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Economic value for traits of breeding objective of crossbred chickens under different production systems

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Abstract
A linear, deterministic model was used to calculate the annual profit of a hen and economic value for important traits of Hilly and Fayoumi (Fay) crossbred chickens under intensive and semi-intensive production systems in consideration of output and input variables. The economic value of different traits was calculated after re-running the model with changes of one unit of each trait value and holding other trait value as constant. Results showed that the sale of growers and culled breeding stock has impacted the revenues. Surplus growers (cockerel and pullet) accounted for 75 to 78% of the total revenues. The higher revenue was obtained from Hilly × Fay (F_1) in intensive production system and the lowest for Hilly × F_1 generation in other system. Feed costs account for 80 to 86% of the total production costs. The annual profit of a hen varied from USD 4.97 to 11.78. The economic values of egg production, fertility, hatchability and live weight were positive, however, negative values were obtained for age at sexual maturity of males and feed intake. The positive economic values of traits lead the higher profitability. Changes in the base price of egg, live weight and feed cost ±10% found the profitability and economic values were fluctuated.

Keywords: Chicken, Economic value, Objective traits, Sensitivity.

Introduction

In Bangladesh, the deshi chickens, included non-descriptive deshi, Assel, Naked Neck, and Hilly chickens, which are mostly variable in their morphological and phenotypic features, but they are well adaptive under natural conditions (Noor et al*.,* 2021). In addition, some pure breeds (for example Fayoumi (Fay), Rhode Island Red (RIR), White Leghorn) and crossbreds (Sonali, RIR x Fay) are also available in Bangladesh. Among them non-descriptive deshi and Sonali are dominant and distributed throughout the country. The Fayoumi are good scavengers, hardy and disease resistant than any other exotic chicken (Khan et al. 2007). On the other hand, among the deshi chickens the Hilly chickens are unique for their well adaptive, relatively higher disease resistance, having broodiness, the potential superiority of egg and body weight gain and higher survivability in comparison to other natives (Faruque *et al.* 2015 and Khan et al. 2017).

As Fayoumi and Hilly chickens carry the native gene pool and they are adaptive under local environment, combination of these two types will

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produce a suitable adapter composite. Therefore, to increase the meat and eggs of chickens for rural conditions by reciprocal crossing between Hilly and Fayoumi chickens was undertaken to produce a composite for meeting the demand of the nation in a short period of time (Khan et al. 2007 and 2017). For increasing the productivity of the chickens, the genetic improvement is the permanent and stable solution, however, it needs an objective breeding decision. The profitability of the breeding objective depends on the calculation of the economic values for all traits of the objective (James, 1982).

The studies (Das et al. 2018 and Noor et al. 2021) on poultry breeding in Bangladesh and other developing countries are mainly biological that is the comparisons of productive and reproductive performances. Generally, in Bangladesh the poultry is marketed as live birds per kg basis and the eggs per piece or dozen basis. The economic evaluation was done elsewhere by other workers (Okeno et al. 2013 and Chaowu et al. 2016), however, no detailed information, including all variables is available for economic evaluation on poultry in developing world including Bangladesh. Hence, the present study was conducted in consideration of the objectives (i) to study the performance of different genotypes; (ii) to estimate the costs, revenue and profit of individual hen and calculate the economic value for different traits; and (iii) to undertake a sensitivity analysis of profitability and economic value of the traits by changing the base input and output variable(s).

Materials and Methods

The research was pursued at the poultry shed at the Chattogram Veterinary and Animal Sciences University (CVASU) and the rural areas of Chittagong Hill Tract (CHT) region of Bangladesh from July 2017 to June 2020 following the animal ethics rule and the ethical committee approval of CVASU (Memo No. CVASU/Dir (R&E) EC/2021/ 273(4), Date 22/09/2021).

Animal selection, breeding and study of the performance traits

Ten cockerels of Hilly and 80 hens were collected from the rural areas of CHT districts on the basis of phenotypic similarities like plumage color, comb type, shank color and body conformation and 10 cockerels and 80 pullets of Fayoumi (Fay) were collected from the government poultry farm of Chattogram, Bangladesh. After collection of cockerels and pullets, they were kept in quarantine for 15 days. The collected chickens were vaccinated, ND killed vaccine (against Newcastle diseases). Then the Hilly cockerels and Fayoumi pullets were kept in three separate pens and the Fayoumi cockerels and Hilly pullets were kept other three pens at a ratio of 1:8 (male: female) under intensive conditions. Each pen contains 3 cockerels and 24 pullets. After obtaining the F_1 generation from the Hilly ♂ × Fay ♀ cross in the first year of the experiment, their performance was compared. And in the second year, the F_2 generation from the F_1 generation and Hilly ♂ × F_1♀& genotype was obtained. All three crossbreds (F_1, F_2 and Hilly × F_1) were reared under both intensive and semi-intensive production systems. Each genotype was reared in three separate pens under both production systems and each pen contained 10 males and 80 females. Egg production of the crossbreds (F_1, F_2 and Hilly × F_1) was recorded from the onset of laying up to 200-days of laying on a daily basis and calculated the 200 days of hen house egg production. The eggs were collected twice daily and stored at room temperature for 7 days. These stored eggs were hatched using an electric incubator. Twenty eggs were collected from each genotype at 15 days intervals and egg weight was taken using a digital balance on the second day after the collection date of the eggs. The hatched-out chicks were weighed and their subsequent live weight upto the attainment of age at sexual maturity was kept and recorded in both sexes. The mature live weight of all three crossbreds was recorded. The fertility and hatchability of the crossbred population were recorded accordingly. Mortality of all genotypes was observed and recorded for calculating the survivability. For calculating the age and weight at sexual maturity, the age and weight of each chicken based on genotype and production system were recorded at the time of first laying. All the chickens were fed with the same formulated ration in both systems. Feed intake data of different crossbred chickens were recorded on a weekly basis by deducting leftover feed from the supplied feed. From this weekly feed intake data, the daily average feed intake of each genotype was calculated in both sexes.

