

Article

Genetic and phenotypic parameter estimates for body weight and egg production at sexual maturity in Hilly×Fayoumi crossbred chickens

Ashutosh Das^{1*}, Mukta Das Gupta², Md. Kabirul Islam Khan¹, MD. Moksedul Momin¹ and Omar Faruk Miazi¹

¹Department of Genetics and Animal Breeding, Faculty of Veterinary Medicine, Chittagong Veterinary and Animal Sciences University, Khulshi, Chittagong-4225, Bangladesh

²Department of Microbiology and Veterinary Public Health, Faculty of Veterinary Medicine, Chittagong Veterinary and Animal Sciences University, Khulshi, Chittagong-4225, Bangladesh

*Corresponding author: Dr. Ashutosh Das, Associate Professor, Department of Genetics and Animal Breeding, Faculty of Veterinary Medicine, Chittagong Veterinary and Animal Sciences University, Khulshi, Chittagong-4225, Bangladesh. E-mail: ashutosh.das@cvasu.ac.bd

Received: 07 June 2018/Accepted: 23 June 2018/ Published: 30 June 2018

Abstract: A crossbreeding experiment between Hilly, a locally adapted chicken type in Bangladesh and Fayoumi, an egg type light chicken breed was carried out to evaluate phenotypic performances and to estimate genetic parameters for body weight and egg production at sexual maturity. Results show the mean hatch weight of Hilly♂ × Fayoumi♀ (H♂×F♀) crosses was 35±0.1 gm. In this study, H♂×F♀ crossbred showed a heavier body weight (1551± 32.0 gm/bird) at 20 weeks in comparison with other indigenous chicken genotypes in Bangladesh. The highest body weight gain was found in 8-10 weeks of age. H♂×F♀ crossbred hens exhibited sexual maturity at an average age of 147.5±1.6 days with an average body weight of 1350± 16.8 gm/bird. The mean weight of eggs at sexual maturity was 33.7±0.5 gm/egg. The estimates of heritability for body weight were ranged from 0.15 to 0.26. We observed a positive genetic correlation between weight at sexual maturity (WSM) and egg weight at sexual maturity (EWSM), meaning that hens with high weight at sexual maturity would produce heavier eggs.

Keywords: chicken; crossbreeding; genetic correlation; heritability; performances

1. Introduction

Chicken constitutes 71.5 % of Bangladesh's total livestock population with a census size of 268.3 million (Bhattacharjee and Khatun, 2016). Fifty percent of the chicken populations in Bangladesh are raised in the backyard farming system. This backyard poultry production yet contributes largely to the income of low-input rural farmers. In addition, backyard poultry remains an important source of the rural nutrition as they can provide a regular supply of meat and egg. However, till to date, the production performance of the native chicken in Bangladesh is nominal. Therefore, it is significant to improve meat and egg production performance of native chickens.

The native chicken population in Bangladesh comprises non-descript Deshi, Aseel, Naked Neck, Hilly and Red Jungle Fowls (Bhuiyan *et al.*, 2005). These breeds/types are well known for their disease resistance and lower nutritional requirement (Barua, 1990). These features make them easily adaptable to the low input farming condition in rural Bangladesh. Over the last few decades, a number of studies have been carried out to produce commercial hybrid for meat and egg type chicken by crossing native chickens with exotic breeds (Bhuiyan *et al.*, 2005).

The highest egg producer among native Bangladeshi chicken breeds is the Hilly (Khan *et al.*, 2007). The breed also reported higher survivability under intensive management (96.7%) and broodiness (Khan *et al.*, 2007). Fayoumi, an exotic egg producing chicken breed can produce 140-159 eggs/egg under intensive management

condition whereas under backyard system they produce around 150 egg/year (Regassa *et al.*, 2013). These observations led to test whether Hilly (male; ♂) × Fayoumi (female; ♀) crossbred chicken can be used as a benchmark for improved chicken genetic resources in rural Bangladesh.

Information on phenotypic and genetic parameters is crucial for any genetic upgrading program. There is literature on phenotypic parameters for unselected native chickens of Bangladesh (Faruque *et al.*, 2013; Ferdous *et al.*, 2016; Talukder *et al.*, 2016; Jahan *et al.*, 2017); however, these values may not be appropriate to the breeding for crossbred chickens. Therefore, the aim of this study was to estimate phenotypic and genetic parameters for body weight, performances related to sexual maturity and early egg production traits to understand which traits should be included in breeding programs for this crossbred chicken.

