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Research Article

Growth Performance and Heterosis in Meat-type White Crossbred Chickens

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ABSTRACT

A study was conducted to evaluate the body weight, weight gain, meat yield, livability and heterosis of different crossbred chickens produced by mating three pure lines of meat-type chickens i.e., Male line white (MLW), Male line white2 (MLW2), Female line white (FLW). A total of 369 crossbred as hatched chicks of 2 genotypes i.e., MLW2 × FLW2(MLW♂ × FLW♀), MLW × FLW2 were brooded with electric brooder on litter floor and standard broiler diets were fed from day old to 42 days of age. Proper management strategies were practiced for all genotypes. Body weight and feed consumption were recorded weekly. One male and two female chickens from each cross were sacrificed to record their dressing yield. The body weight was significantly ($p<0.01$) higher in MLW2 × FLW2 (1768.66 ± 15.61g) than MLW × FLW2 (1684.39 ± 17.62g) at 6 weeks of age. The weight gain followed similar trend as body weight. The overall feed conversion ratio was slightly better in MLW × FLW2 (1.63) than in MLW2 × FLW2 (1.65). The dressing percentage was similar in MLW2 × FLW2 (72.66%) and MLW × FLW2 (72.35%). The livability percentage was near 100% in both crosses. The heterosis for body weight gain was 61% and 68% in the MLW2 × FLW2 and MLW × FLW2 crossbred. So, it may be concluded that the 3-way white crossbred (MLW2 × FLW2) may be used for meat production based on overall performance and characteristics.

Introduction

Commercial poultry production is a leading sector of Bangladesh for the last two decades. The sector has become an important avenue for the people of the country in terms of agricultural growth and combating malnutrition (Da Silva and Rankin, 2014). Direct and indirect employment of about 6 million people is created from this sector and allied support services. About 14% of the total value of livestock output (Raihan and Mahmud, 2008) and 22-27% of the total animal protein supply is contributed by poultry (Prabakaran, 2003). Poultry meat contributes 37% of the total meat production in Bangladesh of which commercial broiler plays the most vital role. It supplies high-quality animal protein at a cheaper rate that can mitigate malnutrition in developing countries (Onyimonyi *et al.,* 2009, Neumann *et al.,* 2002). About 525 million broilers are annually consumed in Bangladesh and the investment in the sector is approximately $4.16 billion (332 billion tk.) (PSSB, 2020). Short generation interval, quick return on investment, high-quality protein and increasing demand for poultry meat have strengthened broiler farming prospects (Adeyemo *et al.,* 2010). The type of genetic resources, feeding practices, the prevalence of diseases, prevention and control, the management of flocks and the interactions among these factors are the determinates of broiler performance (Thieme *et al.,* 2014). Most of the high-yielding breeds/strains have developed in temperate climates (Singh, 2005). They suffer from reduced feed intake and impaired feed efficiency in the peak summer. Arrangement of costly environmentally controlled houses with cooling devices to combat the heat is not a desirable option for rural farmers.

To improve the productivity of locally available genotypes the conservation of the desirable genes (e.g., disease resistance, feather color and meat texture) is essential which is performed by crossbreeding worldwide (Kato *et al.,* 2008). The crossbred progenies are superior to pure breed in terms of growth, meat quality and feed conversion efficiency, [Azharul *et al*. (2005), Ahmed *et al*. (2007), Keambou *et al.* (2010),

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Bekele *et al.* (2010), Adeleke *et al*. (2011) and Khawaja *et al*. (2012)]. Hybrid produced from indigenous and exotic chicken cross-breeding would be more resistant to harsh tropical conditions and can produce a reasonable amount of meat (Barua *et al.,* 1998; Iraqi *et al.,* 2005; Mekki *et al.,* 2005). In a report, Adebambo *et al.* (2011) mentioned that either by selection or cross-breeding genetic progress can be attained.

There are continuous efforts to develop meat-type chicken to reduce dependency on foreign countries which will reduce both cost and risk factors like transboundary disease spread. And situation like COVID-19 has increased the demand for such activity. The present study is a part of research with the same goal to develop meat-type chicken using available and adapted local and exotic genetic resources. Here, two newly developed meat-type crosses of chickens are evaluated in terms of their performance and mid-parent heterosis after six generations of selection.

