it was difficult to choose between the 3 broiler crosses. However, the CB cross was considered the best as a local broiler male line according to its growth, carcass performance, and good immune response.

Keywords: broiler crosses, body weight, carcass traits, Immune response, lymphoid organs

INTRODUCTION

In poultry breeding programs, crossbreeding can be used in genetic improvements for increasing productive performance in meat and egg type chickens. This could be done with or without genetic selection in the parent lines. This could be achieved through upgrading through within-line selection or by repeated backcrossing to a superior parent breed. In addition, crossbreeding sometimes originates new genotypes within old phenotypes. Moreover, the advantages of application of crossbreeding will increase the expression of heterosis and hybrid vigour which will lead to improve fitness characteristics (Hoffmann 2005, Khawaja et al., 2013).

Local chicken breeds are among the best genotypes for genetic improvement. However, the process of selection is a relatively time consuming and a slow process (Nassar et al., 2018). Therefore, the crossbreeding process is an important tool used in commercial production of broiler chickens that can be applied for the improvement of local breeds. Crossbreeding is also the best solution for obtaining birds that are characterized by rapid growth and are adapted to the local environmental conditions (Nassar, 2017).

In poultry breeding companies, mainline pedigree broiler populations consist of female and male lines. These lines will be selected

continuously by using positive genetic selection to achieve higher productive performance in the major economic traits. These include live body weight, meat yield, and livability (Pollock, 1999; Muir et al., 2008; Ramadan et al., 2018). Thus, a balance between economic traits, related to growth and reproduction, must be considered when originating and maintaining commercial strains of broiler chicken from great-grandparent lines (Decuypere et al., 2003). Stainton et al., (2017) stated that the development of broiler chickens over the last 70 years has been accompanied by large phenotypic changes. Moreover, growth and meat yield are the most valuable traits that must be considered when applying genetic improvement in broiler breeding programs (Nassar et al., 2012). In addition, commercial broiler breeds are produced from different crosses of highly selected strains at the breeder level (Wolanski et al., 2006). Thus, it is very important to determine the production efficiency and to evaluate the yield of different parts of these broiler crosses (Wang et al., 2018).
Selection for Immune response is one of the most important traits for poultry breeding companies which need to be accurately balanced with other traits (Fulton, 2004).In poultry production, Newcastle Disease Virus (NDV) differ widely in its strain and severity of the disease produced. It is an acute and highly infectious disease that is epidemic worldwide and is responsible for great economic losses to chicken flocks (Zhang et al., 2018).

The NDV agglutinates the chickens red blood cells. Such hemagglutination is inhibited or neutralized by ND immune serum. This provides a simple and useful diagnostic method. So hemagglutination inhibition (HI) titers are used for measuring the immune response by obtaining serum antibody titers (Alexander, 2003). Also, Newcastle disease HI titer is an indicator of specific humoral immunity, so it is of great importance to increase the HI titers (Swayne and Halvorson, 2003).Nassar et al., (2012) selected the Cairo B-2 line as the first Egyptian broiler female line at the Faculty of Agriculture, Cairo University, Egypt. This selection improvement program started since 2003 until now. Thus, the purpose of this study was to compare the growth performance, carcass yield, and immune response of three commercial male lines crosses with a local Egyptian breed (Bandarah). This step will help us to choose the best commercial crosses to produce a local broiler male line. This male line will be mated with the Cairo B-2 line to produce the first local broiler chicks in the near future.

MATERIALS AND METHODS

Experimental populations and management

Three commercial broiler breeder male line males (Arbr Acers, Hubbard Classic, and Cobb 500) were crossed with Bandarah female chicken (Eltanany et al., 2011), as native breed, to produce three types of broiler crosses. A total of 300 day old chicks form each broiler crosses: Cross CB (Cobb 500 ♂ × Bandarah ♀), Cross AB (Arbr Acers ♂×Bandarah ♀), Cross HB (Hubbard Classic ♂ × Bandarah ♀) were used in the current study. At hatch, all produced chicks were wing banded and sexed, using the vent method. A total of 900 day old chicks were reared intermingled at the Poultry Farm, Faculty of Agriculture, Cairo University, Egypt, 10 birds/m^2, in an open house, deep litter system, until 5 weeks of age.