2. Materials and Methods

2.1. Experimental animals

The experimental animals comprised two generations of chickens- F_0 and F_1 . F_0 consisted of 10 Hilly males and 50 Fayoumi females. Fayoumi females were collected from the Regional Poultry Farm, Chittagong, Bangladesh. The age records for Fayoumi pullets were recorded from farm register. Hilly males were procured from five different household farms in Chittagong Hilltracts of Bangladesh. After collection male and female chickens were reared separately under intensive floor management system with a balanced grower ration while from the start of laying the Fayoumi hens were fed with a layer ration (Table 1). F_1 generation consisted of 78 H × F birds (42 females and 36 males). A total of five Fayoumi hens were mated with one Hilly male to produce F_1 birds. Dams were not used for hatching and brooding. Eight broody native hens were used for hatching (12 eggs/hen/incubation). F_1 chicks were brooded initially with the broody hens and then placed under the electrical brooder up to 4 weeks. All F_1 birds were nurtured under same feeding and management practice used for the F_0 birds. Essential vaccinations and medications were provided in addition to standard management procedures.

2.2. Traits measured

The traits measured during the experimental period were, age at sexual maturity (ASM), weight at sexual maturity (WSM), hen-housed egg production (HHEP), egg weight and egg hatchability for Fayoumi chicken; body weight (BW), body weight gain (BWG) age at sexual maturity (ASM), weight at sexual maturity (WSM) and egg weight at sexual maturity (EWSM) for F_1 birds. Age at sexual maturity was considered as the day when two eggs were collected from five hens. The hen-housed egg production was calculated as the number of eggs in relation to existing hens. For each bird, body weight at a specific age was measured from hatching to 20 weeks of age at 2-week intervals. Body weights were recorded as body weights at hatch (BW0) and body weights at weeks 2 (BW2), 4 (BW4), 6(BW6), 8 (BW8), 10(BW10) and so forth. Body weight gain during each 2-week period was recorded from hatching to 20 weeks of age. (i.e., weight gain from hatch to 2 weeks of age [BW0–2], weight gain from 2 to 4 weeks of age [BW2–4], weight gain from 4 to 6 weeks of age [BW4–6], weight gain from 6 to 8 weeks of age [BW6–8], weight gain from 8 to 10 weeks of age [BW8–10] and so forth). EWSM, defined as the mean weight of the number of eggs produced from first egg to about two weeks of egg production, was used to study early egg production traits.

2.3. Statistical and genetic analyses

Descriptive statistics for all traits were carried out in the MiniTab statistical software 18.1 using all available records. Only records from birds which survived to end of the experiment were included in the analysis of ASM, WSM and EWSM. The heritability for ASM, WSM and EWSM were estimated with the following univariate animal model using the ASReML-R (Butler *et al.*, 2009) on the R statistical software. The model was as follows-

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Za} + \mathbf{e}$$

Where, \mathbf{y} is a vector of observations; \mathbf{b} is the vector of fixed effects including sex, and hatch number; \mathbf{a} is a vector of random additive genetic effects; \mathbf{e} is a vector of random residual effects and \mathbf{X} and \mathbf{Z} are incidence matrices relating records to fixed and random effects, respectively. Genetic correlations were estimated by following a bivariate analysis using ASReML-R (Butler *et al.*, 2009). Phenotypic correlations were estimated using the Minitab program.

3. Results and Discussion

3.1. Performance of Fayoumi chickens

In this study, Fayoumi chickens were observed to be sexually mature at the mean age of 155.80 ± 0.80 days under intensive floor management system. A comparison with a dataset from birds with similar genetic background Khan *et al.* (2006) showed agreement with the results of this study. However, Geleta *et al.* (2013)