Materials and Methods

Experimental location, shed, birds and layout

The experiment was carried out at Bangladesh Agricultural University (BAU), Poultry Farm, Mymensingh, Bangladesh. The experimental chickens were brooded and reared up to marketing age in a semi-monitor building with concrete floor. The experiment was set up with BAU-Bro white day-old chicks (DOC) and their parental lines. Three pure lines (MLW♂ × MLW♀, MLW2♂ × MLW2♀ and FLW♂ × FLW♀), one parental line (FLW2♀ (MLW♂ × FLW♀)) and two crossbreds (MLW2♂ × FLW2♀ and MLW♂ × FLW2♀) were used in the study. A total of 234 pure and parental lines and 369 crossbred as hatched chicks were used. All DOCs of all genotypes were individually identified by wing band. The chicks were individually weighted and distributed in separate pens according to genotypes. The layout of the experiment is given in Table 1.

Table 1. Layout of the experiment

Cross	Number of chickens
MLW2♂ × FLW2♀	184
MLW♂ × FLW2♀	185
Total	369

MLW2: Male Line White2, FLW2: Female Line White2, MLW: Male Line White

General flock management

The chicks were brooded with electric brooder. Standard brooding conditions were maintained. Balanced feed and clean water were supplied *ad-libitum*. Three types of diet namely starter (0−20 day, ME 2920 kcal/kg, CP 21.30%), grower (21−28 day, ME 3008 kcal/kg, CP 19.29%) and finisher (29−42 day, ME 3090 kcal/kg, CP 18.26%) were used during the experimental period. Water soluble multivitamins (Allvit MA) were supplied two days per week during the early growing period. Standard vaccination (Newcastle disease and Infectious Bursal Disease) program was maintained. 23.5 hours lighting per day was provided and the dark period was given to make chickens familiar with the possible darkness during electricity failure.

Parameters recorded

Body weight & Body weight gain

Live body weight of individual chickens of each pure line was recorded at day-old, 1, 3, 5 and 6 weeks of age. The body weight of individual chicken of each crossbred was recorded at day-old, 1, 2, 3, 4, 5 and 6 weeks of age with a digital balance at early morning before supplementation of feed and water. The body weight gain of individual chickens of each genotype was calculated during 0-1, 1-3, 3-5, 5-6 and 0-6 weeks of age.

Feed consumption and feed conversion ratio

Feed supplied was recorded daily and leftover feed was measured weekly.
Feed intake (g/chicken/day) was measured using the formula:

$$\text{Feed intake} = \frac{\text{Total feed consumption (g)}}{\text{No of chickens x No.of days}}$$

FCR was calculated by using the following formula:

FCR = Feed intake (g)/Live weight gain (g)

Dressing meat yield

When the chickens attained market age (i.e., 35-42 days) one male and two females from each genotype were dressed to record their dressing meat yield.
The dressing meat yield was calculated using the following formula:

$$\text{Dressing yield (\%)} = \frac{\text{Dressed weight x 100}}{\text{Live weight}}$$

Shank color, plumage color and comb type

The shank color, plumage color and comb type of each individual chicken of each genotype were recorded at 5 weeks of age and was expressed as percentage.

Mating layout for estimation of heterosis

The mid-parent heterosis was estimated by partial crossing of the genotypes.

MLW♂ × FLW♀	MLW♂ × FLW♀
↓	↓
MLW♂ × FLW2 (F_1♀)	MLW2♂ × FLW2 (F_1♀)
↓	↓
Estimation of mid-parent heterosis of 3-way chickens	Estimation of mid-parent heterosis of 3-way chickens

Data analysis

Body weight and body weight gain were analyzed by linear mixed model. Statistical Discovery Software JMP® 5.01 (SAS Institute Inc., Cary, North Carolina, USA) and/or Stata (2013) were used to analyze the data. Significant differences were identified by Turkey's HSD test. The mid-parent heterosis was estimated by the following formula.

