ISSN 1682-8356
ansinet.org/ijps

INTERNATIONAL JOURNAL OF POULTRY SCIENCE

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International Journal of Poultry Science 8 (3): 299-306, 2009
ISSN 1682-8356

A Model for the Genetic Employment of Chickens Local to Warm Climate 1. Crossing with a Fast Growing Strain and Growth Patterns of the Crossbreds

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Abstract: A breeding program aims to develop a chicken population inherent for heat tolerance and fast growth was started using a naked-neck local breed in Egypt that performs heat tolerance. The local breed was crossed with the sire line of a normally feathered commercial broiler strain. The crossbreds were raised in a heating treatment (35°C from hatch to 6 weeks, then reduced to 24°C) or a non-heating treatment (35°C from hatch to 3 days, and reduced gradually to reach 24°C). Body weights of the crossbreds, across ages, were significantly around twofold heavier than those of the locals. The crossbreds weighed 641.8 g at 6 weeks of age versus 303.0 g for the locals. The 2-4 week growth rate was 73.7% for the crossbreds versus 60.2% for the locals. The Na/na crossbreds were significantly heavier than na/na crossbreds when heated, and the differences were not significant when non-heated. The spread of 6-week body weights of the crossbreds was remarkably different from that of the locals and the difference was mainly attributed to the variation brought in through the flow of genes. The heterotic effects on body weights were significant in both heated and non-heated crossbreds and expressed a large source of non-additive genetic variation. Heterosis estimates in body weights and growth rates were age and environment specific, and were significantly higher for the heated than for non-heated crossbreds, indicating the flow of genes influence growth and heat tolerance. The results demonstrate remarkable changes in the frequencies of non-allelic genes that influence growth and propose the genetic selection for increased 6-week body weight in the naked-neck and normally feathered crossbreds.

Key words: Gene flow, growth performance, heterosis, local breeds, warm climate

INTRODUCTION

A variety of several views recently appears and indicates that the genetic employment of local breeds is anticipated to be a new course in poultry breeding. The increased demands on poultry products during the last 3 decades, the trade volume of poultry meat increased even faster than production (Windhorst, 2006). Many countries in several regions of the world stepped further into considerable economical development and this was followed by the shift of people's food consumption into different nutritional habits. The impacts on production and consumption due to the outbreaks of Avian Influenza would probably include serious functioning problems of major producers and new spatial patterns of production and trade flow. The continental transportation encounters difficulties related to several hygienic considerations. On the other hand, local breeds show much genetic variation unexploited yet (El-Gendy *et al.*, 2007) and the massive information generated by genome scanning and collaborated with the phenotypic information has brought the local breeds into valuable research. Local breeds adapt the environments in which they have been developed (Horst, 1989) and there are ample evidences that the environment is a limiting factor for the performance of commercial strains (Washburn, 1985; Washburn *et al.*, 1992) and the bird performance is reduced when environmentally stressed (El-Gendy *et al.*, 1995; Gous, 2007). Therefore in any scenario for the employment of local breeds, the genotype-environment concord should be ultimately implicated (El-Gendy *et al.*, 2007). The response of grown birds to heat waves is based on their genetic backgrounds (Washburn, 1985; Cahaner and Leenstra, 1992; El-Gendy and Washburn, 1995; Yalcin *et al.*, 1997; El-Gendy *et al.*, 2007). The naked-neck broiler chicks grew faster under heating conditions than the normally feathered correspondents because they were capable to dissipate heat and, in turn, lower body temperature (Eberhart and Washburn, 1993; Beaumont *et al.*, 1998; Yunis and Cahaner, 1999; Mazzi *et al.*, 2002; Patra *et al.*, 2002, 2005). The results denoted to the possible breeding for fast growth in heat tolerant strains. The inter-mating of different parental populations possessing fast growth and the adaptation to heat could be a suitable approach, where the obtained hybrids are often at species borders and probably undergo rapid genetic change (Hedrick, 2000). In this study, a breeding program has started on a naked-neck Egyptian local breed, named Baladi, tolerant to the heating waves pertaining the subtropical climate and is randomly bred in small closed flocks at the rural households. It has been crossed with an exotic fast growing normally feathered strain. The research reported herein aimed to evaluate the growth performance of the crossbreds when heated versus when non-heated.