Management of chickens

For rearing the chickens under an intensive and semi-intensive system, all the equipment was cleaned, disinfected and fumigated. Intensive system: chickens were reared in confined and supplied them balanced ration, with all health care and proper management; and semi-intensive system: chickens were kept partially in confinement and supplemented and balanced ration and all health care, and they were also allowed to scavenge in the homestead or in the fence during day time. Footbath and other biosafety measures were taken properly. In the laying house, one feeder for every six birds (1:6) and one waterer for every 8 birds (1:8) were placed in equal intervals. Adlibitum fresh water and formulated ration with the ingredients of broken corn, wheat, rice polish, soybean meal, protein concentrates, di-calcium phosphate, protein concentrates, vitamin-mineral premix, soybean oil and common salt. The nutrient composition of the formulated ration was 2950 kcal/kg for chicks, 2800 kcal/kg for the grower and 2660 kcal/kg for layer, protein 20%, 17% and 16%, calcium 1.0%, 0.75% and 3.50%, phosphorus 0.50%, 0.50% and 0.70%, respectively was supplied twice daily. Standard vaccination schedules (Baby chicks Newcastle disease vaccine (BCRDV), Gumbroo, Newcastle disease (ND-killed), Fowl pox and Fowl cholera) were followed and other farm operations like debeaking, deworming, lightening were also carried out as per the appropriate procedure. Adequate number of egg laying boxes were placed in the secure place in each pen. Supplements such as vitamin C, glucose, and salt were supplied with water as needed.

Economic evaluation

In this study, a deterministic, modified model (equation-1) of Khan et al. (2014) was used, to calculate the annual profit of a chicken and the economic value for the traits of the crossbreds under intensive and semi-intensive production systems in considering the biological traits, nutritional and management variables. The revenues were derived from the sales of extra eggs, growers and spent breeding stocks, including consumed by the households and sales of used litter and gunny bags. The expenditure was incurred for the feed, veterinary health care, brooding, labourer and chicken marketing costs. On-farm and on-station, experimental data on production, nutrition and management variables were used in this study (Table 1). The current average market price of input and output variables was considered in the model. The current market price for per piece egg was BDT 10.00 and live weight per kg of chicken was BDT 360.00. The chickens was marketed at the age at sexual maturity. After running the base model, the individual chicken income was calculated and changing the interests' trait by one unit and keeping constant with other traits value in the model, the economic value (EV) was calculated by re-running this model. In considering a year of operation, the EVs of different traits were estimated on a per chicken per year basis.

The following modified (Khan et al. 2014) profit equation was used to estimate the annual profit per hen per year.

$$Profit = \sum_{i=1}^{2} N_{(MF)_i} a_k p_j S + (SurER + LitR) - (Feedcost = \sum_{l=1}^{3} N_l Pd_l FI_l P_l)) - (LbC + MC + VC + BC) - FC \ldots$$

(Equation 1)

Where,

N_{MFi} is the number of sold males and females in grower and culled breeding stock, (Egg production × (1- setting rate) × fertility (%) × hatchability (%), a_k is the weight of birds in each stage (chicks, grower, breeder and layer), Pj is the price per kg live birds, S is the survivability = (1- death and missing)

SurER is the surplus egg revenue = 200 days Egg production/hen × (1- setting rate) × price per egg LitR is the litter and gunny bag revenue per bird was assumed as 200 taka/year.

FeedC is the feed cost for i^{th} stage (i, 1=chicks, 2=grower and 3= layer, breeder), N_i = No of birds in each stage. Per kg, feed cost was BDT 32.00.

Pd_i = period of each stage (chicks 6 weeks, grower up to age at sexual maturity, layer (365- age at sexual maturity) = average feed intake per bird /day in each stage, P_i= price per kg feed

The labour costs and brooding costs of this model current were calculated by following the equations of Okeno et al. (2013) and are presented as: LbC is the labour costs = 0.17 ×t×365×0.12×Wage per day for 8 working hours. According to Menge et al. (2005) 10 min. per birds per day was considered, where it is the proportion of time spent in different production systems (that is semi-intensive 60% and intensive 100%); 0.17 number of hours spent attending to each bird per day and 0.12 is the 12 hours each day.

BC is the brooding costs = {(Egg production (EP) ×Setting rate × (1-(fertility (%) × hatchability)) + ((EP ×105)/365) × price per egg), is the hen was not in lay due to incubation and brooding. Hens were assumed to take 15 weeks (105 days) to incubate eggs and brood chicks to weaning. Labourer costs per day were BDT 400.00. MC is the marketing costs, 1 Bangladeshi Taka (BDT) per bird levy and carrying costs. VC is the veterinary costs, (3 and 6 BDT/bird/year for semi-intensive and intensive conditions, respectively) and FC is the fixed costs (25 and 50 taka/bird/year for semi-intensive and intensive conditions, respectively).