$$\text{Mid-parent heterosis} = \frac{F1-(P1+P2)/2}{(P1+P2)/2}$$

Where,

P_1: Sire body weight and body weight gain

P_2: Dam body weight and body weight gain

F_1: Progeny performance

Results and Discussion

Body weight

The least-square means of body weight are presented in Table 2. It is evident that the DOC weight was insignificantly higher in MLW2♂×FLW2♀ (36.75 ± 0.25g) than MLW♂×FLW2♀ (36.19 ± 0.28g). The slight difference in one-day-old chick weight was primarily due to genotypic variation that may affect egg size among the genotypes which ultimately affected the day-old body weight of the chicks, since the chick weight is the function of egg weight (Sharma *et al*., 1971). The results are consistent with the observation of Adebambo (2011) and Siwendu *et al*. (2013). They found different day-old weights in different exotic genotypes. The body weight of the two crosses continued to be similar up to 4th week of age and at 5 and 6 weeks of age significantly higher (p<0.01) body weight was observed in MLW2♂×FLW2♀ (1312.77 ± 11.59 & 1768.66 ± 15.61g) than MLW♂×FLW2♀ (1234.14 ± 12.93 & 1684.39 ± 17.62g). The results indicated that the body weight of crossbreds was tremendously improved during 5 and 6 weeks of age. The results are comparable with the observation of Adebambo *et al.* (2011) and Yahaya *et al*. (2009). They found higher growth in crossbred during finishing. Haque (2005) demonstrated that synthetic broiler attained 1459.25g body weight at 5 weeks of age which is higher than our findings (1312.77 ± 10.59g). Pervin (2005) reported initial, 1st, 2nd, 3rd, 4th and 5th week's body weight of synthetic broiler as 48.7g, 134.8g, 391.6g, 697.2g, 1127.0g and 1391.0g respectively which is also slightly higher than our present study.

Table 2. Least square means (g) ± SE of body weight of 3-way crosses

Crosses	Body weight (g)						
	DOC Weight	1st week BW	2nd week BW	3rd week BW	4th week BW	5th week BW	6th week BW6
MLW2♂×FLW2♀	36.75 ± 0.25	130.71 ± 1.59	307.55 ±2.65	562.73 ± 6.54[a]	929.96 ± 8.2	1312.77 ± 11.59[a]	1768.66 ± 15.61[a]
MLW♂×FLW2♀	36.19 ± 0.28	126.55 ± 1.79	305.70 ±3.12	548.40 ± 7.37[ab]	902.30 ±9.33	1234.14 ± 12.93[b]	1684.39 ± 17.62[b]
p value	0.098	0.083	0.110	0.031*	0.072	0.009**	0.006**

SE: standard error, means with different superscript within a column differed significantly, P>0.05: non-significant, *: P<0.05, **: P<0.01

The least-square means for sex-separated 6th-week body weights of different crosses are presented in Table 3. The body weight of males was non significantly higher in MLW2♂×FLW2♀ (1969.98 ± 17.57g) than in MLW♂×FLW2♀ (1868.49 ± 17.74g). Female 6th week body weight was significantly higher in MLW2♂×FLW2♀ (1657.78 ± 15.04g) than MLW♂×FLW2♀ (1530.37 ± 18.37g) cross. The results of the current study strongly support the findings of Kishore *et al.* (2002). They found improved weights at 6 weeks of age in crossbreds. The result is also supported by Fanatico *et al.* (2005) and Schmidt *et al*. (2006) who reported that body weight in female lines improved slower than body weight in male lines.

Table 3. Body weight of male and female chickens at 6 weeks of age (Mean ± SE)

Crosses	Male body weight (g) at 6 weeks	Female body weight (g) at 6 weeks
MLW2♂×FLW2♀	1969.98 ± 17.57	1657.78 ± 15.04[a]
MLW♂×FLW2♀	1868.49 ± 17.74	1530.37 ± 18.37[b]
p value	0.082	0.007**

SE: standard error, means with different superscripts within a column differed significantly, P>0.05: non-significant, **: P<0.01

Body weight gain

The least-square means of body weight gain of the crosses during 0−1, 1−3, 3−5 and 0−6 weeks of age are presented in Table 4. It is evident that the growth pattern at different ages followed the pattern of body weight. Body weight gain of MLW2×FLW2♀ was significantly higher than MLW×FLW2♀ from 3rd week and onwards. It shows different genetic make-up generate differences in performance, which is comparable with the findings of Yahaya *et al.* (2009), Keambou *et al*, (2010) and Adebambo *et al.* (2011). Pervin (2005) observed 693.8g body weight gains in synthetic broilers between the 3rd and 5th week which is lower than our findings (754.70 ± 8.94g). Diwyanto *et al.* (1980) and Yakubu *et al.* (2010) found a similar 0-6 weeks body weight gain to our present result while Fanatico *et al.* (2005) found no significant effect of genotype on body weight gain.