MATERIALS AND METHODS

Breeding program: A breeding program aims to develop a local experimental population inherent for heat tolerance and fast growth has started using Baladi breed, a naked-neck heat tolerant Egyptian breed. The local breed was crossed with the sire line of a commercial broiler strain as an exotic normally feathered fast growing strain. Eight males of the commercial broiler sire line artificially inseminated thirty-two female Baladi chickens, genotyping for Na/Na or Na/na and pedigreed eggs were collected. Since the breeding program aims to develop a local population inherent for heat tolerance and fast growth, so the local breed (Baladi) has also served as the genetic control population. Therefore, random natural mating was allowed in Baladi chickens genotyping for Na/Na and Na/na and eggs were mass collected. The collected eggs of the cross and control populations were simultaneously incubated and the hatched chicks were pedigreed by wing banding. The following diagram outlines for the breeding program.

♂♂Comm. broiler sire line (na/na)X♀♀baladi (Na/–)	♂♂Baladi (Na/–) X♀♀baladi (Na/–)
⇩	⇩
Na/na and na/na (A crossbred population)	**Na/na, Na/na and na/na (A genetic control population)**

Management: The newly hatched chicks within population and neck feathering were split into two groups. A group was raised in a heating treatment, in which the ambient temperature was 35°C from hatch to 6 weeks, then reduced to 24°C for the rest of experiment, and humidity was at 45-55% RH. The other group was raised in a non-heating treatment, in which the ambient temperature was 35°C from hatch to 3 days and reduced by 2-3°C a week until it reached 24°C at 4-5 weeks of age and held and humidity was at 45-55% RH. The group chicks of the same thermal treatment were intermingled together and floor-housed in chambers (3*3*2.5 m/each, 10 birds/1 m^2), in a conventional brooding house. The ambient temperatures were provided to chicks according to their thermal treatment and efforts were practiced to keep deviation from targeted temperature minimal. The chicks were fed *ad libiium* a broiler starter ration (22-23% CP and 2800 Kcal ME/ kg.) during 0-4 weeks of age, then a broiler finisher ration (19-20% CP and 3100 Kcal ME/ kg.) during 4-8 weeks. Birds received a growing ration (15% CP and 2700 Kcal ME/kg., 120 g/bird/d) during 8-16 weeks, then a pre-laying ration (17% CP and 2800-2850 Kcal ME/ kg., 140 g/bird/d) until 20 weeks. By 20 weeks of age, birds received a laying ration (16% CP and 2800-2850 Kcal ME/kg., 150 g/bird/d). Water was provided *ad libiium*. Birds were subjected to continuous illumination from hatch to 8 weeks of age, followed by the diurnal natural light from 8-16 weeks and to 16 h light thereafter. Birds received routine medical treatments and immunization against the common diseases.

Measurements: Individual day-old and 2-week interval body weights until 22 weeks of age were obtained, to the nearest gram, for all chicks. Biweekly growth rates were then derived.

Statistical analysis: The data set were statistically analyzed using SAS computer package program (SAS, 1999), for the effects of genetic group (crossbreds vs. local Baladi chickens), neck feathering, sex and thermal treatment and their two-way interactions. The general linear model analysis for Least Squares Means (LSM) was applied and mean comparison were assessed by Duncan (1955). The significance of heterotic effect was determined by the contrast of the crossbreds versus the local Baladi chickens. Heterosis was estimated, overall, as the percentage difference between the crossbreds and the local Baladi chickens and *t* test was used to examine the effect of thermal environment on heterosis estimates.