and Miah *et al.* (2002) reported an earlier age at sexual maturity in Fayoumi chicken with a different genetic background. This finding might be due to genetic variation between the two populations, as the onset of sexual maturity in female chicken is genetically associated (Wright *et al.*, 2012). The observed mean weight at sexual maturity for Fayoumi chicken was 1260.60 ± 7.20 gm that corroborates the finding of Khan *et al.* (2006). This study showed a higher egg production for Fayoumi chicken (116 egg/hen/180 days of egg production) compared to average number of eggs per hen reported by Khawaja *et al.* (2012), Khan *et al.* (2006) and Sazzad (1992) under intensive management system. This variation in egg production might be attributed to differences in nutrition and other management factors that influence the egg production in chicken (Cluckin, 2012; Johnson, 2015). The HHEP for Foyoumi in the present study was 45%. A similar percentage of HHEP for Fayoumi was reported by Miah *et al.* (2002). Khan *et al.* (2006) reported a lower HHEP (38.55%) for Fayoumi chicken. This difference in HHEP could be explained by the variation in flock size, stocking rate and other management procedures between these studies. However, a peak in HHEP (60%) was observed in 30-40 weeks of age (Figure 1) which agreed the finding of a previous study on this breed (Khan *et al.*, 2006). In this study, the mean egg weight of Fayoumi was observed as 46.27 ± 0.39 gm. Khan *et al.* (2006) obtained a similar egg weight (45.79 ± 0.14 gm) under the same geographical condition in Bangladesh. In contrast to the above studies, Ali *et al.* (1993) in Bangladesh, Khawaja *et al.* (2012) in Rawalpindi, Pakistan, Dutta (1993) in India and Geleta *et al.* (2013) in Ethiopia reported lower egg weight for Fayoumi chicken (44.10 g, 43.34 g and 41.36 g and 44.3 g, respectively) in the Fayoumi chicken than the present study. Physical characteristics of an egg are associated with the egg production in all types of chickens and correlate with the body weight of the bird. Using broody hens, hatchability from a set egg (%) of Fayoumi was 86.9%. Miazi *et al.* (2012) obtained a similar hatchability for Fayoumi chicken in Chittagong division of Bangladesh. Jahan *et al.* (2015) reported a slightly higher hatchability (93.3%) for Fayoumi eggs using broody hens. In contrast, Geleta *et al.* (2013) reported a lower (63.5%) hatchability for Fayoumi eggs. Egg hatchability in poultry can be influenced by egg size, incubation factors and environmental factors (King' Ori, 2011; Senbeta, 2017).

3.2. Performance of Hilly♂ × Fayoumi♀ crossbred chickens

3.2.1. Body weight

The mean body weight of H♂ × F♀ crosses under intensive floor management system from hatch up to 20 weeks of age is presented in Table 2. Under intensive management system, the observed mean weight at hatch for H♂ × F♀ crosses was 35 ± 0.1 gm, which is in line with the finding of Khan *et al.* (2007). The hatch weight observed for H♂ × F♀ crosses in present study was higher when compared with observations from previous studies on different native chicken genotypes in Bangladesh (Faruque *et al.*, 2007; Faruque *et al.*, 2013; Faruque *et al.*, 2015; Ferdaus *et al.*, 2016 and Faruque *et al.*, 2017). Ferdaus *et al.* (2013) observed a lower weight for native dwarf and normal shanked chicken at 4th weeks of age compared to the present study. A slightly higher weight at 4th weeks of age in hilly chicken reported by Rahman *et al.* (2013b) was attributed to a high protein energy diet supplement. While considering body weight by sex and for both sexes combined, H♂ × F♀ crosses in the present study showed a higher body weight at 8 weeks of age compared to other native and improved native chicken genotypes (Faruque *et al.*, 2013; Rahman *et al.*, 2013a; Faruque *et al.*, 2015 and Ferdaus *et al.*, 2016). The average body weight at 12 weeks of H♂ × F♀ crosses in this study coincides with the observed body weight for Hilly and desi chickens by Faruque *et al.* (2017). H♂ × F♀ crosses also showed a heavier body weight at 16 weeks in comparison with the average body weight for improved indigenous chicken genotypes recorded by Faruque *et al.* (2015). Ferdaus *et al.* (2016) found 1212 and 1764 gm live weight of female and male indigenous chicken, respectively at 20 weeks of age which is much lower than the present study at the same age. The mean body weights of male birds were significantly heavier ($p < 0.001$) than their female counterpart at hatch and from 4 to 20 weeks of age. Faruque *et al.* (2015) observed a similar fashion of weight difference between male and female birds while improving Bangladeshi indigenous chicken with ex-situ breeding. A noticeable dimorphism in body weight with males being significantly heavier than females could be attributable to the effect of male growth hormones (Singh *et al.*, 1982).