Table 4. Least square means (g) ± SE of body weight gain of 3-way crosses

Crosses	Body weight gain				ADBWG
	0-1 week	1-3 week	3-5 week	0-6 week	0-6 week
MLW2×FLW2♀	94.01 ± 1.60	432.52 ± 5.67	754.70 ± 8.94^{a}	1731.83 ± 15.61^{a}	41.21 ± 1.08^{a}
MLW×FLW2♀	90.29 ± 1.80	420.80 ± 6.40	692.7 ± 10.09^{b}	1648.25 ± 17.62^{b}	39.24 ± 1.21^{b}
p value	0.290	0.446	0.006**	0.007**	0.009**

SE: standard error, ADBWG: Average Daily Body Weight Gain, means with different superscript within a column differed significantly, P>0.05: non-significant, **: P<0.01

Hascik *et al.* (2010) found the daily body weight gain of broiler was 8.93, 30.07and 45.08 g at 0-1, 0-3, and 0-6 weeks of age, respectively. Similar daily body weight gains were observed by Onyimonyi *et al.* (2009) and Kumar *et al.* (2010) which are quite a bit higher than our findings (41.21 ± 1.08 and 39.24 ± 1.21g). While, Wang *et al.* (2007) and Iheukwumere *et al.* (2007) observed the daily body weight gain of broiler during 0-6 weeks of age varies from 28.38 to 40.50g which matches with the present findings.

Feed conversion ratio (FCR)

Feed conversion ratio of different crosses of chickens up to 6 weeks of age is presented in Table 5. It is evident that the feed conversion ratio of MLW2♂×FLW2♀ and MLW♂×FLW2♀ crossbred chickens were almost similar in most of the ages. The overall (1-6 weeks) feed conversion ratio was 1.65 and 1.63 in MLW2♂×FLW2♀ and MLW♂×FLW2♀. The FCR of different crosses can be compared well with the commercial broiler. Haque (2005) found 1.88 FCR in broiler at 5th week of age which is similar to our findings. Sarkar *et al.* (2008) found an overall FCR of 1.62 after 6 weeks of age in synthetic broilers which is similar to our results as well. Schmidt *et al.* (2006) found 1.81 FCR at the 6th week of age which is better than our result. Pervin (2005) found 1.74 FCR at 5th week of age which is slightly better than our findings. The present results also differ from the findings of Hascik *et al.* (2010) and Zavaragh *et al.* (2011). They observed the FCR of the broiler was 1.66 and 1.55±0.02 at 5 weeks of age.

Table 5. Feed conversion ratio of different crosses of chickens

Crosses	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week	1-6th Week
MLW2♂×FLW2♀	1.14	1.44	1.74	1.61	1.77	1.91	1.65
MLW♂×FLW2♀	1.21	1.38	1.6	1.49	1.88	1.89	1.63
p value	0.882	0.771	0.622	0.520	0.540	0.910	0.852

P>0.05: non-significant

Meat yield characteristics

Meat yield and their quality characteristics such as edible meat, giblet, dressed weight, and dressing percentages of crosses are shown in Table 6. The edible meat, giblet weight and dressing percentages were similar in MLW2♂×FLW2♀ and MLW♂×FLW2♀. Present result agrees with the observation of Fanatico *et al.* (2005). They found 70.30, 70.00 and 69.50 percent carcass yield in slow, medium and fast-growing genotypes of broiler at 6 weeks of age. Safalaoh (2006) found 69 ± 5.00 and 67 ± 6.51 percent dressing yield in commercial broilers at 6 weeks of age. Islam *et al.* (1993) found 67.3 and 68.9 percent dressing yield in Ross and Shaver broilers, slightly lower than our findings. Dolmany *et al.* (1991) found 63% percent dressing yield at the 6th week of age in commercial broilers (Hybro). The result also differs from Avila *et al.* (2003) who found significant differences among the broiler strains for carcass yield.

Table 6. Least square means ± SE of meat yield of different crosses of chicken

Crosses	Number of observations	Live weight (g)	Carcass weight (g)	Giblet weight (g)	Dressing meat yield (%)
MLW2♂×FLW2♀	3	1285.5 ± 45.94	873.75 ± 32.56	60.75 ± 2.41	72.66 ±0.66
MLW♂×FLW2♀	3	1247.25 ± 45.94	844.25 ± 32.56	59 ±2.41	72.35 ±0.66
p value		0.992	0.870	0.790	0.830

SE: standard error, P>0.05: non-significant

Shank color, plumage color and comb type of different genotypes of chicken

The shank color, plumage color and comb type of different genotypes of chickens are shown in Table 7. The results are comparable with Prodhan *et al.* (2013), who found 68.15% whitish and 31.85% yellowish shank color in meat-type chicken. While contradicting Ahmed *et al.* (2007) who got a 100% yellowish shank color in the synthetic broiler. The variation of shank color in different genotypes of chickens might be due to variations in genes of skin color (Smyth, 1990).