RESULTS

Growth performance: Body weights of the crossbred chicks, by age, were around twofold significantly heavier than those of the local breed (Table 1). The crossbreds weighed 33.6, 641.8 and 2755.2 g at day old and at 6 and 22 weeks of age versus 32.7, 303.0 and 1471.9 g for the local breed. The statistical model was highly significant for all body weight measurements, but day old. The coefficients of determination (R^2) estimated for the variation in body weights steadily increased over age and reached to 0.6089 at 22 weeks of age. The marginal contributions of these effects, estimated by the coefficients of partial determination, varied in their magnitudes over age. The effects of genetic group and sex tended to increase. However, the effects of neck feathering and thermal environment tended to decrease. No significant contribution was observed for any of the 2-way interactions on body weights, except the interaction between thermal environment and neck feathering at particular ages. The Coefficients of Variation (CV) tended to fluctuate over age.

The biweekly growth rates are presented in Table 1. The crossbreds significantly grew faster than the local Baladi chicks until 4 weeks of age, then the differences were insignificant. The growth rate at 2-4 weeks was 73.7% for the crossbreds versus 60.2% for the local Baladi, however at 20-22 weeks was 0.6% for the crossbreds compared to 7.8% for the local Baladi. The CV in growth rates consistently increased with age.

No significant differences were found in body weights, at all ages, between non-heated crossbreds of Na/na and na/na (Table 2). Whereas, heated crossbreds of Na/na

Table 1: Growth patterns (LSM ± SE) of the crossbreds and local Baladi and summary of the model statistical analysis

	Growth Pattern		Model Statistical Analysis		
Age	Crossbreds (314)[1]	Local Baladi (93)	P≤F	R^2	cv
Body Weight (g)					
1-day	33.6 ± 0.6[a]	32.7 ± 0.8[a]	0.0768	0.0323	14.39
2 wks	159.2 ± 4.3[a]	88.9 ± 6.8[b]	< 0.0001	0.3399	21.07
4 wks	359.0 ± 11.1[a]	162.8 ± 7.6[b]	< 0.0001	0.3953	24.16
6 wks	641.8 ± 16.6[a]	303.0 ± 26.4[b]	< 0.0001	0.4698	20.32
8 wk	964.7 ± 25.7[a]	493.3 ± 40.6[b]	< 0.0001	0.4714	20.70
10 wk	1275.1 ± 36.3[a]	638.1 ± 57.4[b]	< 0.0001	0.4820	22.30
12 wk	1589.7 ± 49.1[a]	796.2 ± 81.4[b]	< 0.0001	0.5564	20.46
14 wk	1874.9 ± 79.5[a]	943.1 ±127.0[b]	< 0.0001	0.3908	22.28
16 wk	2196.1 ± 31.9[a]	1145.7 ± 64.4[b]	< 0.0001	0.4813	20.85
18 wk	2295.3 ± 35.8[a]	1262.4 ± 58.8[b]	< 0.0001	0.4988	21.64
20 wk	2520.6 ± 37.1[a]	1354.6 ± 62.1[b]	< 0.0001	0.5358	20.14
22 wk	2755.2 ± 47.8[a]	1471.9 ± 63.9[b]	< 0.0001	0.6080	18.84
Growth Rate (%)					
0-2 wks	127.4 ± 1.9[a]	92.5 ± 3.0[b]	< 0.0001	0.4002	11.37
2-4 wks	73.7 ± 2.2[a]	60.2 ± 3.6[b]	< 0.0001	0.1390	19.35
4-6 wks	57.3 ± 1.7[a]	58.8 ± 2.6[a]	0.0156	0.0454	21.89
6-8 wks	---	---	---	---	---
8-10 wks	25.6 ± 1.6[a]	26.7 ± 2.5[a]	0.0497	0.0416	43.99
10-12 wks	21.1 ± 1.9[a]	21.5 ± 3.1[a]	0.2297	0.0386	60.38
12-14 wks	14.7 ± 2.7[a]	25.6 ± 4.2[a]	0.2077	0.0561	71.76
14-16 wks	12.4 ± 0.8	---	---	---	---
16-18 wks	5.3 ± 0.4[a]	6.0 ± 3.0[a]	0.4084	0.0323	145.34
18-20 wks	7.3 ± 0.5[a]	7.7 ± 1.0[a]	0.1654	0.0502	108.70
20-22 wks	0.6 ± 0.6[b]	7.8 ± 1.2[a]	0.0004	0.1552	461.62