3.2.2. Body weight gain

The mean weekly body weight gains of H♂ × F♀ crossbred chickens is depicted in Figure 2. The highest body weight gain was found in 8-10 weeks of age where the lowest body weight gain was found during 0-2 weeks of age for H♂ × F♀ crossbred chickens in the present study. Ferdaus *et al.* (2016) also reported the highest body weight gain at an almost same age for the indigenous chicken. Yeasmin and Howlider (2013) observed that higher weight gains for indigenous chickens from 5-18 weeks than the birds of 0-4 weeks of age which agreed the findings of the present study. Table 3 shows the body weight gain of female birds was significantly lower

throughout the experimental period than the male which is supported with the findings of Ferdaus *et al.* (2016) and Faruque *et al.* (2015).

Table 1. Ingredients composition of ration fed to experimental birds.

Ingredients	Percent in per kg feed	
	Grower ration	Layer ration
Maize	56	56
Soyabean	16	18
Fish meal	7	7
Rice polish	13	9
Oyster shell	4	8
Salt	0.35	0.35
DCP	0.50	0.50
Lysine	0.10	0.10
Toxin binder	0.20	0.20
Methionine	0.10	0.10
Coline	0.50	0.50
Vitamin	2	-
Grozyme	0.25	0.25

Table 2. Means±SE and heritability estimates for body weight in Hilly♂ × Fayoumi♀ crossbred chickens.

Trait ^a	Mean body weight, g ±SE			Heritability
	Female	Male	Both sex as combined	
BW0	34.9±0.1	35±0.1*	35 ± 0.1	0.23
BW2	100.9±0.8	100.6±0.7	100.7± 0.5	0.24
BW4	205.7± 2.0	244± 3.0*	223.5 ± 2.8	0.24
BW6	268± 2.7	412.8± 3.5*	335± 8.5	0.15
BW8	405.8± 1.6	633± 3.6*	510.8±13.0	0.19
BW10	595.9± 6.0	914± 3.9*	696.8± 13.0	0.21
BW12	710.7± 5.6	1043± 5.5*	864± 19.3	0.17
BW14	853.8± 4.9	1243.9± 5.0*	1033.8± 22.0	0.26
BW16	992± 6.5	1461± 6.6*	1208.7± 27.0	0.16
BW18	1120.5± 8.2	1670± 8.0*	1374±31.7	0.23
BW20	1291± 5.7	1854± 7.6*	1551± 32.0	0.22
WSM	1350± 16.8	1932.5± 33.6*	1641± 77.0	0.21

^aBW0, hatch weight; BW2, BW4, BW6, BW8, BW10, BW12, BW14, BW16, BW18 and BW20, body weights at 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 weeks of age, respectively, *mean of body weights of male is significantly ($p<0.001$) heavier than their female counterparts for the same week, WSM, weight at sexual maturity

Table 3. Mean±SE of body weight gain by sex in Hilly♂ × Fayoumi♀ crossbred chickens.

Trait ¹⁾	Female	Male	p
BW0-2	65.9±0.8	65±0.7	0.580
BW2-4	64.9±2.5	103.7±2.5	<0.0001
BW4-6	62.7±1.4	168.6±3.5	<0.0001
BW6-8	137±3.1	220.6±3.4	<0.0001
BW8-10	190±5.5	181±2.7	0.167
BW10-12	114.8±2.1	208.9±5.1	<0.0001
BW12-14	143±2.9	200.6±3.7	<0.0001
BW14-16	138.6±2.8	217±5.6	<0.0001
BW16-18	128±3.1	208.9±7.1	<0.0001
BW18-20	170.6±6.8	184±12.9	0.380

¹⁾ BW0-2, weight gain from hatch to 2 weeks of age; BW2-4, weight gain from 2 to 4 weeks of age; BW4-6, weight gain from 4 to 6 weeks of age; BW6-8, weight gain from 6 to 8 weeks of age; BW8-10, weight gain from 8 to 10 weeks of age; BW10-12, weight gain from 10 to 12 weeks of age; BW12-14, weight gain from 12 to 14 weeks of age; BW14-16, weight gain from 14 to 16 weeks of age; BW16-18, weight gain from 16 to 18 weeks of age; BW18-20, weight gain from 18 to 20 weeks of age.

Table 4. Heritability (diagonal), genetic (above diagonal) and phenotypic (below diagonal) correlation estimates for age at sexual maturity (ASM), weight at sexual maturity (WSM) and egg weight at sexual maturity (EWSM) in Hilly ♂ × Fayoumi ♀ crossbred chickens.