Sensitivity Analysis

To test the sensitivity of the economic value of different traits and profitability of different genotypes under two production systems, a sensitivity analysis was done by changing the prices of feed costs, sale price per egg, and live bird (price per kg live weight). Changes of ±10% in respect to the current (original value) value in the model.

Statistical Analysis

The research was conducted considering the two-production system and three genotypes; and each genotype was allocated thrice/replicate in each production system randomly following the randomized block design (RBD). The recorded data were analysed using Proc GLM of SAS (2008) following RBD and obtained the mean value of all studied traits. The least significant different test (Steel et al. 1997) at the 5% level of significance was used for comparing the mean differences.

Results and Discussion

Performance of different crossbred chickens

The production performance of the different crossbreds of Hilly and Fayoumi chickens under intensive and semi-intensive production systems are presented in Table 1. The 200-days hen house egg production (92 to 122 no), egg weight (43 to 46g), fertility (77 to 80%), hatchability (74 to 79%), age at sexual maturity (159 to 169 days for male (cockerel), and 161 to 171 days for females (pullet) and live weight at sexual maturity for males 1.39 to 1.78 kg and for females 1.20 to 1.49 kg, respectively, and mature live weight of males (cock) was 1.70 to 1.98 kg and females (hen) were 1.31 to 1.53 kg regardless of genotype and production system (Table 1). These values differed significantly ($P<0.05$) between production systems and genotypes. All the genotypes showed higher values for these traits under intensive conditions than the semi-intensive conditions,which might be due to the supply of adequate amount of feed and comparatively better management in an intensive system than in semi-intensive conditions. The production system has the greatest influence on chicken's performance, as shown by Noor et al. (2021), Sanka and Mbaga (2014) and Khan et al.

(2007). Similarly, traits also differed between genotypes, and this statement was supported by Khan et al. (2007, 2017) and Soro et al. (2014). For both productive and reproductive performances, the Hilly × Fay (F_1) genotype showed better than the other genotypes. This might happen due to 100 per cent heterozygosity and the highest heterosis was observed in the F_1 generation in a single cross. These findings agree with the findings of Munisi et al. (2015), who observed that the live weight of F_1 (Black Australorp × broiler stocks) were significantly higher than the F_2 generation and backcross population. The survivability of male and female chickens significantly differed between production systems and genotypes (Table 1).

Comparatively higher survivability of different genotypes and sexes of chickens was observed in intensive conditions (for example, survivability of growers: males, 79 to 84% and females, 83 to 86%) than in semi-intensive conditions (for example, survivability of growers: males, 68 to 79% and females, 74 to 79 %) which might be due to semi-intensive conditions that lead to extra loss of chicken due to predator. This finding was similar to the findings of Khan et al. (2007 and 2017). In the current study, the survivability of Hilly ♂ × Fay ♀ (F_1) (mature male vs female was 88 vs 90%) and Hilly♂ × F_1♀ (mature male vs female was 91 vs 83%) under intensive conditions was better than other genotype and also for the genotypes of semi-

Table 1. Production, management, nutritional and economic variables used in the profit equation

VariablesUnit	Production system								
	Intensive				Semi-intensive				SEM
	Hilly♂ × Hilly♀		Hilly♂ × F_1♀	Ave. of Hilly cross	Hilly♂ × Hilly♀		Hilly♂ × F_1♀	Ave. of Hilly cross	
	F_1	F_2			F_1	F_2			
Production variable									
200-days house day egg production (No)	122ᵇ	118ᵇ	104ᶜ	114.7ʸ	102ᵇᶜ	98ᵇᶜ	92ᶜ	97.3ˣ	4.761
Egg weight (g)	45ᵇ	46ᵇ	45ᵇ	45.3	45ᵇ	43ᵇ	44ᵇ	44.0	0.422
Hatchability (%)	79ᵇ	76ᶜ	78ᵇ	77.7	75ᵇᶜ	74ᵈ	76ᶜ	75.0	0.760
Fertility (%)	80ᶜ	77ᵈ	79ᶜᵈ	78.7	80ᵇ	79ᶜᵈ	77ᵈ	78.7	0.558
Age at sexual maturity of male (days)	166ᵇ	159ᶜ	169ᵃ	164.7	167ᵃᵇ	160ᶜ	167ᵇ	164.7	1.687
Age at sexual maturity of female (days)	168ᵃ	161ᵇ	170ᵃ	166.3	171ᵃ	163ᵇ	167ᵃ	167.0	1.606
Weight at sexual maturity of male (kg)	1.78ᵇ	1.76ᵇᶜ	1.73ᵇ	1.76	1.49ᵇ	1.46ᶜ	1.39ᵇᶜ	1.45	0.071
Weight at sexual maturity of female (kg)	1.45ᵃ	1.49ᵇ	1.40ᶜ	1.45ʸ	1.20ᵃ	1.20ᵇ	1.21ᶜ	1.20ˣ	0.056
Mature weight of male at 26 weeks of age (kg)	1.98ᶜ	1.95ᵈ	1.97ᵇ	1.97ʸ	1.70ᵈ	1.70ᵈ	1.82ᵇ	1.74ˣ	0.054
Mature weight of female at 35 weeks of age (kg)	1.49ᶜ	1.53ᵈ	1.48ᵇ	1.50ʸ	1.39ᶜ	1.33ᵈ	1.31ᵇ	1.34ˣ	0.037
Survivability of 6 weeks age of male (%)	84	83	82	83.0ʸ	79	76	78	77.7ˣ	1.282
Survivability of 6 weeks age of female (%)	79	75	80	78.0ʸ	80	76	77	77.7ˣ	0.872
Survivability of grower male (%)	84ᵇ	81ᵇᶜ	79ᶜ	81.3ʸ	73ᶜ	68ᶜ	75ᶜ	72.0ˣ	2.376
Survivability of grower female (%)	86ᵇ	83ᵇᶜ	84ᶜ	84.3ʸ	78ᵇ	79ᵇ	74ᶜ	77.0ˣ	1.820
Survivability of 1-year aged male(%)	88ᵃ	85ᵃ	91ᵃ	88.0ʸ	79ᵃ	76ᵃ	78ᵃ	77.7ˣ	2.469
Survivability of 1-year aged female (%)	90ᵃ	89ᵃ	83ᵃ	87.3ʸ	79ᵃ	75ᵇ	75	76.3ˣ	2.713
Nutrition variables									
Feed intake for male up to 6 weeks (g)	20.0ᶜ	18.5ᵇᶜ	19.0ᶜ	19.2y	15.2ᵃ	14.8ᵃ	16.0ᵃᵇ	15.3ˣ	0.894
Feed intake for female up to 6 weeks (g)	18.0ᶜ	16.5ᵇ	17.0ᵇ	17.2ʸ	14.5ᵃ	14.8ᵃ	15.0ᵃ	14.7ˣ	0.575
Feed intake of male up to ASM (g)	62ᵇ	59ᵇ	59ᵇ	60.0ʸ	45ᵃ	44ᵃ	47ᵃ	45.3ˣ	3.333
Feed intake of female up to ASM (g)	58ᵇ	56ᵇ	51ᵇ	55.0ʸ	43ᵃ	42ᵃ	41ᵃ	42.0ˣ	3.101
Feed intake of male at mature age (g)	113ᶜ	113ᶜ	111ᵇᶜ	112.3ʸ	97ᵃ	99ᵃ	98ᵃ	98.0ˣ	3.229
Feed intake of female at mature age (g)	106ᵇᶜ	100ᵇ	100ᵇ	102.0ʸ	80ᵃ	84ᵃ	84ᵃ	82.7ˣ	4.455