[1] : number of chicks is between parentheses. [a,b], significant differences between crossbreds and local Baladi (p<0.05).
--- : the parameter was not obtained.

were significantly heavier than na/na at 6, 8 and 10 weeks of age. Body weights, by age, of the non-heated local birds genotyping for Na/na or Na/Na were mostly significantly heavier than those of the non-heated local birds genotyping for na/na, whereas the differences were insignificant when birds heated. The differences in all biweekly growth rates of heated and non-heated birds were insignificant, regardless the genetic group.

Gene flow: The distribution pattern of 6-week body weights, as an economical criterion for meat deposit, was graphed for the crossbreds and local chicks (Fig. 1). The extent of spread of hybrids was remarkably different from that of local chicks, having more individuals heavier in 6-week body weight. The flows of Na and na alleles from parental populations into the crossbreds were estimated (Table 3). The flow of Na allele from the dam parental local breed was at rate of 1.0767, whereas the flow of na allele from the sire and dam parental populations was at rates of 0.7958 and 0.1588, respectively. Accordingly, the frequency of Na allele in the crossbreds has changed, compared to the frequency in mid-parents, by +0.0285, versus a reduction in the frequency of na allele by -0.0285.

Heterotic effect: The heterotic effects on body weights were significant in both heated and non-heated crossbreds, except at day old (Table 4). The heterosis gained in non-heated crossbreds was 1.5% at day old and gradually increased to 132.5% at 14 weeks and then declined to 88.5% at 22 weeks of age. In comparison, the heated crossbreds gained heterosis of 5% at day old and increased to 142.1% at 4 weeks of age and then declined to 79.9% at 14 weeks of age. Heterosis estimates of the heated crossbreds were consistently and significantly (p<0.0062) higher during the heat exposure period, 0-6 weeks, and were significantly (p<0.0330) lower during the heat termination, 6-14 weeks, than those of the non-heated crossbreds. The heterotic effect on growth rate measurements was significant until 4 weeks, regardless the thermal treatment. The heterosis gained in 2-4 week growth rate was 18.9 and 26.7% for the non-heated and heated crossbreds, respectively.

DISCUSSION

The results reveal that variation in body weight by age was significant and accounted for the effects of crossing, sex and thermal treatment. The effect of neck feathering was age and thermal treatment specific. The effects of crossing and sex on body weights, over age, were in upward trends, whereas the effect of thermal treatment was in a downward trend. Segura *et al.* (2004) reported a significant improvement in meat production of native

Table 2: Growth patterns (LSM) of different genotypes within genetic group and thermal treatment