Chicks were vaccinated against Newcastle disease at 7 days (eye drop, Hitchner, Nobilis®), at 10 days (S/C injection by Newcastle inactivated vaccine, Nobilis®), and at 21 days (eye drop, La Sota strain, Nobilis®). Chicks were also vaccinated against infectious bursal disease at 14 and 24 days (eye drop) using Gumboro D_{78} strain (Nobilis®). In February 2006, there was an outbreak of the virulent avian influenza virus (H_5N_1) in Egypt (Nassar, 2008). Thus, the baby chicks from that time on are vaccinated against avian influenza virus by using S/C injection of H_5N_2 inactivated vaccine at one week of age. The inactivated H_5N_2 vaccine was injected subcutaneously in the lower back of the neck region.

Experimental diets

All experimental diets were formulated to cover the nutrient requirements of all parent' lines according to El-Husseiny et al., (2018). Table 1 represents the composition and calculated chemical analysis of the female and male diets. The breeder experimental diets were formulated to contain 2800 or 2700 kcal kg-1 metabolizable energy and 15 or 13% crude protein (CP) for female or male lines, respectively. Constant amounts of mash feed were presented to hens and roosters being 125 and 130 g, respectively. Broiler crosses were provided with a commercial broiler starter (23% CP and 3,050 kcal ME/kg) and a grower (21% CP and 3,100 kcal ME/kg) diets from 1 to 14 days and from 15 days to 5 weeks of age, respectively.

Table 1. The composition and calculated analysis of the commercial male line males and local breed diets*

Ingredients	Local female breed	Commercial male line males
Yellow corn	69.70	66.40
Soybean meal-44	20.26	09.43
Wheat bran	01.00	20.40
Lime stone	06.89	01.62
Di-Calcium Phosphate	01.25	01.25
Vitamin mix[2]	0.200	0.200
Mineral mix[2]	0.300	0.300
Salt	0.400	0.400
DL. Methionine	--------	-------
Total	100.00	100.00
Chemical composition[1]		
Metabolizable energy Kcal/kg	2800	2700
Crude protein %	15.0	13.0
Crude fiber%	3.06	4.36
Ether Extract%	2.84	3.21
Calcium %	3.00	1.00
Available Phosphorus %	0.35	0.35
Sodium %	0.16	0.16
Methionine %	0.25	0.22
Methionine + cysteine %	0.52	0.47
Lysine %	0.73	0.55

*Each 1 kg diet contains vitamin A 11000 IU, vitamin D3 3500 IU, vitamin E 100 mg, vitamin K3 4.4 mg, vitamin B1 6.6 mg, vitamin B2 12 mg, vitamin B6 4.4 mg, Vitamin B12 0.022 mg, pantothenic acid 15.5 mg, nicotinic acid 50 mg, folic acid 2 mg, Biotin 0.22 mg, choline chloride 2.422 gm, manganese 120 mg, zinc 110 mg, iron 44 mg, copper 9 mg, iodine 1.2 mg, selenium 0.4 mg and cobalt 0.30 mg. [1]Chemical composition of feedstuffs was calculated according to NRC (1994).

Water and feed were provided ad libitum. Light was provided 24 hours per day.

Traits measured

For all crosses, LBW at hatch, 7, 14, 21, 28, 35 days were obtained individually by using a digital scale. Also, daily gains for each cross were calculated. At 28 and 35 days at random of age, blood samples (1 ml/bird) were collected from the wing vein of 30 birds per cross in non-heparinized tubs, and the blood was allowed to clot. These samples were centrifuged at 3000 rpm for 10 minutes and serum was separated. Serum samples were stored at -20^{o} C until analysis. Serum antibody titers against NDV were determined by using log^2 of the hemagglutination inhibition (HI) test (Hanson, 1972; Swayne and Halvorson, 2003).

At 5 weeks of age 30 males from each broiler cross, were chosen at random. Birds were weighted as LBW and slaughtered after 8 hours of fasting (Papa, 1991). Birds were slaughtered by slitting the throat, cutting the carotid arteries, jugular veins, esophagus and trachea without severing the head (Salwani et al., 2016). After slaughtering each bird was hanged in a bleeding funnel for 3 minutes then weighed then scalded in a 68^{O} C water bath for 30 seconds, and then the feathers were removed by an automatic circular feather plucker. Birds were then weighed the eviscerated, the head and shanks were removed and weighed and the carcasses were weighed then chelled.