Trait	ASM	WSM	EWSM
ASM	0.21	0.55	-0.73
WSM	0.47	0.24	0.90
EWSM	-0.60	0.87	0.19

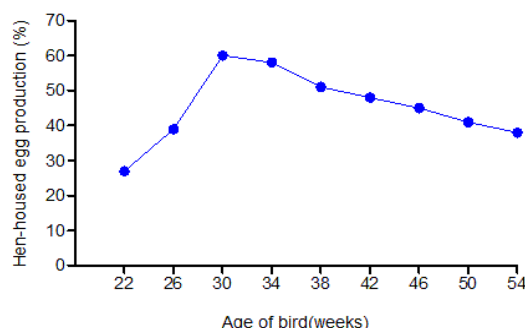


Figure 1. Hen house egg production (%) of Fayoumi chicken.

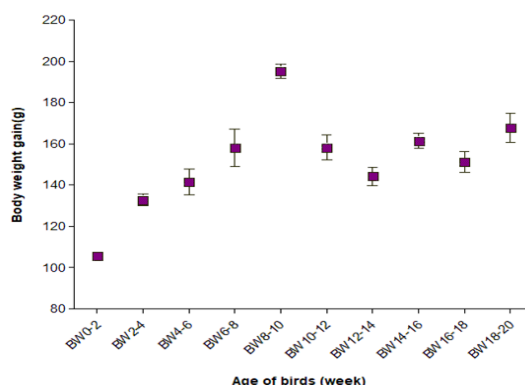


Figure 2. Body gain for both sexes combined in Hilly ♂ × Fayoumi ♀ crossbred chickens.

3.2.3. Age and weight at sexual maturity

Under intensive floor rearing system with a balanced grower ration, H♂ × F♀ crossbred showed sexual maturity at an average age of 147.5±1.6 days, which was lower in comparison with parental breeds and other native genotypes (Faruque *et al.*, 2015; Ferdaus *et al.*, 2016; Talukder *et al.*, 2016). Khan *et al.* (2007) recorded a comparatively higher age at sexual maturity for H♂ × F♀ crossbred. The average live weight of H♂ × F♀ crossbred at sexual maturity was 1350±16.8 gm, which was comparatively higher than that reported by Khan *et al.* (2007) for H♂ × F♀ crossbred. We observed a significant sexual dimorphism for weight at sexual maturity in H♂ × F♀ crossbred. Nonetheless, under intensive floor management H♂ × F♀ crosses displayed a heavier weight at sexual maturity compared to other Fayoumi crossbreds (Islam and Nishibori, 2010).

3.2.4. Egg weight at sexual maturity

The mean weight of egg at sexual maturity was 33.7±0.5 gm/egg in H♂ × F♀ crossbreds. Khan *et al.* (2007) reported a similar weight (35.98±2.63 gm/egg) for H♂ × F♀ crossbreds up to 90 days of egg production. Faruque *et al.* (2007) found a lower egg weight at sexual maturity in Hilly and in Naked-Neck chickens compared to the present findings, which could be attributable to the effect of genotypes on egg weight (Faruque *et al.*, 2013).

3.3. Genetic parameter estimates for the traits

Estimated heritability values for body weights are presented in Table 2. The estimates of heritability for body weight ranged from 0.15 (BW6) to 0.26 (BW14). These moderate heritability estimates coincide with the heritability estimates for body weight in Horro chicken of Ethiopia ((Nigussie *et al.*, 2011) and in native chickens in Iran (Niknafs *et al.*, 2012). However, Faruque *et al.* (2013) reported a wide range of heritability values (0.16 to 0.73) for body weights in Hilly, Naked-Neck and non-descriptive indigenous chickens in Bangladesh.

The heritability estimate for ASM was 0.21 (Table 4). Niknafs *et al.* (2012) reported a slightly higher heritability value (0.36) for ASM in Iranian native chickens. The estimated heritability for WSM (0.24) in the present study was lower than the reported by Niknafs *et al.* (2012). Variation in heritability estimates could be attributed to the method of estimation, genotype, environmental effects and sampling error due to small data set or sample size. Table 4 shows the estimated genetic correlation between ASM and WSM was 0.47, means that hens with high weight have later sexual maturity. The positive genetic and phenotypic correlations between WSM and EWSM implies that hens with heavier weight at sexual maturity would produce heavier eggs. Niknafs *et al.* (2012) and Firozjah *et al.* (2015) also reported positive correlations between WSM and early egg weight.