Fay= Fayoumi, F_1 = First filial generation, F_2 = Second Filial Generation, SEM= Standard Error of Mean, ♂ = Male (Cock), ♀ = Female (Hen), BDT= Bangladeshi Taka. Different superscript of mean values a, b, c and d between genotype and x and y between production systems indicated significant differences (P<0.05).

♂

intensive conditions, and this result was supported by Malago et al. (2009) and Soro et al. (2014). In these crosses, Hilly (local) genetics were increasing, and the local chickens were known for their adaptation superiority in terms of their resistance to endemic diseases and other harsh environmental conditions. This finding was similar to the study of Chitate and Guta (2001). On the other hand, feed intake of chickens also differed between the production systems and genotypes (Table 1).

Under the intensive conditions, the chickens were fully fed by supplying a balanced ration and their average feed intake was comparatively higher regardless of genotypes than the chickens reared under the semi-intensive conditions. Under semi-intensive conditions, the chickens were supplemented by the supplied balanced ration and the extra amount of feed they took from the surroundings.

Costs, benefits and revenues

Costs, benefits and revenues of different genotypes under an intensive and semi-intensive production system on a per hen per year basis are presented in Table 2. The results show that the sales of eggs, surplus growers (cockerels and pullets) and spent bird (cock and hen) all have the impact on revenues. However, surplus growers (cockerel and pullet) have a major impact on profitability of the different genotype under the two production systems. That accounts from 71 – 74 per cent (cockerel 37 to 43% and pullet 29 to 35% contributes of total revenues) of the total revenues and highest for Hilly♂ × Fay♀ (F_1) (73%) in intensive conditions and the lowest was for F_2 generation (71%) of the same cross under semi-intensive management system. Similar results were observed by Okeno et al. (2013), who developed a bio-economic model to evaluate the utilization of indigenous chickens under different production systems accounting for the risk attitude

Table 2. Costs, benefits and revenues of different genotypes under intensive and semi-intensive production systems on a per hen per year basis