Each chelled carcass was weighed to obtain the carcass weight. The wings with bones were then removed from the front parts and weighed as wings with bones weight. Also, the skinless pictoralis major and minor muscles were removed to obtain breast muscles weight. The bones from the thighs and drumsticks were removed then the skinless leg muscles were weighed as leg meat weight. Internal organs and abdominal fat pad were removed and then weighed to obtain abdominal fat pad weight, heart weight, gizzard weight empty and without the fat adhering, liver weight. Also, lymphoid organs were removed and weighted to obtain Spleen weight, Thymus weight, and Bursa weight. Moreover, all previous muscles and organs weights were also calculated as percentages of live body weight.

Statistical analysis

Data were analyzed as a two-way analysis of variance using the SAS software, general linear model (SAS Institute, 2009). The main effects were cross and sex. Traits analyzed were: 5-week live body weights (LBW5) and carcass parts, and muscles as weights and as percentages of LBW5 for males and females CB, AB, and HB crosses. All data were reported as least square means (LSM) ± standard errors (SE). Mean values were separated, when significance existed, using Duncan's multiple range test (Duncan's, 1955). Significance level was set at 5%. The following model was used:

$Y_{ijk} = \mu + L_i + S_j + LS_{ij} + e_{ijk}$

Where,

Y_{ijk}: The Kth observation of the jth sex within the ith Crosses.

μ: The overall mean.

L_i: The effect of the ith Crosses.

S_j: The effect of the jth sex.

LS_{ij}: The interaction between the ith Crosses and the jth sex.

e_{ijk}: Random error.

RESULTS AND DISCUSSION

Live body weight from hatch until 5 weeks of age

The present results indicated that, Cross CB had significant higher LBW at most all ages studied compared to the AB and HB crosses (Table 2). The results indicated that, Cross CB exhibited significantly higher LBW (average = 1098 g) at 5 week of age compared with Cross AB (average = 850 g) or Cross HB (average = 722 g), (Table 2). Benyi et al., (2015) stated that the genotype in broiler production had effect on LBW. Moreover, Souza et al. (1994) stated that there were continuous genetic improvements in economical traits in birds under selection. The current result indicates that, the genotype had an effect on growth performance and LBW5 of the different crosses. There were genetic differences in body weights as a result of crossing commercial broiler breeds with a local breed. Current results are similar to those reported by Shim et al., (2012) when they compared live body weights of six commercial broiler crosses at different ages and they found significant differences in LBW between these crosses at various ages.

In the present study, the effect of genotype, sex, and interaction between sex and genotype on LBW from hatch until 5 weeks of age for all crosses is shown in (Table 2). Moreover, sex influenced LBW from hatch till 35 days of age. As expected, males had significantly higher LBW from hatch until 35 days of age compared to females. There were significant genotype with sex interaction effects from hatch until 35 days of age in all crosses (Table 2).

Many research's stated that, age at marketing, sex, and genotype are primary factors affecting broiler performance (Siegel et al., 1984; Havenstein et al., 1994). In broiler production, LBW is mainly influenced by the interaction between genotype and sex. Thus, a correct evaluation of broiler performance should consider these factors (Moreira et al., 2003; Fernandes et al., 2013). In addition, Benyi et al., (2015) stated that the interaction between genotype and sex, in broiler production, had significant effects on LBW. The results of the current study indicated the presence of differences between crosses due to the effects of genotype with sex interaction on LBW5. These results are in agreement with the results previously reported by Fernandes et al., (2013) and Benyi et al., (2015). Also, differences in LBW between females and males in different crosses were in agreement with those previously reported (Lopez et al., 2011; Shim et al., 2012).

Also, differences in LBW5 between the CB cross with the AB and HB crosses were 29.3% and 52.1%, respectively. Differences Between crosses could be due to the general and specific combining abilities. Also, crossbreeding allows for the expression of hybrid vigour and heterosis. These can result in improved fitness characteristics in different broiler line crosses. These results are in agreement with the results previously reported by Hoffmann (2005) and Khawaja et al., (2013).

Slaughter traits of the different crosses

The results indicated that cross the CB cross had significantly higher carcass, breast muscles, Leg muscles, wings with bones, and abdominal fat pad weights in comparison with the other two crosses (Table 3). Also, the CB cross had significantly higher carcass, breast muscles, Leg muscles, and abdominal fat pad percentages compared to the AB and HB crosses. Moreover, the CB and AB crosses had significantly lower wings with bones percentages compared to HB cross (Table 3).