4. Conclusions

In comparison with other native chicken genotypes Hilly♂ × Fayoumi♀ crossbred chicken showed better performances under intensive management system. Moderate heritability estimates are suggestive of selecting for body weight might be useful in this cross. A large scale backcrossing would be worthy to perform to establish a nucleus breeding flock, since we require a satisfactory egg production from the maternal breed (Fayoumi) and desired meat production from the paternal breed (Hilly). A genotype x environment study to test and optimize the productivity of this crossbred on-farm conditions under low-input production in different agro-ecologies is also recommended.

Acknowledgements

This project was funded under the research assistance fund by University Grant Commission of Bangladesh through Chittagong Veterinary and Animal Sciences University. The services of field staff and support staffs of the Department of Genetics and Animal Breeding, Chittagong Veterinary and Animal Sciences University are thankfully acknowledged.

Conflict of interest

None to declare.

References

- Ali M, 1993. Reproduction and growth of Rhode Island Red (RIR), Fayoumi (FO) and RIR× FO chicken in Bangladesh. *Poultry Adv.*, 24: 47-50.
- Barua A, 1990. Prospects of native chicken in Bangladesh. *Poultry Adv.*, 22: 57-61.
- Bhattacharjee B and H Khatun, 2016. Brief on Livestock Statistics. Available: http://www.fao.org/fileadmin/templates/rap/files/meetings/2016/160801_BGD-SurveyCalendar_Brief_of_Livestock_Statistics.pdf
- Bhuiyan A, M Bhuiyan and G Deb, 2005. Indigenous chicken genetic resources in Bangladesh: Current status and future outlook. *Anim Genet Resour.*, 36: 73-84.
- Butler D, B Cullis, A Gilmour and B Gogel, 2009. ASReml-R. Reference Manual Version 3, Queensland Department of Primary Industries and Fisheries, Brisbane, Australia.
- Cluckin L, 2012. Factors that influence & affect egg laying. Available: <https://www.backyardchickens.com/articles/factors-that-influence-affect-egg-laying.64361/>
- Dutta K, 1993. Studies on egg weight, feed requirement per dozen of egg and yolk color of the miri birds of assam white leghorn and their cross, managed on liteer, cage and free range system of management. *Indian Vet J.*, 70: 142-144.
- Faruque S, A Bhuiyan, MY Aliand ZF Joy, 2017. Breeding for the improvement of indigenous chickens of Bangladesh: performance of foundation stock. *Asian J. Med. Biol. Res.*, 3: 80-87.
- Faruque S, M Islam, M Afroz and M Rahman, 2013. Evaluation of the performance of native chicken and estimation of heritability for body weight. *J. Bangladesh Acad. Sci.*, 37: 93-101.
- Faruque S, M Islam and A Bhuiyan, 2015. Ex situ improvement of indigenous chicken in Bangladesh. *Trop. Agri. Res.*, 26: 596-607.