	Crossbreds				Local Baladi					
	Non-heated		Heated		Non-heated			Heated		
Age	Na/na	na/na	Na/na	na/na	Na/Na	Na/na	na/na	Na/Na	Na/na	na/na
Body Weight (g)										
1 day	33.6^{a}	32.7^{a}	34.3^{a}	33.9^{a}	33.3^{a}	33.1^{a}	31.0^{a}	31.2^{a}	33.2^{a}	31.1^{a}
2 wks	166.5^{a}	162.1^{a}	156.4^{a}	153.2^{a}	91.4^{ab}	96.9^{a}	76.0^{b}	85.1^{a}	87.0^{a}	87.0^{a}
4 wks	395.0^{a}	381.2^{a}	333.6^{a}	329.4^{a}	168.4^{ab}	200.9^{a}	129.3^{b}	154.5^{a}	129.5^{a}	141.0^{a}
6 wks	704.8^{a}	676.4^{a}	590.0^{a}	566.8^{b}	342.3^{a}	356.4^{a}	250.7^{b}	293.1^{a}	246.5^{a}	255.0^{a}
8 wks	1067.0^{a}	1024.6^{a}	880.2^{a}	821.4^{b}	522.3^{a}	531.7^{a}	352.3^{b}	495.5^{a}	453.5^{a}	464.0^{a}
10 wks	1417.6^{a}	1371.9^{a}	1177.7^{a}	1095.9^{b}	621.3^{ab}	693.2^{a}	494.7^{b}	637.7^{a}	598.5^{a}	598.0^{a}
12 wks	1727.5^{a}	1694.0^{a}	1489.8^{a}	1494.8^{a}	765.1^{ab}	842.6^{a}	631.3^{b}	769.2^{a}	734.0^{a}	---
14 wks	1991.9^{a}	1952.7^{a}	1741.8^{a}	1736.9^{a}	1146.3^{a}	839.0^{a}	754.0^{a}	924.8^{a}	1050.0^{a}	---
16 wks	2473.1^{a}	2377.3^{a}	2032.3^{a}	1992.8^{a}	983.3^{a}	1183.9^{a}	---	---	---	---
18 wks	2582.0^{a}	2455.8^{a}	2150.0^{a}	2134.9^{a}	1204.6^{a}	1272.7^{a}	---	---	---	---
20 wks	2814.5^{a}	2687.5^{a}	2304.1^{a}	2401.4^{a}	1318.4^{a}	1361.5^{a}	---	---	---	---
22 wks	2924.2^{a}	2953.7^{a}	2557.8^{a}	2555.4^{a}	1570.0^{a}	1542.3^{a}	---	---	---	---
Growth Rate (%)										
0-2 wks	130.8^{a}	130.4^{a}	126.5^{a}	123.6^{a}	91.8^{a}	96.4^{a}	83.8^{a}	92.1^{a}	90.8^{a}	94.7^{a}
2-4 wks	79.4^{a}	78.0^{a}	72.4^{a}	70.8^{a}	85.7^{a}	68.1^{a}	51.0^{a}	56.3^{a}	64.3^{a}	47.4^{a}
4-6 wks	56.6^{a}	56.9^{a}	53.9^{a}	52.4^{a}	65.1^{a}	54.0^{a}	62.9^{a}	61.9^{a}	57.4^{a}	57.6^{a}
6-8 wks	---	---	---	---	---	---	---	---	---	---
8-10 wks	26.0^{a}	27.2^{a}	27.3^{a}	28.5^{a}	21.0^{b}	26.3^{ab}	33.6^{a}	25.7^{a}	29.0^{a}	25.2^{a}
10-12 wks	19.6^{a}	19.3^{a}	19.5^{a}	21.8^{a}	27.6^{a}	19.0^{a}	24.2^{a}	18.7^{a}	20.4^{a}	---
12-14 wks	14.6^{a}	17.9^{a}	19.1^{a}	20.5^{a}	19.1^{a}	21.5^{a}	15.2^{b}	18.4^{a}	37.9^{a}	---
14-16 wks	14.2^{a}	12.1^{a}	13.3^{a}	9.8^{a}	---	---	---	---	---	---
16-18 wks	4.9^{a}	6.4^{a}	5.3^{a}	5.4^{a}	6.3^{a}	6.8^{a}	---	---	---	---
18-20 wks	7.1^{a}	6.9^{a}	6.5^{b}	11.6^{a}	8.6^{a}	7.5^{a}	---	---	---	---
20-22 wks	1.0^{a}	2.9^{a}	-1.1^{a}	-4.7^{a}	8.6^{a}	7.7^{a}	---	---	---	---

^{a,b} : least square means of different genotypes within genetic group and thermal environment differ significantly ($p<0.05$).

--- : the parameter was not obtained.

Table 3: The flow of Na and na alleles from the parents to crossbreds and their frequencies in the parents and crossbreds

	Gene Flow[1]		Gene Frequency			
Allele	Sires	Dams	Sires	Dams	Crossbreds	Δ[2]
Na	0.0000	1.0767	0.0000	0.8004	0.3717	-0.0285
na	0.7958	0.1588	1.0000	0.1996	0.6283	+0.0285

[1]: gene flow was estimated according to the basis given by Hedrick (2000).