The increase in broiler performance has been tremendous in recent years, as measured by growth rate and carcass yield (Pishnamazi et al., 2008). In general, for any breeding program we need to carefully select to maximize the yield of sealable products from each bird. This is because carcass yield increases as body weight increases (Havenstein et al., 2003). In addition, the major effects of broiler body weight selection is the increase in overall muscle mass of the chicken, and this is particularly evident in the breast muscles. In addition, the heavier body weight of the CB cross explains the higher relative yield of its breasts. The heavier birds produce greater breast portions. These results are in agreement with the results reported by Schmidt et al., (2009) and Sandercock et al., (2009).

In general, wings with bone percentages decrease for both CB and AB crosses. This may be explained by the fact that the increase in breast meat portion would result in decreases in the other parts on relative basis (Fletcher and Carpenter, 1993). Also, the differences observed in yields percentages, for different crosses, may be attributed to the different genetics origins of the flocks (Goliomytis et al., 2003).

Intense selection for rapid growth induces increased fat deposition (Rance et al., 2002; Schmidt et al., 2009). Also, broiler genotype differences in weight and carcass traits may be mainly attributed to the different genetic makeup of the broiler breeder strains. Significant strain differences for carcass and abdominal fat as a percentage of body weight were also reported (Boschiero et al., 2009).

The effect of genotype and sex on carcass characteristics is shown in Table 3. Genotype and sex interaction was observed for 5 weeks LBW with significant effect on the carcass characteristics. In addition, males from the CB cross had significantly higher carcass, breast muscles, leg muscles, wings with bones, and abdominal fat pad weights compared to females from the same cross with males and females of the AB and HB crosses. Also, males from the CB cross had significantly higher carcass, breast muscles, leg muscles, wings with bones, and abdominal fat pad weights percentages compared to males and females from the same cross with males and females of the AB and HB crosses (Table 3). Moreover, females from the CB cross had significantly higher carcass, breast muscles, leg muscles, wings with bones, and abdominal fat pad weights compared to males and females and of the AB and HB crosses. Also, females from the CB cross had significantly higher carcass and breast muscles percentages compared to males and females and of the AB and HB crosses (Table 3).

Carcasses yield are mainly influenced by sex breed and slaughter age. For breast and legs yield, a significant interaction was observed between breed, sex and slaughter age (Fernandes et al., 2013).Thus, a correct evaluation of the yield should consider these factors in order to avoid misleading decision-making, which will certainly affect any company profit (Fernandes et al., 2013). Also, effects of genotype and sex were observed in carcass yield and parts. Males had higher meat yield and percentages than females which indicates, as expected, the presence of sexual dimorphism. These results are in agreement with the results previously reported by Nassar et al., (2012) and Zhao et al., (2015).

Internal organs and lymphoid organs index of different crosses

The results indicated that the CB cross had significantly higher heart, gizzard, liver, spleen, bursa of Fabricius, and thymus weights compared to the AB and HB crosses (Table 4). On the other hand, the CB cross had significantly lower heart, gizzard, liver, spleen, and thymus percentages in comparison with the AB and HB crosses. Moreover, there were no significant differences in the bursa of Fabricius percentages between the different crosses (Table 4). In general, since the LBW5 in the CB cross was the heaviest, this resulted in a decrease in the percentages of the internal and lymphoid organs. These results are also in agreement with the results of Gaya et al. (2006) and Schmidt et al., (2009).

The effects of genotype and sex on different internal and lymphoid organs are shown in Table 4. Sex and genotype interaction was observed for 5 weeks live body weight with significant ($P<0.05$) effect on internal and lymphoid organs. In addition, males from the CB cross had significantly higher heart, gizzard, liver, spleen, bursa of Fabricius, and thymus weights compared to females from the AB and HB crosses. Also, males from the CB cross had significantly lower heart, gizzard, liver, spleen, bursa of Fabricius, and thymus percentages in comparison with males and females of the AB and HB crosses (Table 4).