Table 7. Frequency of shank color, plumage color and comb type of different crosses

Crosses	No.	Frequency of shank color (%)			Frequency of plumage color (%)			Frequency of comb type (%)		
		Whitish	Yellowish	Blackish	White	Brown/red/ barred	Black/ barred	Single	Rose	Pea
MLW2♂×FLW2♀	184	31.6	68.4	0	100	0	0	100	0	0
MLW♂×FLW2♀	185	76.2	23.8	0	100	0	0	100	0	0

It is evident that the plumage color was 100% white in MLW2♂×FLW2♀ and MLW♂×FLW2♀. Smyth (1990) reported white color is the most dominant and is controlled by gene e^{wh}. Ahmed *et al.* (2007) found 100 percent white plumage color in synthetic broilers which is similar to our findings. The comb type in all crosses was 100% single.

Livability of different genotypes of chickens

The least-square means of the livability of different line-crossed chickens at different stages of growth is presented in Table 8. The overall livability percent up to 6 weeks of age was almost similar. Michalczuk *et al.* (2012); Haque (2005) and Pervin (2005) found 100% livability in broiler. On the other hand, Ahmed *et al.* (2007) found lower livability than our study in synthetic white broiler up to 5 weeks of age.

Table 8. Livability of different white crosses of chickens (%)

Crosses	No.	0-1 week	1-3 weeks	3-6 weeks
MLW2♂×FLW2♀	184	100±0% (184)	99.46±0.33% (183)	99.45±0.29% (182)
MLW♂×FLW2♀	185	100±0% (185)	99.46±0.33% (184)	100±0% (184)
p value		1.0	1.0	0.15

P>0.05: non-significant

Mid-parent heterosis of chicken by 3-way crosses

The mid-parent heterosis of body weight and body weight gain estimated from 3-way crossbred is presented in Table 9. It is evident that positive heterosis was observed for body weight and weight gain at most ages. Significantly (p<0.001) higher heterosis was found in MLW♂×FLW2♀ than in MLW2♂×FLW2♀ at 3 weeks of age. The best heterosis of body weight was found in MLW♂×FLW2♀ (64.25%) than in MLW2♂×FLW2♀ (59.13%) at 6 weeks of age though the difference was non-significant (p>0.05). With the advances of age, the heterosis of body weight was improved. The results are consistent with the findings by Deeb and Lamont (2002), who reported that heterosis of body weight, depends on age. The highest positive heterosis on body weight gain was found in MLW♂×FLW2♀ at most ages. During 0-6 weeks of age the best heterosis of body weight gain was found in MLW♂×FLW2♀ (68.26%) than in MLW2♂×FLW2♀ (61.11%). The results are comparable with the observation of Adebambo *et al.* (2011) and Yahaya *et al.* (2009). They found positive hybrid vigor on growth in crossbred. While, Keambou *et al.* (2010) found 80.60% improved live weight in synthetic broilers which is greater than our findings.

Table 9. Mid-parent heterosis (%) of 3-way crosses

Crosses	Heterosis of body weight (%)				Heterosis of body weight gain (%)				
	1 week	3 week	5 week	6 week	0–1 week	1–3 week	3–5 week	5-6 week	0-6 week
MLW2♂×FLW2♀	-4.8ᵇ ± 1.7	1.06ᵇ ± 1.71	37.7ᵇ ± 1.86	59.1 ± 2.2	-1.83ᵇ ± 3.16	2.93ᵇ ± 1.87	91.0 ± 3.4	256.55ᵃ ± 21.76	61.11ᵇ ± 2.35
MLW♂×FLW2♀	19.0ᵃ ± 1.9	22.66ᵃ ± 1.92	49.54ᵃ ± 2.08	64.2 ± 2.5	40.82ᵃ ± 3.57	23.87ᵃ ± 2.12	87.1 ± 3.9	155.47ᵇ ± 24.62	68.26ᵃ ± 2.66
p value	<0.001***	<0.001***	<0.001***	0.662	<0.001***	<0.001***	0.710	0.006**	0.043*

Means with different superscript within a column differed significantly, P>0.05: non-significant, *: P<0.05, **: P<0.01, ***: P<0.001

Conclusion

The current study was designed to know the advancements made in the performance and characteristics of two crossbred chickens after six generations of selection for meat production. Based on the outcome achieved it is evident that the performance of MLW2♂×FLW2♀ crossbred is comparatively better. Farmer-level study and few more generations of selection are recommended to ensure the fixation of genes.