Variables	Production system								SEM
	Intensive				Semi-intensive				
	Hilly♂ × Fay♀		Hilly♂ × F_1♀	Ave of Hilly cross	Hilly♂ × Fay♀		Hill♂ × F_1♀	Ave of Hilly cross	
	F_1	F_2			F_1	F_2			
Revenue									
Eggs	366^{c}	354^{c}	318^{bc}	346	300^{b}	294^{ab}	276^{ab}	290	14.45
Cockerel	9884^{d}	8038^{bc}	7109^{b}	8343^{y}	4641^{a}	3899^{a}	4243^{a}	4261^{x}	987.73
Pullet	7384^{d}	6252^{c}	5691^{c}	6442^{y}	3864^{b}	3784^{ab}	3146^{a}	3598^{x}	681.48
Culled cock	3023^{d}	2424^{c}	2389^{c}	2612	1464^{b}	1205^{a}	1408^{a}	1359	296.99
Culled hen	2689^{e}	2213^{d}	2038^{c}	2313	1554^{b}	1297^{ab}	1139^{a}	1330	242.56
Liter and Gunny bag	200	200	200	200	200	200	200	200	0.00
Total revenue (BDT)	23546^{d}	19480^{c}	17745^{c}	20257^{y}	12023^{ab}	10679^{a}	10413^{a}	11038^{x}	2211.31
Costs									
Feeding male	4411^{d}	3370^{bc}	3319^{c}	3700	2083^{ab}	1680^{a}	1974^{a}	1912	433.59
Feeding female	14449^{d}	12002^{bc}	10166^{b}	12206^{y}	6694^{ab}	6076^{a}	5370^{a}	6047^{x}	1494.56
Labour	2978^{b}	2978^{b}	2978^{b}	2978	1787^{a}	1787^{a}	1787^{a}	1787	266.31
Veterinary	204^{d}	162^{c}	208^{bc}	191	53^{ab}	42^{a}	99^{ab}	65	30.10
Marketing	142^{c}	121^{b}	119^{b}	128	64^{a}	58^{a}	58^{a}	60	15.43
Fixed	50	50	50	50	25	25	25	25	5.59
Brooding	382^{c}	374^{c}	333^{b}	363	316^{ab}	310^{ab}	291^{a}	306	14.89
Total costs (BDT)	22616^{d}	19058^{c}	17175^{bc}	19616^{y}	11022^{a}	9979^{a}	9604^{a}	11595^{x}	2230.87
Profit (Rev-costs), BDT	930^{cd}	422^{b}	570^{c}	641	1001^{d}	699^{cd}	809^{cd}	836	89.56
Profit (USD) 1 USD=85 BDT	10.94^{cd}	4.97^{b}	6.71^{c}	7.54	11.78^{d}	8.23^{cd}	9.52^{d}	9.80	1.053

Fay= Fayoumi, F_1 = First filial generation, F_2 = Second Filial Generation, ♂= Male, ♀= Female, SEM= Standard Error of Mean, BDT= Bangladeshi Taka. Different superscript of mean values a, b, c and d between genotype and x and y between production systems indicated significant differences ($P<0.05$).

of the farmers. Spent cock and hen produced second of the total revenues, which account for 22 to 25 per cent of the total revenue. The highest revenue was generated from selling of spent birds in Fay × Hilly cross (F_1 generation) in both production systems and the lowest was for Hilly × F_1 genotype in semi-intensive conditions. The egg revenue varied 22-25 per cent under both production conditions. The litter revenue was assumed same for all genotypes in both production systems. As feeds were the most important cost for the rearing of chickens, it accounted for 80 per cent in intensive conditions and 78 per cent for semi-intensive conditions for crossbreds irrespective of the sexes. The feeding costs of chickens under semi-intensive conditions were comparatively lower than the chickens under intensive conditions. The birds under the semi-intensive conditions supplied comparatively lower amounts of balanced rations as they scavenged the rest of the feeds from the homestead, thus the feed costs were lower for chickens under semi-intensive conditions. The feed costs are more than all other costs, which was also reported elsewhere (Khan et al. 2014 and Okeno et al. 2013). However, Okeno et al. (2013) showed the feed costs were lower for free range chickens than the chickens of other rearing systems. The second highest costs incurred the labour costs followed by veterinary costs, which were higher in intensive farming than semi-intensive farming as under semi-intensive conditions labour cost was less than 40 per cent in all types of chickens. The opportunity costs of using a broody hen to hatch eggs and brood chicks upto weaning. Generally, farmers sell their chickens in their homestead and village markets, therefore, the marketing costs contributed the least cost in total production costs. The live weight of chickens is very important, as it affects the profitability consequently it also affected feed requirements for maintenance as well as the value of the carcass. Similar findings were reported by Lopez-Villalobos et al. (2000) and Khan et al. (2014). The profitability on a chicken per year basis was estimated considering the biological traits, nutritional and management variables and the total annual profit was derived from the difference between costs and revenue using a deterministic model. The farming operation was for a year only. The highest profitability was observed for the Hilly ♂ × Fay ♀ (F_1) genotype (USD 10.94 vs 11.78, in both production systems) than the other genotypes. The higher profitability of the F1 population obtained, as this genotype produced more eggs, heavier and higher survivability than the other genotypes. The more eggs produced more chickens, which generated higher profitability. These findings were supported by Munisi et al. (2015). The profitability of some genotype under semi-intensive conditions were comparatively higher than under intensive conditions. This might be due to the chickens under semi-intensive condition requiring less feed, labour and veterinary costs. These findings were supported by the study of Okeno et al. (2013).

Economic value of different traits of chickens

The economic value of different traits of breeding objectives of Hilly, Fayoumi (Fay) crossbreds under the intensive and semi-intensive system is presented in Table 3. The economic value of different traits was estimated on a chicken per year basis, reflecting from a year of operation. The economic value of 200-days hen house egg production (USD 0.28 to 0.38), fertility (USD 0.96 to 2.13), hatchability (USD 0.97 to 2.19), age at sexual maturity for males and females USD -0.36 to -0.14 and USD 0.11 to 0.36, respectively), weight at sexual maturity for male USD 0.31 to 0.65 and for USD 0.30 to 0.59 respectively, mature live weight and survivability for male was USD 0.08 to 0.18, and USD 0.38 to 0.49 were varied from production systems and genotypes (Table 3). The positive economic value of egg production, fertility and hatchability as in the current model number of egg sets was 70 per cent of the total number of eggs, fertility and hatchability of fertile eggs was a key factor concerned with the costs of producing chicks and the profit of hen.