Table 2. Effect of crossing on LBW (gm) from hatch to 35 days of age for the three broiler crosses

Crosses*	**Age**					
	Hatch	**7 days**	**14 days**	**21 days**	**28 days**	**35 days**
CB	37.3^{a}	123.3^{a}	262^{a}	459^{a}	730^{a}	1098^{a}
AB	36.9^{b}	120.4^{a}	$238.^{b}$	405^{b}	586^{b}	850^{b}
HB	36^{c}	112.7^{b}	199^{c}	325^{c}	508^{c}	722^{c}
SEM	0.10	1.73	1.96	3.18	4.05	6.03
Sex						
Male	37.1^{a}	130.8^{a}	251^{a}	432^{a}	662^{a}	961^{a}
Female	36.4^{b}	106.9^{b}	216^{b}	362^{b}	562^{b}	821^{b}
SEM	0.10	1.24	1.95	3.56	5.49	9.41
Cross*sex						
CB ♂	37.8^{a}	133.8^{a}	284^{a}	498^{a}	786^{a}	1190^{a}
CB ♀	36.9^{c}	112.9^{c}	240^{c}	421^{c}	675^{b}	1008^{b}
AB ♂	37.4^{b}	131.4^{ab}	250^{b}	433^{b}	638^{c}	913^{c}
AB ♀	36.5^{d}	109.6^{c}	226^{d}	378^{d}	555^{d}	787^{d}
HB♂	$36.2d^{e}$	127.3^{b}	217^{e}	365^{e}	561^{d}	778^{d}
HB ♀	35.9^{e}	98.4^{d}	181.03^{f}	287^{f}	457^{e}	668^{e}
SEM	0.13	2.11	2.11	2.76	2.79	4.63
Probability						
Cross	0.001	0.001	0.001	0.001	0.001	0.001
Sex	0.001	0.001	0.001	0.001	0.001	0.001
Cross*Sex	0.0001	0.001	0.001	0.001	0.001	0.001

*Cross CB =Cobb 500 ♂ × Bandarah ♀, Cross AB =Arbr Acers ♂×Bandarah ♀, Cross HB= Hubbard Classic ♂ × Bandarah ♀
a-bMeans between crosses or sex or the interaction, within age, followed by different superscripts, differ significantly ($p \leq 0.05$).

Table 3. Effect of crossing on carcass characteristics of the three broiler crosses at 35 d of age.

Crosses*	Traits										
	LBW (gm)	Carcass		Breast Muscles		Leg Muscles		Wings with Bones		Abdominal Fat Pad	
		Weight (gm)	% LBW	Weight (gm)	% LBW	Weight (gm)	% LBW	Weight (gm)	% LBW	Weight (gm)	% LBW
CB	1228^{a}	861^{a}	70.13^{a}	236^{a}	19.21^{a}	199^{a}	16.12^{a}	95^{a}	7.72^{b}	20^{a}	1.59^{a}
AB	992^{b}	648^{b}	65.21^{b}	169^{b}	17.00^{b}	154^{b}	15.53^{b}	80^{b}	8.06^{b}	14^{b}	1.40^{b}
HB	799^{c}	518^{c}	64.81^{b}	136^{c}	17.03^{b}	120^{c}	14.47^{c}	69^{c}	8.63^{a}	8^{c}	1.04^{c}
SEM	12.16	10.93	0.54	3.15	0.16	3.51	0.19	2.44	0.15	0.53	0.04
Sex											
Male	1060^{a}	727^{a}	68.25^{a}	196^{a}	18.36^{a}	174^{a}	16.32^{a}	94^{a}	8.89^{a}	16^{a}	1.47^{a}
Female	962^{b}	624^{b}	65.19^{b}	165^{b}	17.13^{b}	141^{b}	14.77^{b}	69^{b}	7.38^{b}	12^{b}	1.22^{b}
SEM	27.07	21.77	0.52	6.35	0.18	5.06	0.15	1.77	0.07	0.76	0.40
Cross*sex											
CB ♂	1285^{a}	911^{a}	70.90^{a}	254^{a}	19.72^{a}	220^{a}	17.12^{a}	110 ^{a}	8.53^{c}	22^{a}	1.68^{a}
CB ♀	1170^{b}	812^{b}	69.36^{b}	219^{b}	18.69^{b}	177^{b}	15.14^{cd}	81^{c}	6.91^{f}	18^{b}	1.51^{b}
AB ♂	1019^{c}	701^{c}	68.79^{b}	186^{c}	18.22^{c}	169^{c}	16.68^{b}	91^{b}	8.96^{b}	17^{b}	1.66^{a}
AB ♀	966^{d}	595^{d}	61.64^{c}	152.37^{d}	15.77^{e}	139^{d}	14.42^{e}	69^{d}	7.16^{e}	11^{c}	1.15^{c}
HB♂	876^{e}	570^{e}	65.06^{c}	150^{d}	17.13^{d}	133^{d}	15.19^{c}	80^{c}	9.18^{a}	9^{d}	1.08^{cd}
HB ♀	720^{f}	466^{f}	64.57^{d}	122^{e}	16.93^{d}	106^{e}	14.76^{de}	58^{e}	8.07^{d}	7^{e}	1.00^{d}
SEM	8.22	7.57	0.53	1.40	0.10	2.24	0.15	1.25	0.08	0.51	0.04
Probability											
Cross	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sex	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cross*Sex	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