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References

Adebambo, A.O.I., Ikeobi, C.O.N., Ozoje M.O., Oduguwa O.O., Adebambo O.A. 2011. Combining abilities of growth traits among pure and crossbred meat type chickens. *Archivos de Zootecnia,* 60 (232): 953-963. https://doi.org/10.4321/S0004-05922011000400012

Adebambo, O.A. 2011. Combining abilities among the breeds of chicken for feed efficiency variation: a preliminary assessment for chicken improvement in Nigeria. *Tropical Animal Health and production,* 43 (8): 1465-1466. https://doi.org/10.1007/s11250-011-9844-y

Adeleke, M.A., Peters, S.O., Ozoje, M.O., Ikeobi, C.O., Bamgbose, A.M., Adebambo, O.A. 2011. Growth performance of Nigerian local chickens in crosses involving an exotic broiler breeder. *Tropical Animal Health and Production,* 43(3): 643-650. https://doi.org/10.1007/s11250-010-9747-3

Adeyemo, G.O., Olohgobo, A.D., Adebiyi, O.A. 2010. The effects of graded levels of dietary methionine on the haematology and serum bio-chemistry of broilers. *International Journal of Poultry Science,* 9 (2)**:** 158-161. https://doi.org/10.3923/ijps.2010.158.161

Ahmed, S.T., Ali, M.A., Howlider, M.A.R. 2007. Effects of crossbreeding on performance to reduce market age of different genetic groups of chicken. *The Bangladesh Veterinarian,* 24: 34-38.

Avila, V.S. de., Pens, Jr. A.M., Rosa, P.S., Brum, P.A.R. de., Guidoni, A.L., Ledur, M.C. 2003. Influence of feeding time on sexual maturity and carcass composition in female broiler breeders. *Revista Brasileira de Ciência Avícola,* online version ISSN 1806-9061. https://doi.org/10.1590/S1516-635X2003000300006

Azharul, I. M., Ranvig, H., Howlider, M. A. R. 2005. Comparison of growth rate and meat yield characteristics of cockerels between Fayoumi and Sonali under village conditions in Bangladesh. *Livestock Research for Rural Development*, *17*(2), 77-82. http://lrrd.cipav.org.co/lrrd17/2/azha17021.htm

Barua, A., Howlider, M.A.R., Yashimura, Y. 1998. Indigenous naked neck fowl of Bangladesh. *World’s Poultry Science Journal,* 54: 279-286. https://doi.org/10.1079/WPS19980019

Bekele, F., Adnoy, T., Gjoen, H.M., Kathle, J. 2010. Production performance of dual purpose crosses of two indigenous with two exotic chicken breeds in sub-tropical environment. *International Journal of Poultry Science,* 9 (7): 702-710. https://doi.org/10.3923/ijps.2010.702.710

Da Silva, C.A., Rankin, M. 2014. Contract farming for inclusive market access. Food and Agriculture Organization of the United Nations, Rome, Italy, ISBN: ISBN 9789251080610, 227. https://www.cabdirect.org/cabdirect/abstract/20143323379

Deeb, N., Lamont, S. J. 2002. Genetic architecture of growth and body composition in unique chicken populations. *The Journal of heredity*, *93*(2), 107–118. https://doi.org/10.1093/jhered/93.2.107

Diwyanto, K., Sabarani, M., Sitorus, P. 1980. Performance of six strains of broilers. Bulletin Lembaga Penelitian Peternakan (Indonesia), 25: 9-17. https://agris.fao.org/agris-search/search.do?recordID=XB8101284

Dolmany, T., Gippert, T., Gati, L. 1991. Comparision of Hybro and Tetra broiler end products, ratio of slaughtering yield and valuable body parts. *Allattenyesztes es Takarmanyozas (Hungary),* ISSN : 0230-1814, 40 (2)**:** 173-178. https://agris.fao.org/agris-search/search.do?recordID=HU9300184

Fanatico, A.C., Pillai, P.B., Cavitt, L.C., Owens, C.M., Emmert, L.L. 2005. Evaluation of slower-growing broiler genotypes grown with and without outdoor access: Growth performance and carcass yield. *Poultry Science,* 84: 1321-1327. https://doi.org/10.1093/ps/84.8.1321

Haque, M.F. 2005. Hatchability and growth performance of synthetic population as obtained from synthetic broilers. MS Thesis, Department of Poultry Science, Bangladesh Agricultural University, Mymensingh.

