Modelling the biological aspects of broiler breeding: integrated and non-integrated systems

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Summary

The objective of present study was to derive the economic values for important traits in broiler breeding program and to specify their sensitivity to production circumstances, using a deterministic bio-economic model, reflecting an integrated or non-integrated broiler chicken's production system. Model focuses on multiplier breeder, hatchery, commercial grower and processor stages. The estimated economic values ranged from -0.2035 to 0.2318 for both integrated and non-integrated systems. The estimated economic values based on non-integrated system were higher than those of integrated system except for hatching egg number (0.0009 vs. 0.0014), mortality (-0.0078 vs. -0.0068) and wings yield (0.0206 vs. 0.0158). In integrated situation, the effect of changes in the mean of hatching egg number, finishing weight and mortality on the economic values of traits was examined. The results showed that hatching egg number did not affect the economic values of traits at the preceding stages. On the other hand, changes in traits at the commercial grower, namely finishing weight and mortality affected the economic values of traits at both commercial grower and processor stages. The results of sensitivity analysis (± 20%) showed that traits at the multiplier and hatchery stages were sensitive to changes in feed costs at rearing and laying periods and also changes in the price of parental stock chicks, but the traits relating to commercial stage did not show any sensitivity to these factors. Among different factors, feed cost in commercial stage had the most impact on economic values of finishing weight, feed consumption and mortality.

Key words

broilers, economic values, integrated and non-integrated systems

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Introduction

The first stage of developing organized breeding programs for livestock is generally the explanation of a breeding goal (Harris, 1970; Danell, 1980; Ponzoni, 1986; Groen, 1989). A breeding goal comprises some traits that are more important than the others because of their contribution to the improved returns to the producer (Kahi and Nitter, 2003). This does not apply to all cases, i.e., pet species (Dekkers, 1994). The selection index established the basis for the best combination of the traits considered (Fuerst-Waltl and Baumung, 2009), maximizing genetic improvement in overall breeding objectives (Hazel and Lush, 1942).

Economic value of a trait is the extent to which improvement of its genetic merit can contribute to an improvement of economic efficiency of animal production systems (Brascamp, 1978; Jiang et al., 1998). One of the best tools available to determine the economic value of genetic changes in various traits is a bio-economic model (Groen, 1989; Kosgey et al., 2003; Jones et al., 2004; Haghdoost al., 2008).

There have been relatively few published papers on the derivation of economic values for broiler chickens (Harris and Newman, 1994; Jiang et al., 1998). Hogestt and Nordskog (1958) obtained economic values in layer chickens based on marginal costs and revenues on simple functions (per bird). Using a single profit function, Shalev and Pasternak (1983) derived economic values (per marketable broiler) in a fully integrated broiler enterprise. Dickerson (1970) suggested that considering the whole production-marketing system to derive economic values is much more important than part of the system. Hence, Groen et al. (1998) modeled a broiler production system, including multiplier breeder, hatchery, commercial grower and processor. They estimated the economic values of the traits related to levels of production system per unit of product. Fallah-Khair et al. (2009) studied the economic values of the economic traits of broiler breeders in a partially integrated system by using a deterministic model per unit of product (chick yield).

In Iran, there is no data available to construct a country-specific national genetic index for broiler chickens (Ebrahimpourtaher et al., 2018). Therefore, in the current study a system including multiplier breeder, hatchery, commercial grower and processor was modeled. The objectives of the present study were: (i) to derive economic values for traits of broiler chickens using a deterministic model under Iran's production system, (ii) to test the sensitivity of economic values under different production and economic circumstances and (iii) to compare the economic values based on non-integrated and integrated systems.

Materials and methods

Data description

The data used in this study were obtained from 17 broiler farms distributed in three provinces (Tehran, Guilan and Mazandaran) of Iran, where most industrial broiler enterprises are located. The data were obtained from the enterprises upon the official request from the Guilan University. Descriptive statistics for performance data are shown in Table 1 (the mean values of data from 17 broiler enterprises). Economic input parameters and marketing circumstances were based on data collected in 2018 (Table 2). All participating broiler enterprises were subjected to recording program.