- Faruque S, N Sarker, M Islam and M Sarker, 2007. Performance of native chicken under intensive system. *J. Bangladesh Agri. Uni.*, 5: 283-288.
- Ferdaus A, M Bhuiyan, B Hassin, A Bhuiyan and M Howlider, 2016. Phenotypic characterization and productive potentialities of indigenous dwarf chicken of Bangladesh. *Bangladesh J. Anim. Sci.*, 45: 52-61.
- Firozjah NG, H Atashi and A Zare, 2015. Estimation of genetic parameters for economic traits in Mazandaran native chickens. *J. Anim. Poultry Sci.*, 4: 20-26.
- Geleta T, S Leta and E Bekana, 2013. Production performance of Fayoumi chickens under intensive management condition of Adami Tulu research center. *Int. J. Livest. Prod.*, 4: 172-176.
- Islam MA and M Nishibori, 2010. Crossbred chicken for poultry production in the tropics. *J. Poultry Sci.*, 47: 271-279.
- Jahan S, F Islam, M Bhuiyan and A Bhuiyan, 2017. Productive and reproductive performances of indigenous chicken in the rural condition of Bangladesh. *Bangladesh J. Anim. Sci.*, 46: 121-127.
- Jahan S, M Islam, M Howlider, M Sarder, M Islam and Z Hossain, 2015. Hatchability of Deshi, Fayoumi, RIR and Sonali chickens in forced draft incubator and under broody hens in Bangladesh. *Livest. Res. Rural Devel.*, 27:15. Available: <http://www.lrrd.org/lrrd27/1/jaha27015.html>
- Johnson L, 2015. Factors that affect egg production in chickens. Available: <http://nwdistrict.ifas.ufl.edu/phag/2015/02/27/factors-that-affect-egg-production-in-chickens/>
- Khan MKI, N Debnath, M Bhuiyan, M Khatun, M Karim and B Dey, 2007. Development of crossbred chickens for semi-scavenging system by the crossing of Hilly (native) with Rhode Island Red and Fayoumi. *Indian J. Anim. Sci.*, 77: 257-261.
- Khan MKI, M Khatun, M Bhuiyan and R Sharmin, 2006. Production performance of Fayoumi chicken under intensive management. *Pakistan J. Biol. Sci.*, 9: 179-181.
- Khawaja T, SH Khan, N Mukhtar, MA Ali, T Ahmed and A Ghafar, 2012. Comparative study of growth performance, egg production, egg characteristics and haemato-biochemical parameters of Desi, Fayoumi and Rhode Island Red chicken. *J. Applied Anim. Res.*, 40: 273-283.
- King' Ori A, 2011. Review of the factors that influence egg fertility and hatchability in poultry. *Int. J. Poultry Sci.*, 10: 483-492.
- Miah M, 2002. Growth and egg production performance of exotic pure breeds and crossbreds chicken. *Bangladesh Veterinarian*, 19: 43-47.
- Miazi OF, G Miah, MM Miazi, MM Uddin, MM Hassan and M Faridahsan, 2012. Fertility and hatchability of Fayoumi and Sonali chicks. *Scholarly J. Agril. Sci.*, 2: 83-86.
- Nigussie D, E Vander Waaij and J van Arendonk, 2011. Genetic and phenotypic parameter estimates for body weights and egg production in Horro chicken of Ethiopia. *Trop. Anim. Health Prod.*, 43: 21-28.
- Niknafs S, A Nejati-Javaremi, H Mehrabani-Yeganeh and SA Fatemi, 2012. Estimation of genetic parameters for body weight and egg production traits in Mazandaran native chicken. *Trop. Anim. Health Prod.*, 44: 1437-1443.
- Rahman M, S Faruque, M Islam, M Islam and A Mahmud, 2013a. Productive and reproductive performances of Hilly and Jungle Fowl. *The Agriculturists*, 11: 10-13.
- Rahman M, S Faruque, M Islam, M Islam and M Rashid, 2013b. Comparison of growth performance and meat yield of Hilly Chicken under two feeding regimens. *The Agriculturists*, 11: 38-43.
- Regassa SL, E Bekana and T Geleta, 2013. Production performance of Fayoumi chicken breed under backyard management condition in Mid Rift Valley of Ethiopia. *Herald J. Agri. Food Sci. Res.*, 2: 78-81.
- Sazzad M, 1992. Comparative study on egg production and feed efficiency of different breeds of poultry under intensive and rural conditions in Bangladesh. *Livest. Res. Rural Devel.*, 4: 65-69.
- Senbeta EK, 2017. Effect of egg size on hatchability and subsequent growth performance of Fayoumi chicken. *J. Agril. Sci.*, 9: 116.
- Singh BP, R Chaudhary, R Singh and S Ahlawat, 1982. Diallel crosses in poultry for broiler production-estimation of heterosis for various broiler traits. *Indian Vet. J.*, 59: 882-892.
- Talukder MAI, MA Alam, MM Rahman, MA Hemayet and MA Islam, 2016. Comparative performances of hilly chicken and naked neck hilly chicken at Naikhongchari hilly areas of Bangladesh. *Asian J. Med. Biol. Res.*, 2: 348-351.
- Wright D, C Rubin, K Schutz, S Kerje, A Kindmark, H Brandström, L Andersson, T Pizzari and P Jensen, 2012. Onset of sexual maturity in female chickens is genetically linked to loci associated with fecundity and a sexual ornament. *Reprod. Domes. Anim.*, 47: 31-36.
- Yeasmin T and M Howlider, 2013. Effects of autosomal dwarf gene on growth and shank length of chicken. *Bangladesh Veterinarian*, 30: 25-32.