Hascik, P., Kacaniova, M., Mihok, M., Pochop, J., Benczova, E. 2010. Performance of various chicken hybrids fed synthetically produced feed mixtures. *International Journal of Poultry Science,* 9(11): 1076-1082. https://doi.org/10.3923/ijps.2010.1076.1082

Iheukwumere, F.C., Ndubuisi, E.C., Mazi, E.A., Onyekwere, M.U. 2007. Growth, blood chemistry and carcass yield of broilers fed cassava leaf meal (*Manihot esculenta Crantz*). *International Journal of Poultry Science,* 6(8): 555-559. https://doi.org/10.3923/ijps.2007.555.559

Iraqi, M.M., Afifi, E.A., Abdel-Ghany, A.M., Afram, M. 2005. Diallel crossing analysis for livability data involving two standard and two native Egyptian chicken breeds. *Livestock Research for Rural Development,* 17(7). http://www.lrrd.org/lrrd17/7/iraq17075.htm

Islam, M.Z., Islam, M.A., Ahmed, S.U. 1993. A comparative study on the performance of Ross-1 and Shaver Tropicbro broilers in humid tropics. *Poultry Adviser*, *26*, 57-57.

Kato, R., Hyuha, T., & Mugisha, J. 2008. Competitiveness of crossbred chicken and its implications for poverty reduction in Eastern Uganda. International Journal of Emerging Markets, 3, 302-310. https://doi.org/10.1108/17468800810883701.

Keambou, T.C., Manjeili, Y., Boukila, B., Mboumba, S., Mezui, T., Hako, B.A. 2010. Heterosis and reciprocal effects of growth performances in F1 crosses generations of Local x Hubbard chicken in the western highlands of Cameroon. *Livestock Research for Rural Development,* 22(1). https://www.researchgate.net/deref/http%3A%2F%2Fwww.lrrd.org%2Flrrd22%2F1%2Fkeam22011.htm

Khawaja, T., Khan, S.H., Mukhtar, N., Parveen, A. 2012. Comparative study of growth performance, meat quality and haematological parameters of Fayoumi, Rhode Island Red and their reciprocal crossbred chickens. *Italian Journal of Animal Science,* 11: 211-216. https://doi.org/10.4081/ijas.2012.e39

Kishore, P.V.L., Narasimna, R.G., Sharma, R.P., Praharaj, N.K., Ramesh, G.B., satyanarayana, A. 2002. Inheritance of body weight in synthetic broiler chickens. *Indian Journal of Poultry Science,* 37(2): 175-178. https://www.indianjournals.com/ijor.aspx?target=ijor:ijps&volume=37&issue=2&article=014

Kumar, S., Sharadamma, K.C., Radhakrishna, P.M. 2010. Effects of garlic active based growth promoter on growth performance and specific pathogenic intestinal microbial counts of broiler chicks. *International Journal of Poultry Science,* 9(3): 244-246. https://doi.org/10.3923/ijps.2010.244.246

Mekki, D.M., Yousif, I.A., Abdel, R.M.K., Wang, J.Y., Musa, H.H. 2005. Growth performance of indigenous x exotic crosses of chicken and evaluation of general and specific combining ability under Sudan condition. *International Journal of Poultry Science,* 4: 468-471. https://doi.org/10.3923/ijps.2005.468.471

Michalczuk, M., Lukasiewicz, M., Niemiec, J., Pietrzak, D., Walas, E. 2012. Effects of genetic stock on production results and growth rate of chickens. *Annals of Warsaw University of Life Science- SGGW, Animal Science,* 51: 81-88. http://annals-wuls.sggw.pl/files/files/animal/asc2012no51full.pdf#page=81

Neumann, C., Harris, D.M., Rogers, L.M. 2002. Contribution of animal source foods in improving diet quality and function in children in the developing world. *Nutrition Research,* 22: 193-220. https://doi.org/10.1016/S0271-5317(01)00374-8

Onyimonyi, A.E., Oabode, A., Okeke, G.C. 2009. Performance and economic characteristics of broilers fed varying dietary levels of neem leaf meal (*Azadirachta indica*). *International Journal of Poultry Science,* 8(3): 256-259. https://doi.org/10.3923/ijps.2009.256.259

Pervin, S. 2005. Comparative performance of synthetic broiler and commercial broiler, MS Thesis, Department of Poultry Science. Bangladesh Agricultural University, Mymensingh.