[2]Δ: indicates the rate of change in gene frequency after one generation.

Mexican breeds when crossed with commercial strains. The increase in R^2 over age indicates that the effects of crossing, sex, neck feathering and thermal treatment on body weights were in linear pattern (Ott, 1984; Neter *et al*., 1990). The fluctuation of CV in body weights over age reflects an asymmetrical pattern in the variation. This is expected since different body weights, by age, concern different genes (Falconer and Mackay, 1997), resulting in different magnitudes for the effects of crossing. In addition, the effects of neck feathering, sex and thermal treatment on each of the body weight measurements were in different extents, too.

Biweekly growth rates were in different trends. The differences among grown chicks up to 4 weeks were significant and due to the effects of sex and thermal treatment, then the differences were mainly due to the effect of sex. The consistent increases in CV in growth rates over age reveal that the effect of sex on growth rates was increased with age. Therefore, the differences in growth rate measurements were mainly attributed to normal sex variation. Growth rate is consequently inappropriate variable that could be relied on for the growth improvement of the crossbred chicks under the warm climate.

Heated birds always practice a compensatory growth pattern, once heat is terminated (El-Gendy *et al*., 1995, 2007). In this experiment, body weight at 6 weeks of age for the heated crossbreds reflected the weight gained during the period of heat exposure, however body weights at 8 and 10 weeks of age reflected the compensatory growth following heat termination. Therefore, the naked neck crossbreds grew faster than normally feathered birds when heated. The naked-neck gene (Na) is responsible for general reduction of feathers over the body surface and total loss of feathers in the neck region (Mathur, 2003) and it has shown to be

Table 4: Contrast analysis for the crossbreds versus local Baladi chickens within thermal treatment and the heterosis percentage (H) estimates

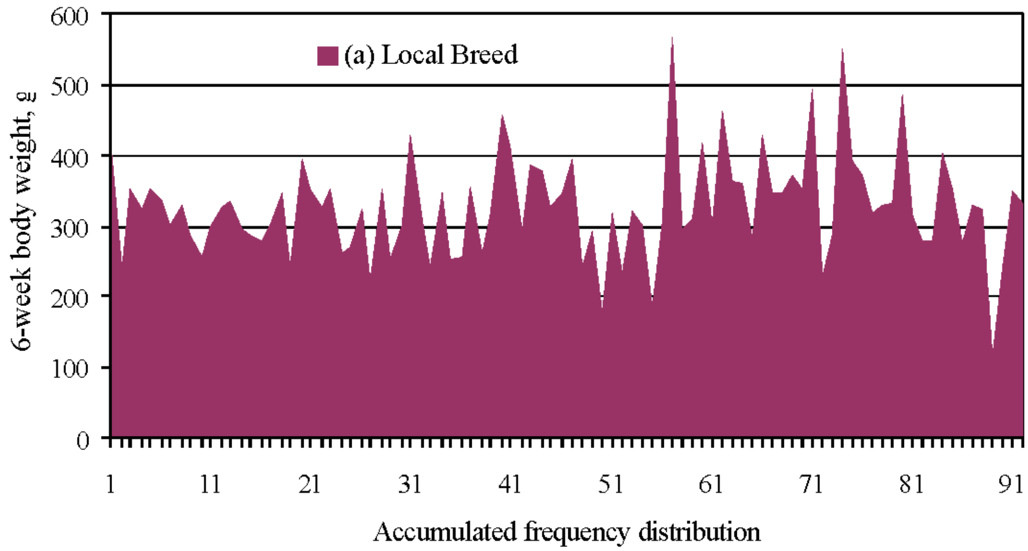
	Non-Heated Birds				Heated Birds			
Age	Crossbreds	Locals	H	P <	Crossbreds	Locals	H	P <
Body Weight (LSM, g)								
1 day	33.9	33.4	1.5	NS	33.7	32.1	5.0	NS
2 wks	163.9	93.3	75.7	**	155.5	82.7	88.0	**
4 wks	381.2	184.5	106.6	**	337.5	139.4	142.1	**
6 wks	693.0	341.3	103.0	**	590.5	261.4	125.9	**
8 wks	1054.7	515.2	104.7	**	883.8	451.5	95.7	**
10 wks	1386.9	660.9	109.9	**	1171.5	597.8	96.0	**
12 wks	1688.2	798.5	111.4	**	1455.5	763.8	90.6	*
14 wks	2048.1	881.0	132.5	**	1720.4	956.1	79.9	*
16 wks	2366.1	1145.7	106.5	**	2012.6	---	---	---
18 wks	2515.8	1274.3	97.4	**	2142.5	---	---	---
20 wks	2766.6	1381.2	100.3	**	2386.5	---	---	---
22 wks	2943.3	1561.4	88.5	**	2556.6	---	---	---
Growth Rate (LSM, %)								
0-2 wks	128.8	93.7	37.5	**	125.8	90.4	39.2	**
2-4 wks	76.1	64.0	18.9	**	71.2	56.2	26.7	*
4-6 wks	60.0	58.4	2.7	NS	54.5	58.7	-7.2	NS
6-8 wks	---	---	---		---	---	---	---
8-10 wks	24.5	25.7	- 4.7	NS	27.5	27.3	0.7	NS
10-12 wks	23.5	23.5	0.0	NS	19.7	19.0	3.7	NS
12-14 wks	16.2	19.2	-15.6	NS	18.9	22.8	-17.1	NS
14-16 wks	13.3	---	---		11.6	---	---	---
16-18 wks	5.4	6.0	- 10.0	NS	5.4	---	---	---
18-20 wks	8.5	8.2	3.7	NS	9.1	---	---	---
20-22 wks	2.6	9.2	- 71.7	**	---	---	---	---