The sale proceeds of cockerel (80%) and pullet (25%) as live bird at an age at sexual maturity

Table 3. Economic values (USD) of different traits of breeding objective on a per hen per year basis

Traits with unit	Production system								SEM
	Intensive Hilly♂ × Fay♀		Semi-intensive Hilly♂ × F_1♀	Ave of Hilly cross	Hilly♂ × Fay♀		Hill♂ × F_1♀	Ave of hilly cross	
	F_1	F_2			F_1	F_2			
Egg production (No)	0.36^{c}	0.32^{b}	0.38^{c}	0.35^{y}	0.30^{ab}	0.28^{a}	0.31^{b}	0.30^{x}	0.015
Fertility (%)	2.13^{c}	1.93^{c}	1.63^{b}	1.90^{y}	1.09^{a}	1.01^{a}	0.96^{a}	1.02^{x}	0.207
Hatchability (%)	2.19^{c}	1.95^{c}	1.65^{b}	1.93^{y}	1.16^{a}	1.08^{a}	0.97^{a}	1.07^{x}	0.206
Age at sexual maturity of male (days)	-0.36^{d}	-0.29^{c}	-0.26^{b}	-0.30^{x}	-0.17^{b}	-0.14^{a}	-0.16^{a}	-0.16^{y}	0.036
Age at sexual maturity of female (days)	0.36^{c}	0.31^{b}	0.25^{b}	0.31^{y}	0.13^{a}	0.12^{a}	0.11^{a}	0.12^{x}	0.044
Weight at sexual maturity of male (kg)	0.65^{c}	0.53^{b}	0.48^{b}	0.55^{y}	0.37^{a}	0.31^{a}	0.36^{a}	0.35^{x}	0.052
Weight at sexual maturity of female (kg)	0.59^{c}	0.49^{b}	0.48^{b}	0.52y	0.37^{a}	0.37^{a}	0.30^{a}	0.35^{x}	0.043
Mature weight of male at 24 weeks of age (kg)	0.18^{c}	0.14^{b}	0.14^{b}	0.15	0.10^{a}	0.08^{a}	0.09^{a}	0.09	0.016
Mature weight of female at 35 weeks of age (kg)	0.21^{c}	0.17^{b}	0.16^{b}	0.18	0.13^{ab}	0.11^{a}	0.10^{a}	0.11	0.017
Survivability of Male (%)	0.49^{c}	0.46^{c}	0.52^{c}	0.49^{y}	0.44^{b}	0.47^{c}	0.38^{b}	-0.43^{x}	0.019
Survivability of Female (%)	0.36^{c}	0.30^{c}	0.27^{b}	0.31	0.20^{a}	0.17^{a}	0.19^{a}	0.19	0.030
Feed intake of male (g/day)	-0.92^{a}	-0.78^{ab}	-1.05^{a}	-0.92^{y}	-0.58^{b}	-0.50^{b}	-0.45^{b}	-0.51^{x}	0.099
Feed intake of female (g/day)	-0.72^{a}	-0.57^{b}	-0.57^{b}	-0.62^{y}	-0.46^{b}	-0.37^{c}	-0.42^{bc}	-0.42^{x}	0.052

Fay= Fayoumi, F_1 = First filial generation, F_2 = Second Filial Generation, ♂= Male, ♀= Female, SEM= Standard Error of Mean
Different superscript of mean values a, b, c and d between genotype and x and y between production systems indicated significant differences (P<0.05).

incurred major portion of the revenue as the maximum birds were sold at this age. The economic value of egg production, fertility and hatchability, female live weight at sexual maturity and mature live weight of both sexes was positive in this current study but was higher than the values of Jiang et al. (1998), Kluyts et al. (2007) and Chaowu et al. (2016). However, Chaowu et al. (2016) reported that the economic value of reproductive traits were lower than the production traits in their study. These differences attributed due to the model used and production and marketing differences. The economic value of the survivability of male was positive under both production systems and in all genotypes. Positive economic values of survivability were also reported by Khan et al. (2014) and Visscher et al. (1994) for dairy cows. However, the economic values of birds (male) for age at sexual maturity were negative. As because of the age at sexual maturity the chicken was sold and those contributed highest revenue. The negative economic values in the age at sexual maturity of males might arise, as after selling the cockerel at this age, the rest of the male cockerel feeding intake was increased and this leads to negative economic weight at sexual maturity of males.

On the other hand, the economic value for feed intake of male and female chickens were negative and also varied between the production systems and genotypes. This negative value of feed intake was arose as the feed prices were higher among the all other items in the production costs. Similarly, the negative economic value of feed intake was reported elsewhere (for example Akbar et al. 1986; Chaowu et al. 2016, Jiang et al.1998).

The profitability of the Hilly♂ × Fay♀ crosses (F_1 and F_2) under two production systems after sensitivity analysis is presented in Table 4. It was found that the profitability of the different genotype under two production systems differed significantly by the changing of the input / output variable (Table 4).Profitability of different genotypes between production systems was fluctuated more by changing the base live weight prices and the feed cost than the changes of egg sale prices. Higher profitability was obtained by +10% changes of live weight prices and -10% live weight changes showed a low profit.