Model Development

A deterministic bio-economic model was developed (Fig. 1) based on Groen et al. (1998). The model focuses on multiplier breeder, hatchery, commercial grower and processor, at the bird and farm levels. In this study an integrated (vertical integration with situation where the whole breeding chain belongs to one owner or an owner group) and a non-integrated (every phase of the chain is handled as a separate enterprise) system were investigated. In an integrated system, the input price is costprice of product but in non-integrated system the input price is marketing price. Therefore, the economic values were different in both systems. In both integrated and non-integrated systems, companies which used the same strain were considered.

For Iran market, there were both of the systems which scattered through the country. In non-integrated system, input parameters included the market prices relating to the products of each single stage, but for the integrated system, the total costs per unit of product were estimated. A preferred scale of 10,000,000 kg final product carcass output at the processor stage was assumed to calculate economic values. The model assumed a fixed consumer market demand (Groen et al., 1998). In the multiplier breeder stage and at the start of rearing period, number of male and female chicks were fixed at a specific ratio. Rearing period was 25 weeks and laying period included 40 weeks. Assuming for male and female separately, three rates of mortality were considered in multiplier stage, including early and late rearing periods (0 to 2 weeks and 2 week of age until the end of rearing period) and of laying period. Feed costs associated with early rearing mortality were neglected. Feed costs associated with mortality during other periods are proportional to live weight of the birds at half time of that period. Feed requirements were estimated for rearing females and males, laying females and breeder males. For the representative economic model, the hatchery stage was separated from the multiplier breeder stage and operated as a distinct section. In the commercial grower stage, males and females were reared interwoven and there is no difference between the prices of male and females. Feed consumption is set for a given finishing weight (six weeks). The rate of mortality in this stage was assumed on two situations, which were related to early (week 1) and late mortality (from weeks 1 to 6). Feed costs associated with early mortality was connived, but the feed costs associated with late mortality were related to 50% of the finishing weight of the birds. In Iran, the commercial growers have been selling final product chicks without any extra payment for their quality. At the commercial stage, the changes of profit, i.e., profit in the base situation minus profit after one unit change in average of a trait, was divided by two because it was assumed that there is no difference between males and females. Traits related to carcass in the processor stage included breast meat, legs and wings as their relative percentages of whole carcass.

Table 1. Descriptive statistics for performance data

Variables[€]	Abbreviation	⊗Mean Value
No. of produced eggs per hen housed (No/HH)	EPS	187.3
No. of culled eggs per hen housed (No/HH)	CE	5.9
Body weight of breeder female at end of laying period (kg/bird)	BWFLPS	4.1
Body weight of breeder male at end of laying period (kg/bird)	BWMLPS	5.2
Feed consumption at rearing period of females (kg/bird)	FCFRPS	11.28
Feed consumption at laying period of females (kg/bird)	FCFLPS	46.7
Feed consumption at rearing period of males (kg/bird)	FCMRPS	14.97
Feed consumption of breeder males (kg/bird)	FSMRPS	46.7
Ratio of males to females at the beginning of rearing period	RATIOR	0.12
Ratio of breeder males selected to females housed	RATIOL	0.11
Sexual error at rearing period (%)	SEXERROR	1.4
No. of male interspiking as a percentage of breeder males, %	MASPIK	20
No. of females died during early rearing (Weeks 0 to 2), %	MORTEFPS	0.5
No. of females died during late rearing (> Week 2), %	MORTLFPS	2.86
No. of males died during early rearing (Weeks 0 to 2), %	MORTEMPS	1
No. of males died during late rearing (> Week 2), %	MORTLMPS	11.3
No. of females died during laying, % # PS females housed	MORTLAFPS	6.1
No. of breeder males died, %	MORTLAMPS	8.9
Faeces per bird at end of laying period (kg/bird)	MULPS	16.85
No. of fertile eggs as a percentage of total produced eggs	FERT	93
No. of chicks (alive) as a percentage of fertile eggs	HATCH	81
Finishing weight of bird (kg/bird)	FINWEI	2.2
Feed conversion ratio during growing period	FCR	2.1
Feed consumption of bird (kg/bird)	FCG	4.6
No. of birds died during late growing, %	MORTLG	8.07
Faeces per bird finished (kg/bird)	MUG	2.6
Carcass yield FP bird, % finishing weight	CY	75.3
Breast yield FP bird, % total carcass weight	BY	33.7
Wings yield FP bird, % total carcass weight	WY	9.6
Legs yield FP birds, % total carcass weight	LY	29.8