*Cross CB =Cobb 500 ♂ × Bandarah ♀, Cross AB =Arbr Acers ♂×Bandarah ♀, Cross HB= Hubbard Classic ♂ × Bandarah ♀.
$^{a-b}$Means between crosses or sex or the interaction, within age, followed by different superscripts, differ significantly ($p \leq 0.05$).

Table 4. Effect of crossing on internal and lymphoid organs of the three broiler crosses at 35 d of age.

Crosses*	Traits											
	Heart		Gizzard		Liver		Spleen		Bursa of Fabricius		Thymus	
	Weight (gm)	% LBW	Weight (gm)	% LBW	Weight (gm)	%LBW	Weight (gm)	% LBW	Weight (gm)	% LBW	Weight (gm)	% LBW
CB	7.1^{a}	0.58^{c}	19.6^{a}	1.60^{c}	23.7^{a}	1.93^{b}	2.7^{a}	0.22^{c}	1.6^{a}	0.13	3.9^{a}	0.32^{b}
AB	6.4^{b}	0.64^{b}	17.9^{b}	1.80^{b}	20.1^{a}	2.02^{a}	2.3^{b}	0.23^{b}	1.4^{b}	0.14	3.3^{b}	0.33^{a}
HB	5.9^{b}	0.73^{a}	16.1^{c}	2.03^{a}	16.6^{b}	2.09^{a}	1.9^{c}	0.24^{a}	1.1^{c}	0.14	2.9^{c}	0.34^{a}
SEM	0.20	0.02	0.21	0.02	0.40	0.03	0.03	0.01	0.02	0.01	0.05	0.01
Sex												
Male	6.9^{a}	0.67^{a}	18.4^{a}	1.75^{b}	21.1^{a}	1.99^{a}	2.4^{a}	0.23^{a}	1.4^{a}	0.14^{a}	3.5^{a}	0.33^{a}
Female	5.9^{b}	0.63^{a}	17.4^{b}	1.87^{a}	19.2^{b}	2.03^{a}	2.2^{b}	0.23^{a}	1.3^{b}	0.14^{a}	3.1^{b}	0.33^{a}
SEM	0.16	0.02	0.27	0.03	0.52		0.05	0.01	0.03	0.01	0.08	0.01
Cross*sex												
CB ♂	7.5^{a}	0.59^{d}	20.8^{a}	1.62^{d}	24.5^{a}	1.91^{c}	2.8^{a}	0.22^{d}	1.7^{a}	0.13^{c}	4.1^{a}	0.32^{b}
CB ♀	6.7^{b}	0.57^{d}	18.5^{b}	1.58^{e}	22.8^{b}	1.94^{c}	2.6^{b}	0.22^{d}	1.5^{b}	0.13^{c}	3.7^{b}	0.32^{b}
AB ♂	6.8^{b}	0.66^{bc}	18.1^{bc}	1.78^{c}	21.2^{c}	2.08^{ab}	2.3^{c}	0.23^{c}	1.4^{c}	0.14^{b}	3.5^{c}	0.33^{b}
AB ♀	5.9^{cd}	0.61^{cd}	17.7^{c}	1.83^{b}	19.1^{d}	1.97^{bc}	2.2^{d}	0.23^{c}	1.4^{d}	0.14^{b}	3.2^{d}	0.33^{b}
HB♂	6.5^{bc}	0.74^{a}	16.2^{d}	1.85^{b}	17.5^{e}	$1.98b^{c}$	2.1^{e}	0.24^{b}	1.2^{e}	0.14^{b}	2.9^{e}	0.33^{b}
HB ♀	5.2^{d}	0.72^{ab}	15.9^{d}	2.22^{a}	15.8^{f}	2.19^{a}	1.8^{f}	0.25^{a}	1.1^{d}	0.15^{a}	2.5^{f}	0.34^{a}
SEM	0.25	0.02	0.24	0.01	0.52	0.04	0.03	0.01	0.02	0.01	0.05	0.01
Probability												
Cross	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Sex	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cross*Sex	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