In the current model the sale proceeds, live bird dominated the revenues. On the other hand, the

Table 4. Profitability of different chickens under different production systems

Input/output	Price (%)	Production system: Intensive Hilly♂ × Fay♀ F_1	Intensive Hilly♂ × Fay♀ F_2	Semi-intensive Hilly♂ × F_1♀	Ave of Hilly cross	HillyB& × Fay♀ F_1	HillyB& × Fay♀ F_2	Hilly♂ × F_1♀	Ave of hilly cross	SEM
Base		10.94^{d}	4.97^{a}	6.71^{ab}	7.54^{x}	11.78^{d}	8.23^{b}	9.52^{c}	9.84^{y}	1.053
Egg	+10	10.95^{d}	4.98^{a}	6.73^{ab}	7.55^{x}	11.79^{d}	8.24^{b}	9.53^{c}	9.85^{y}	1.052
	-10	10.92^{d}	4.95^{a}	6.70^{ab}	7.52^{x}	11.76^{d}	8.21^{b}	9.50^{c}	9.82^{y}	1.052
Live weight	+10	37.97^{c}	27.23^{b}	26.98^{b}	30.73^{y}	25.33^{ab}	20.21^{a}	21.21^{a}	22.25^{x}	2.590
	-10	-16.1^{a}	-17.3^{a}	-13.56^{a}	-15.65^{x}	-1.78^{b}	-3.75^{b}	-2.17^{b}	-2.57^{y}	2.980
Feed	+10	-10.65^{a}	-12.62^{a}	-8.68^{a}	-10.65^{x}	1.83^{b}	-0.53^{b}	1.18^{b}	-0.48^{y}	2.635
	-10	33.12^{c}	23.05^{b}	22.58^{ab}	26.25^{y}	22.10^{ab}	17.35^{a}	18.16^{a}	19.20^{x}	2.297

Fay= Fayoumi, F_1 = First filial generation, F_2 = Second Filial Generation, ♂ = Male, ♀= Female, SEM= Standard Error of Mean. Different superscript of mean values a, b, c and d between genotype and x and y between production systems indicated significant differences (P<0.05).

profitability changed with the changes of feed prices, by -10% feed price.

The profitability of sensitivity analysis significantly differed between genotypes and highest profitability was observed for Hilly × Fay (F_1 generation) than other genotypes in all scenarios. Live bird prices and feed costs incurred more profitability, and these findings were supported by Okeno et al. (2016) for indigenous chickens' profitability analysis model and feed was the major elements for profitability observed by Khan et al. (2014) for dairy breed study.

Sensitivity analysis

The economic value of different traits in relation to change in the base price of input (feed) and output (sale of egg and per kg live bird) variables ±10% of all genotypes under two production systems are given in Table 5 and 6, respectively. The changing of egg sale price does not influence the economic values between genotype and production systems. On the other hand, the economic values were changed by changing the price of a per kg live weight, and per kg feed prices ±10% has the greatest impact on profitability and economic value. More fluctuated values of economic values were observed in the changes of per kg live bird price in both production systems and changes in the feed costs showed moderate changes of the economic values. As the product (influenced the corresponding output) prices increase the economic values, which has increased or decreased the economic values. This statement supported the work by Groen et al. (1989), and Jiang et al. (1990), who stated that

Table 5. Economic values after sensitivity analysis under intensive conditions

Input/ output	Price Level (%)	Intensive: Hilly ♂× Fay♀ (F_1) EP	MLwt ♂	MLwt ♀	Sur ♂	Sur ♀	FI ♂	FI ♀	Hilly ♂× Fay♀ (F_2) EP	MLwt ♂	MLwt ♀	Sur ♂	Sur ♀	FI ♂	FI ♀
Base		0.36^{b}	0.18^{b}	0.21^{b}	0.49^{c}	0.36^{b}	-0.72^{b}	-0.91^{b}	0.32^{b}	0.14^{a}	0.17^{a}	0.46^{b}	0.30^{a}	-0.78^{a}	-0.57^{c}
Egg	+10	0.37^{b}	0.18^{b}	0.21^{b}	0.50^{c}	0.37^{b}	-0.72^{b}	-0.91^{b}	0.33^{b}	0.15^{a}	0.17^{a}	0.46^{b}	0.31^{a}	-0.78^{a}	-0.57^{c}
	-10	0.36^{b}	0.18^{b}	0.21^{b}	0.49^{c}	0.36^{b}	-0.72^{b}	-0.91^{b}	0.32^{b}	0.15^{a}	0.17^{a}	0.46^{b}	0.30^{a}	-0.78^{a}	-0.57^{c}
Live weight	+10	0.72^{d}	0.21^{c}	0.25^{c}	0.88^{d}	0.43^{b}	-0.72^{b}	-0.92^{b}	0.63^{d}	0.17^{b}	0.20^{b}	0.80^{c}	0.36^{a}	-0.78^{a}	-0.57^{c}
	-10	0.25^{ab}	0.17^{b}	0.20^{b}	0.37^{b}	0.34^{b}	-0.72^{b}	-0.91^{b}	0.23^{b}	0.14^{a}	0.17^{a}	0.36^{a}	0.29^{a}	-0.57^{b}	-0.78^{a}
Feed	+10	0.18^{a}	-0.63^{a}	-0.60^{a}	-0.50^{a}	-0.45^{a}	-1.60^{a}	-1.82^{a}	0.17^{a}	0.14^{a}	0.17^{a}	0.30^{a}	0.30^{a}	-0.87^{a}	-0.63^{b}
	-10	0.55^{c}	0.18^{b}	0.22^{b}	1.30^{e}	0.97^{c}	-0.04^{c}	-0.27^{c}	0.48^{c}	0.15^{a}	0.17^{a}	1.13^{d}	0.80^{b}	-0.21^{c}	-0.02^{d}
Average		0.40	0.07^{x}	0.10^{x}	0.50	0.34	-0.75	-0.95^{x}	0.35	0.15^{y}	0.17^{y}	0.57	0.38^{y}	-0.68^{x}	-0.53
SEM		0.072	0.004	0.006	0.058	0.065	0.171	0.026	0.061	0.004	0.004	0.049	0.0555	0.018	0.043

Fay= Fayoumi, F1 = First filial generation, F2 Second Filial Generation, EP= Egg production, MLwt = Mature Live weight, Fert= Fertility, Hatch= Hatchability, Sur= Survivability,♂ = Male, ♀= Female, SEM= Standard Error of Mean Different superscript (a, c and d) of mean values indicated significant differences (P<0.05) between price level changed of input and output variable.