[€] The abbreviations of FP, PS and HH are final product, parental stock and hen housed, respectively
⊗ The values are mean value of 17 broiler enterprises considered

Table 2. Prices and costs of economic variables

Variables	Abbreviation	[1]Mean Value
Salvage value parental stock female or male at the end of laying period ($/kg)	sfml	1.000
Salvage value error sex (male and female) at end of rearing period ($/bird)	sesr	1.000
Salvage value for culled eggs ($/kg)	pec	0.078
Cost price of ration PS rearing period ($/kg)	prl	0.290
Cost price of ration PS breeder male and PS laying female ($/kg)	prr	0.270
Cost price of ration FP birds ($/kg)	pf	0.390
Market price PS starting bird ($/chick)	Pfc (pmc)	4.550
Market price FP egg hatched ($/egg)	pe	0.330
Market price FP starting bird (chick) ($/bird)	psb	0.448
Market price FP bird or finishing weight ($/kg)	pfw	1.290
Market price FP carcass ($/kg)	pc	1.830
Market price FP breast yield ($/kg)	pb	2.680
Market Price FP wings yield ($/kg)	pw	2.340
Market Price FP legs yield ($/kg)	pl	2.040
Market Price FP remainder yield ($/kg)	pr	1.020
price FP faeces ($/kg)	pm	0.041
price PS cockerel ($/bird)	ppco	14.760
whole bird base processing cost ($/kg)	wbb	0.160
further processed base processing cost ($/kg)	fpb	0.220

[1] Unit: 1.00 $US = 31840 Rials, 1.00 $US = 0.74 Euro, approx.

Revenues of the system

Revenues are divided into four parts, including revenues from multiplier breeder, hatchery, commercial grower and processor. In the multiplier breeder stage, revenues came from selling final product (FP) fertile eggs, culled males and females as sexual error at the end of rearing period, lay-off females later than week 40, females and males at the end of laying period, non-fertile eggs, and faeces per bird during rearing and laying periods. In the hatchery stage, revenues consisted of final product live chicks. Revenues of the commercial grower arise from selling FP birds finished, and faeces per bird. In the processor stage, revenues came from two situations including whole carcass or breast, wings, and legs (further processed). Some equations on estimation of revenues, such as equations for culled males and females as sexual error at the end of rearing period for mating, lay-off females later than week 40, females and males at the end of laying period and non-fertile eggs, were extracted from Groen et al. (1998). Factors that affect the profit of the whole broiler producer chain were dependent on all the market prices for each stage in non-integrated system and market price of entry in integrated system. As shown in Fig. 3, all the factors (market price of products) affect the profit of the system. Equations for computing number of birds existing at the end of rearing and laying period for multiplier breeder stage and number of birds existing at the end of growing period for commercial grower stage and overall revenues (R) as well as costs (C) of the system were developed and presented in the appendix.