*, significant differences between crossbreds and local breed (p<0.05).
**, significant differences between crossbreds and local breed (p<0.0001).
---, the parameter was not obtained.

favorable in the subtropics and tropics. The necked neck birds are therefore capable to dissipate heat and thus alleviate the negative impact of heating conditions on growth. Naked-neck chicks also performed heavier body weights and weight gains compared to the normally feathered chicks when raised at 26-36°C and performed less body weights and weight gains when raised at 20°C or below (Mérat, 1990; Varoli *et al*., 2000; Deeb and Chahaner, 2001; Patra *et al*., 2002, 2005; Mbaga *et al*., 2003). Hence, Na gene increases the heat tolerance of birds when heated and in turn birds grow faster than those normally feathered if having the genes of fast growth. The results reveal that breeding for fast growth in the naked neck birds undergoing heat waves could be successfully implemented. Body weight measurements of the non-heated local chicks genotyping for Na/Na and Na/na were significantly heavier than those genotyping for na/na, denoting to a pleiotropic action of Na gene. Mérat (1990) reported the pleiotropic effect of Na gene on growth and heat tolerance. Haque and Howlider (2000) reported faster growth for the naked neck crossbreds than for the normally feathered birds. The differences in the biweekly growth rates between naked-neck and normally feathered birds, regardless the genetic group or the thermal environment were insignificant and indicate that growth rate is not a suitable criterion of breeding for growth in naked neck populations in warm climate.

A hybrid population reflects the rapid change in the genetic composition due to gene flow, where genes are spread from one breeding population to others owing to the dispersal of gametes or zygotes (Rieger *et al*., 1981). Therefore, gene flow gives rise to changes of allele frequency and is thus a factor of evolution. The difference in distribution pattern of 6-week body weights of the crossbreds, compared to that of the local breed, is in the majority attributed to the new variation brought in through the flow of genes that increase body weight. This suggests remarkable changes in the frequencies of non-allelic genes influencing growth and proposes the genetic selection for increased 6-week body weight in the crossbreds. It is assumed that there is equilibrium between gene flow bringing in new variation and finite population size reducing variation (Hedrick, 2000), however a small amount of gene flow among different genetic groups within species causes significant genetic changes. The amount of change in allele frequency of Na versus na seems small and this could be due to the narrow range of dispersion of gametes of the sire parental population. Rieger *et al*. (1981) assigned the extent of gene flow in any given hybrid population to the size and structure of the breeding populations and to the range of dispersion of the gametes.