Prabakaran, R. 2003. Good practices in planning and management of integrated commercial poultry production in South Asia. FAO Animal Production and Health paper, 159, FAO, Rome, Italy.

Prodhan, M.M.R., Ali, M.A., Akter, M., Asaduzzaman, M., Kanak, M.A.R. 2013. Selection response on productive performance of meat type sire and dam lines of chicken. *Bangladesh Journal of Progressive Science and Technology,* 11: 161-166.

PSSB. 2020. Poultry sector study Bangladesh. Embassy of the Kingdom of the Netherlands in Bangladesh. https://www.rvo.nl/sites/default/files/2020/12/Poultry%20sector%20study%20Bangladesh.pdf

Raihan, S., Mahmud, N. 2008. Trade and poverty linkages: A case study of the poultry industry in Bangladesh. Cuts Citee Working Paper No. 6. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.549.3022&rep=rep1&type=pdf

Safalaoh, A.C.L. 2006. Body weight gain, dressing percentage, abdominal fat and serum cholesterol of broilers supplemented with a microbial preparation. *African Journal of Food, Agriculture, Nutrition and Development,* 6(1): 1-10. https://doi.org/10.4314/ajfand.v6i1.19170

Sarkar, P.K., Chowdhury, S.D., Kabir, M.H., Sarker, P.K. 2008. Comparative study on the productivity and profitability of commercial broiler cockerel of a layer strain and cross-bred (RIR ♂ × Fayoumi♀) chicks. *Bangladesh Journal of Animal Science,* 37(2): 89–98. https://doi.org/10.3329/bjas.v37i2.9886

Schmidt, G.S., Figueiredo, E.A.P., Ledur, M.C. 2006, Genetic gain for body weight, feed conversion and carcass traits in selected broiler strains. *Brazilian Journal of Poultry Science,* 8(1): 29-32. https://doi.org/10.1590/S1516-635X2006000100004

Sharma, D.P., Acharya, R.M., Jitendra, K. 1971. Collection and evaluation of native fowl. IV. Comparative studies on body weights and carcass yields of Rhode Island Red, indigenous (desi) and their reciprocal crosses. *Indian Journal of Animal Sciences,* 41(3): 185-191.

Singh, D.P. 2005. Indigenous germplasm: Role in improving poultry production. Indian Poultry Science Association Conference and National Symposium. http://www. poulvet. com/poultry/article/family_farming/index. php

Siwendu, N.A., Norris, D., Ngambi, J.W., Shimelis, H.A., Benvi, K. 2013. Heterosis and combining ability for body weight in diallel cross of three chicken genotypes. *Tropical Animal Health Production,* 45(4): 965–970. https://doi.org/10.1007/s11250-012-0317-8

Smyth, J.R. 1990. Genetics of plumage, skin, and eye pigmentation in chickens. In: Crawford RD (Ed.), Poultry Breeding and Genetics. Elsevier Science Publishers, Amsterdam, The Netherlands. pp. 109-167.

Thieme, O., Sonaiya, E. B., Rota, A., Alders, R. G., Saleque, M. A., De'Besi, G. 2014. Family poultry development− Issues, opportunities and constraints. *FAO Animal Production and Health Working Paper*, *12*.

Wang, J., Li, S., Wang, Q., Xin, B., Wang, H. 2007. Tropic effect of bee pollen on small intestine in broiler chickens. *Journal of Medical Food,* 10(2): 276-280. https://doi.org/10.1089/jmf.2006.215

Yahaya, H.K., Oni, O.O., Akpa, G.N., Adeyinka, I.A. 2009. Evaluation of layer type chicken under reciprocal recurrent selection. *Bayero Journal of Pure and Applied Sciences,* 2: 177-182. https://doi.org/10.4314/bajopas.v2i1.58539

Yakubu, A., Ayoade, J.A., Dahiru, Y.M. 2010. Effects of genotype and population density on growth performance, carcass characteristics, and cost-benefits of broiler chickens in north central Nigeria. *Tropical Animal Health and Production,* 42(4): 719-727. https://doi.org/10.1007/s11250-009-9479-4

Zavaragh, F.M., Turkoglu, M., Elibol, O., Yeter, B. 2011. Comparison of hatching and broiler performance between a synthetic broiler parent stocks and its original parent stocks. *Annals of Biological Research,* 2(6): 300-305. https://www.cabdirect.org/cabdirect/abstract/20123056938.