Costs of the system

Cost components for the multiplier breeder stage were the costs of purchasing the female and male chicks, feed costs, other variable costs relating to vaccination, drugs, disinfectors, chick boxes, egg combs and also fixed costs. Estimation of variable and fixed costs were dependent on data collected from the farms. The costs related to the hatchery were assumed to be as variable costs only, and were based on the number of eggs hatched. The commercial grower stage costs assumed to be feed cost, purchasing FP chicks from the hatchery, other variable costs that were assumed to be fixed per bird. Finally, the processor component costs, giving emphasis on the processing in order to achieve economic values of processor traits, were included based on the whole and further

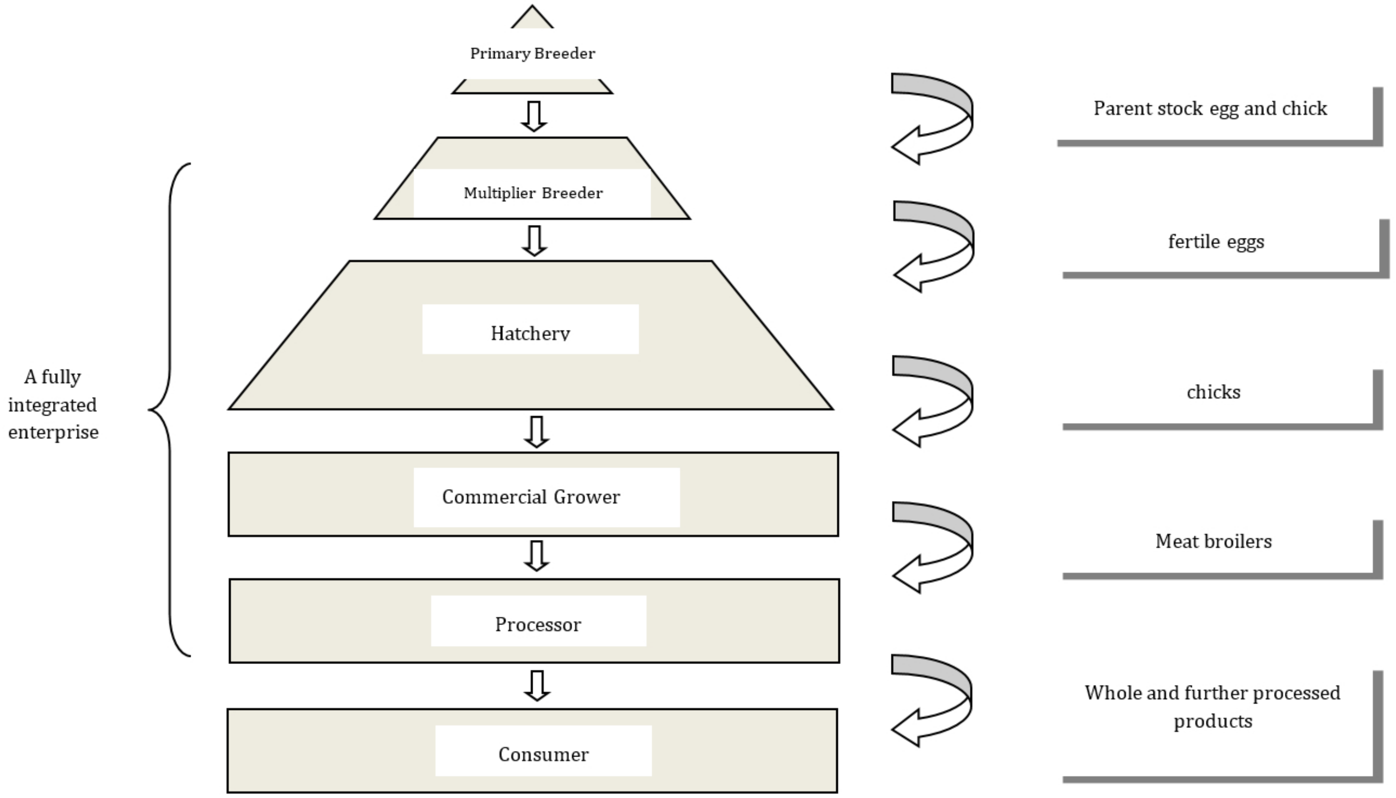

Figure 1. Structure of the broiler production system under the control of a fully integrated enterprise

processed bases. Prices per kilogram of live weight and mortality were assumed to be the same for FP males and FP females. Also, the basis for feed requirements was per kilogram of feed. The costs related to labor, electricity, etc, have been combined into variable costs in each stage. The scheme of the simulation model according to revenues and costs parameters are shown in Fig. 3.