*Cross CB =Cobb 500 ♂ × Bandarah ♀, Cross AB =Arbr Acers ♂×Bandarah ♀, Cross HB= Hubbard Classic ♂ × Bandarah ♀.
a-b Means between crosses or sex or the interaction, within age, followed by different superscripts, differ significantly ($p \leq 0.05$).

Table 5. Effect of crossing on antibody titers against Newcastle disease virus (NDV) of the three broiler crosses at 28 and 35 d of age.

Crosses*	HI titers	
	28 days*	32 days
CB	5.75^{b}	5.20^{b}
AB	6.16^{b}	5.70^{b}
HB	7.65^{a}	6.75^{a}
SEM	0.22	0.19
Probability	0.0001	0.0001

*Cross CB =Cobb 500 ♂ × Bandarah ♀, Cross AB =Arbr Acers ♂×Bandarah ♀, Cross HB= Hubbard Classic ♂ × Bandarah ♀.
$^{a-b}$Means between crosses or sex or the interaction, within days, followed by different superscripts, differ significantly (p≤ 0.05) for each other.

Moreover, females from the CB cross had significantly higher heart, gizzard, liver, spleen, bursa of Fabricius, and thymus weights compared to males and females of the AB and HB crosses. Also, females from the CB cross had significantly lower heart, gizzard, liver, spleen, bursa of Fabricius, and thymus percentages in comparison to males and females of the AB and HB crosses (Table 4). On the other hand, for most studied traits, males had higher internal and lymphoid organs weights than females in the different crosses indicating, as expected, the presence of sexual dimorphism. These results are in agreement with the results previously reported by Mignon-Grasteau et al., (2000); Nassar et al., 2012 , 2017; Zhao et al., (2015).

Humoral Immune response of different crosses against NDV

Results indicated that, the HB cross had significantly higher antibody response against NDV than the CB and AB cross at 4 and 5 weeks of age (Table 5). However, there was no significant difference in HI titer between the CB and AB crosses at 4 and 5 weeks of age. This is probably due to the impact of lighter body weight of the HB cross. Continuous selection for high juvenile body weight might had changed the genetic make-up of commercial broilers since a negative correlation between fast growth and immune response exists (Qureshi and Havenstein., 1994; Shapiro et al., 1998).

Selection for Immune response is one of the most important traits used by the poultry breeding companies. This is needed to be accurately balanced with the other traits (Fulton, 2004). Also, selection for enhancing productive performance in broilers results in reduced relative growth of different lymphoid organs (Cheema et al., 2003). Thus, higher LBW5 that occurred in the CB cross caused change in the relative lymphoid organs weights and the antibody response against NDV compared to the HB cross which had lower LBW5. On the other hand, evaluation of the genetic changes that occurred in immune and organs function, associated with increasing LBW and yield, will require continues evaluation of parents and its progenies for many generations. These results are also in agreement with the results of Qureshi and Havenstein (1994).

CONCLUSION

Broiler breeding programs, are complex and there are great challenges of choosing between different broiler crosses. Generally, the best broiler crosses will involve higher LBW, immune response, and muscle percentages during the meat production cycle. The Cobb male with Bandarah female (CB) was the best proven to be the best choice as a local base broiler male line according to its growth performance, good humoral immune response, and the relative values of carcass parts. Also, differences in LBW5 between the CB cross were 29.3% and 52.1% heavier than the AB and HB crosses. Thus, Cobb broiler male line males seems to be the best choice as a broiler male line males to cross with local Bandarah females to produce the base population of the local broiler male line. This line will be further selected in definitely to produce a local Egyptian male broiler line. This line will be mated with the local broiler female line, Cairo B-2 line, to produce the first local Egyptian broiler chicks in the near future.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

All authors contributed equally in all parts of this study.

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