Table 6. Economic values after sensitivity analysis under semi-intensive conditions

Input/ output	Price Level (%)	Intensive													
		Hilly ♂× Fay♀ (F_1)							Hilly ♂× Fay♀ (F_2)						
		EP	MLwt		Sur		FI		EP	MLwt		Sur		FI	
			♂	♀	♂	♀	♂	♀		♂	♀	♂	♀	♂	♀
Base		0.30^{b}	0.10	0.13^{a}	0.44^{a}	0.20^{c}	-0.46^{a}	-0.58^{a}	0.28^{a}	0.08^{a}	0.11^{a}	0.47^{a}	0.17^{a}	-0.50^{a}	-0.37^{a}
Egg	+10	0.31^{b}	0.10	0.13^{a}	0.45^{a}	0.21^{c}	-0.46^{a}	-0.58^{a}	0.28^{a}	0.09^{a}	0.11^{a}	0.47^{a}	0.18^{a}	-0.50^{a}	-0.36^{a}
	-10	0.31^{b}	0.10	0.13^{a}	0.45^{a}	0.21^{c}	-0.45^{a}	-0.47^{b}	0.28^{a}	0.09^{a}	0.12^{a}	0.47^{a}	0.18^{a}	-0.50^{a}	-0.36^{a}
Live weight	+10	0.52^{d}	0.11	0.15^{b}	0.67^{b}	0.24^{c}	-0.46^{a}	-0.58^{a}	0.48^{c}	0.10^{b}	0.14^{b}	0.69^{b}	0.21^{a}	-0.50^{a}	-0.36^{a}
	-10	0.24^{ab}	0.09	0.12^{a}	0.37^{a}	0.19^{c}	-0.46^{a}	-0.58^{a}	0.21^{a}	0.08^{a}	0.11^{a}	0.40^{a}	0.16^{a}	-0.51^{a}	-0.37^{a}
Feed	+10	0.21^{a}	0.10	0.13^{a}	0.36^{a}	0.20^{c}	-0.50^{a}	-0.63^{a}	0.19^{a}	0.09^{a}	0.12^{a}	0.40^{a}	0.18^{a}	-0.55^{a}	-0.40^{a}
	-10	0.41^{c}	0.10	0.13^{a}	0.93^{c}	0.59^{b}	-0.03^{b}	-0.14^{c}	0.38^{b}	0.09^{a}	0.12^{a}	0.94^{c}	0.55^{b}	-0.08^{b}	-0.04^{b}
Average		0.33	0.10^{y}	0.13^{y}	0.52	0.26	-0.40	-0.51^{y}	0.30	0.09^{x}	0.12^{x}	0.55	0.23^{x}	-0.32^{y}	-0.45
SEM		0.040	0.002	0.003	0.078	0.055	0.062	0.064	0.038	0.003	0.004	0.075	0.053	0.062	0.059

Fay= Fayoumi, F_1 = First filial generation, F_2 Second Filial Generation, EP= Egg production, MLwt = Mature Live weight, Sur= Survivability, ♂= Male, ♀= Female, SEM= Standard Error of Mean Different superscript (a, c and d) of mean values indicated significant differences ($P<0.05$) between price level changed of input and output variable.

changes the product price would only change the economic values of those traits that influence the output of corresponding products. In addition, the sensitivity study showed that the economic values of studied traits was not static as it has been changing with the using computing models (Von Arendonk, 1985; Brascamp et al. 1986 and Weigel et al. 1995), production systems (Okeno et al. 2012) and breeds of animal (Chaowu et al. 2016 and Groen et al. 1997) and time of computation (Khan et al. 2014). As the market prices of input and output variables are changing with the changes of places and periods of time. The estimation of economic values depends on the prediction of future production system characteristics, including future prices of input and output variables, therefore, it is good to revise economic values in an interval of time. The production level and the market are dynamic, a little change of market prices of the input and output variables will result in changes of economic values, which is the key factor in the evaluation of the economic value by Chaowu et al. (2016).

This study reveals that the production performance of different genotypes varied in the production systems and genotypes. For a one-year operation, the sale proceeds of eggs, surplus growers and culled breeding stocks and costs of feeding have impacted on the profitability. The genotype, F_1 (Hilly × Fay) has the better performance traits that contributes to higher profitability of this genotype in both production system. The positive economic value of egg production, fertility, hatchability, live weight and survivability indicated that the incorporation of these traits in future poultry breeding programmes will lead to a profitable poultry industry. Further more, the current deterministic model was developed in an Excel spreadsheet. This model and method of deriving profitability and economic value of different traits in a breeding objective can be widely used for other poultry and livestock species for future breeding decisions.

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