Derivation of economic values

Economic value for each trait was estimated by comparing the profit (R-C) for a base situation and profit after a marginal change in genetic merit for the trait, keeping all other traits in the breeding objective constant. In an integrated system, the cost price of product in each stage is the entry price of the next stage but in non-integrated system the entry price for each stage is the market price. This was the highlighted difference between integrated and non-integrated systems.

The economic value of trait L can be derived as: 1) running the bio economic model using current population means for all traits, including the current mean for trait L, and recording the average profit per bird; 2) increasing the mean of trait L by Δ $(P(\mu_L + \Delta))$, while keeping the means of other traits at their current values $P(\mu_L)$, running the model again and recording the new average profit per bird, and 3) deriving the economic weight for trait L, as follows:

$$v_L = \frac{P_{(\mu_L+\Delta)} - P_{(\mu_L)}}{\Delta_L} = \frac{\Delta_P}{\Delta_L}$$

where Δ_p is change of profit and Δ_L is the change of trait L by one unit of product. Comparison of economic values of two traits and assessment of the importance of a trait in an objective can be fulfilled by estimation of relative economic values (REVs), which were calculated as follows:

$$REV = \sigma_g \times v_L$$

where σ_g is the genetic standard deviation. Used genetic parameters were based on Ahmadpanah (2011).

Results and Discussion

As pointed out by Groen et al. (1998), Rewe et al. (2006) and Wood (2009), economic values are dependent on the assumed performance and price levels. The scale of our deterministic model for deriving the economic values of important traits was fixing the output but there are different methods to set the scale of model including fixing the population size, benefit-cost and output. In all methods, the economic value is the same but if the output of system is the single product, it will be different (Vargas et al., 2002).

Table 3 presents the economic values (EVs) for the integrated and non-integrated broiler enterprise. The highest economic value was obtained for finishing weight (0.2318 US$/kg). Economic value for finishing weight originated from a decrease in the number of birds (per fixed output of product) and consequently a decrease in purchasing day-old chicks and also associated variable costs. The lowest EVs were those related to multiplier breeder stage. More hatching egg number per hen housed resulted to, under fix output situation, lower numbers of parental stock (PS) female and males.

Table 3. Economic values for non-integrated and integrated broiler enterprises under fixed output product

System stage	Performance trait	Unit	Economic value	
			Integrated	Non-integrated
Multiplier breeder	Hatching egg number	egg·hen housed	0.0014	0.0009
	Feed consumption laying hen	kg·hen housed	-0.0018	-0.0014
	Feed consumption rearing PS females	kg·hen	-0.0020	-0.0015
	Late mortality PS females	%	-0.0005	-0.0004
	Laying mortality PS females	%	-0.0006	-0.0005
Hatchery	Fertility	%	0.0031	0.0045
	Hatchability of fertile	%	0.0034	0.0050
Commercial grower	Finishing weight	kg·bird	0.2318	0.2318
	Feed consumption	kg·bird	-0.2035	-0.2035
	Mortality	%	-0.0068	-0.0078
Processor	Carcass yield	%	0.0401	0.0440
	Breast meat	%	0.0267	0.0259
	Wings yield	%	0.0158	0.0206
	Legs yield	%	0.0189	0.0159

Among multiplier and hatchery traits, fertility and hatchability had significant impacts on profit.

Different levels of production traits and price levels were considered to fulfill the sensitivity analysis of economic values (Tables 4 and 5). As shown in Table 4, changes in hatching egg number did not affect the economic values of finishing weight, feed consumption, mortality and carcass yield. On the other hand, changes in traits at the commercial grower stage, such as final weight and commercial feed, affect the economic values of traits at both the commercial grower and processor stages, but not upstream changes, those of the multiplier breeder and hatchery stages.