The heterotic effect results from the effects of the genes flowed from both parental populations into the



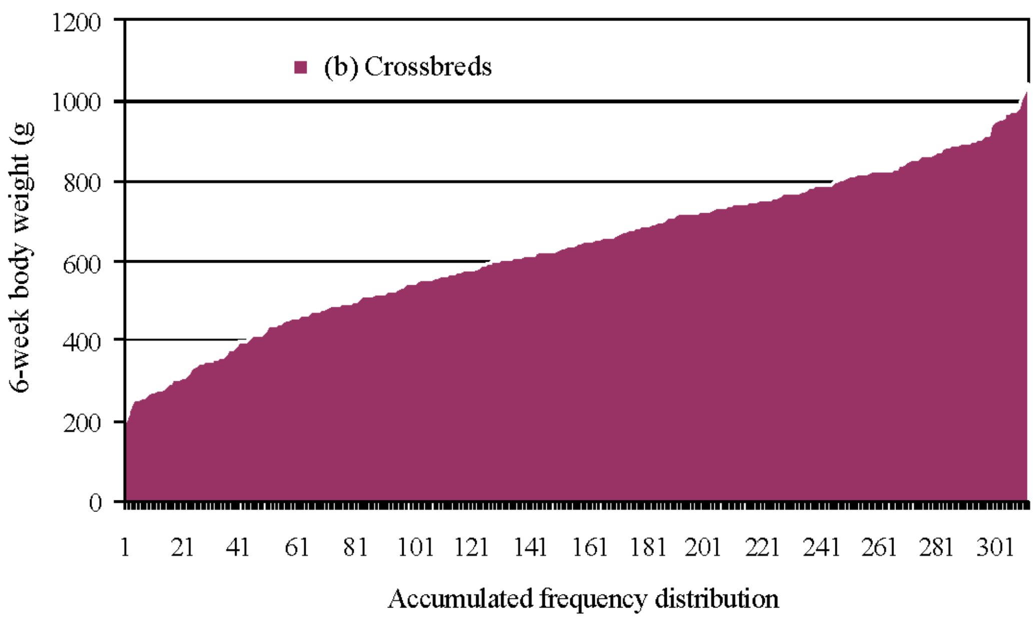


Fig. 1: Distribution of 6-week body weights of the local breed (a) and crossbreds (b)

crossbreds. Heterotic effects on body weights over age were significant and expressed a large source of non-additive genetic variation. Although non-additive genetic effect does not usually contribute much to the sources of variation in growth, it has been reported to contribute significantly in some crosses in which the parental populations differed greatly in body conformation or even selected for fast growth (Marks, 1995; Nestor and Anderson, 1998) and in naked neck and normally feathered crossbreds (Fairfull, 1990; Haque *et al.*, 1999). Heterosis estimates in body weights of the heated crossbreds during the heat exposure period were consistently and significantly higher than those of the non-heated crossbreds, revealing the flow of genes that positively influence growth and heat tolerance. A character measured in two different environments is to be regarded not as one character but as two (Falconer and Mackay, 1997). The physiological mechanisms are to some extent different, and consequently the genes required for high performance are to some extent also different. Therefore, heterosis was an important source of new variation in both heated and non-heated crossbred chicks. The fluctuation, over age, in the heterosis estimates in both non-heated and heated crossbreds seems due to the differences in the growth rates of crossbred and local breed chicks. Heterosis estimates in body weight and growth rate were age and thermal treatment specific and the heterotic effect on body weight was significant, regardless environmental conditions (Marks, 1995; Praharaj *et al.*, 1996; El-Gendy, 2000; Segura *et al.*, 2004). The heterotic effect significantly contributed in the superiority in growth performance of heterozygous naked neck broilers over the normally feathered birds (Deeb and Cahaner, 2001; Patra *et al.*, 2002, 2005; Mbaga *et al.*, 2003).

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