A 20% increase in hatching egg number results in decreases of the economic values of the hatching egg number by 28%, hatchability by 14%, and an increase of the economic value of laying feed by 16%. On the other hand, a 20% increase in finishing weight results in decreases of the economic values of finishing weight by 0.1%, mortality by 14%, and increase of economic values of feed consumption by 87%, carcass weight by 19% (from 0.0401 to 0.0479 $). For instance, a 20% change in finishing weight leads to 0.1818 $ change in economic value of feed consumption. Jiang et al. (1998) showed that a 20% increase in finishing weight make 0.0658 $ change in economic value of feed consumption. Also, changes in economic value of hatching egg number resulted in changes in the economic values of hatching egg number (57%), hatchability (22%), and feed laying (26%).

As the finishing weight increase, the economic value of carcass weight was increased and for mortality decreased. A 10% change in finishing weight made 0.0005 $ change in economic value of mortality. Changes in finishing weight and mortality did not influence the economic values of traits related to multiplier breeder traits.

As shown in Table 5, increased mean egg production leads to a decrease in economic values of traits considered except for laying feed. This is followed by increased total costs and influence system profit. Based on the equations, it was shown that these traits are related to mean egg production (Shultz, 1986; Jiang et al., 1998; Fallah-Khair et al., 2009). This reduce is related to increased costs and its effect on system profit.

In addition to the bio-economic factors considered, farm profitability depends on many other factors including economy of scale, farmer's age, time dedicated to farm activities, use of machinery, land productivity and application of management technologies (Yassin et al., 2012). It is worth noting that farm profitability of broiler breeder production is very challenging because many factors affect the profitability in which statistical analysis is going to be difficult, and getting information from industrial companies are pretty hard. These reasons were also reported by Groen et al. (1998), Faridi et al. (2011) and Yassin et al. (2012). As pointed out by Carvalho et al. (2015), the cost of electricity, as well as area of occupied land, production scale and feed intake per hatching egg significantly affect the economic

Table 4. Absolute economic values ($\$$US·marketable bird^{-1}·unit^{-1}) for the traits with changes in levels of production under modified conditions in an integrated broiler enterprise

Traits	Hatching Egg No.	Base and alternative production level								
		-20	-15	-10	-5	Base	+5	+10	+15	+20
Hatching egg		0.0021	0.0019	0.0017	0.0016	0.0014	0.0012	0.0012	0.0011	0.0010
Hatchability		0.0042	0.0039	0.0037	0.0035	0.0034	0.0032	0.0031	0.0030	0.0029
Laying feed		-0.0023	-0.0022	-0.0020	-0.0019	-0.0018	-0.0016	-0.0015	-0.0015	-0.0015
Fin. weight		0.2318	0.2318	0.2318	0.2318	0.2318	0.2318	0.2318	0.2318	0.2318
Feed cons.		-0.2035	-0.2035	-0.2035	-0.2035	-0.2035	-0.2035	-0.2035	-0.2035	-0.2035
Mortality		-0.0068	-0.0068	-0.0068	-0.0068	-0.0068	-0.0068	-0.0068	-0.0068	-0.0068
Carcass yield		0.0401	0.0401	0.0401	0.0401	0.0401	0.0401	0.0401	0.0401	0.0401
	Fin. weight	-20	-15	-10	-5	Base	+5	+10	+15	+20
Hatching egg		0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014
Hatchability		0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034
Laying feed		-0.0018	-0.0018	-0.0018	-0.0018	-0.0018	-0.0018	-0.0018	-0.0018	-0.0018
Fin. weight		0.2318	0.2318	0.2318	0.2318	0.2318	0.2318	0.2316	0.2314	0.2314
Feed cons.		-0.3853	-0.3399	-0.2944	-0.2490	-0.2035	-0.1581	-0.1126	-0.0713	-0.0258
Mortality		-0.0057	-0.0060	-0.0062	-0.0065	-0.0068	-0.0070	-0.0073	-0.0075	-0.0078
Carcass yield		0.0320	0.0340	0.0360	0.0380	0.0401	0.0421	0.0442	0.0459	0.0479
	Mortality	-20	-15	-10	-5	Base	+5	+10	+15	+20
Hatching egg		0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014
Hatchability		0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034	0.0034
Laying feed		-0.0018	-0.0018	-0.0018	-0.0018	-0.0018	-0.0018	-0.0018	-0.0018	-0.0018
Fin. weight		0.2355	0.2346	0.2336	0.2327	0.2318	0.2308	0.2298	0.2289	0.2279
Feed cons.		-0.2017	-0.2022	-0.2026	-0.2031	-0.2035	-0.2040	-0.2045	-0.2049	-0.2054
Mortality		-0.0065	-0.0066	-0.0066	-0.0067	-0.0068	-0.0068	-0.0069	-0.0069	-0.0070
Carcass yield		0.0401	0.0401	0.0401	0.0401	0.0401	0.0401	0.0401	0.0401	0.0401

Table 5. Economic values of dam traits at different egg production levels in an integrated broiler enterprise. The economic values were expressed as $ per unit per marketable bird. The unit is per egg for hatching egg number, per percent for hatchability/fertility and per kilogram for laying feed

Traits	Mean egg production											
	30	50	70	90	110	130	150	170	190	210	230	250
Hatching Egg	0.0530	0.0190	0.0110	0.0060	0.0041	0.0029	0.0021	0.0017	0.0014	0.0011	0.0009	0.0008
Hatchability	0.0190	0.0118	0.0085	0.0066	0.0056	0.0047	0.0041	0.0037	0.0034	0.0030	0.0028	0.0026
Fertility	0.0174	0.0106	0.0070	0.0059	0.0051	0.0042	0.0037	0.0033	0.0030	0.0027	0.0025	0.0024
Laying feed	-0.0110	-0.0060	-0.0040	-0.0038	-0.0031	-0.0026	-0.0023	-0.0020	-0.0017	-0.0017	-0.0015	-0.0011

efficiency of the broiler breeder farms in Southwestern Parana, Brazil. In this study, the cost of electricity was not considered as a separate cost and it was combined into variable costs, which included the cost of transport, electricity, labor, energy and packing.

Table 6 shows the sensitivity of the economic values to changes in some inputs and outputs with respect to fixed output product. In order to analyze the sensitivity of the economic values to changes in different factors, base level of the price of PS chicks, rearing feed, laying feed, finishing weight and commercial feed were changed by ± 20%, separately. Results of sensitivity analysis showed that economic values of hatching egg number, fertility, hatchability and laying feed had the highest sensitivity to changes in rearing and laying feed. In other words, when the price of feed increased, the economic values of traits mentioned are increased except for laying feed. Increasing the mean of fertility and hatchability make a decrease to purchase PS chicks and decreases feed and variable costs, leading more profit of the system.

By increasing the price of feed, economic values for finishing weight and mortality decreased. In order to obtain fixed carcass output, a decrease in finishing weight made an increase to alive chicks and consequent increment in feed and variable costs. When the price of finishing weight increased, its economic value increased. Changes in finishing weight do not affect the economic value of feed consumption and mortality. Also, changes in the price of feed and finishing weight would not result in changes to multiplier breeder traits. Among investigated different factors in an integrated system, changes in finishing weight had the highest influence on system profit.

Table 7 shows the sensitivity of economic values of hatching egg number and laying feed to PS chicks, rearing feed, laying feed and economic values of finishing weight, feed consumption and mortality to the price of feed and finishing weight in a non-integrated broiler enterprise. The results showed that hatching egg number do not have any sensitivity to changes in PS chicks and laying feed. The economic value of laying feed had the highest sensitivity to changes in rearing and laying feed prices, which is the most important component on system profit. On the other hand, in a non-integrated broiler enterprise, the economic values of finishing weight, feed consumption and mortality were influenced by changes in feed price. The highest change was related to finishing weight because of its effect on revenues. In an integrated system, Chaowu et al. (2016) showed that the economic values are sensitive to production levels, product prices and feed prices; there are both linear and nonlinear relationships between economic values and production circumstances, which is in accordance to our results.

The relative economic values per genetic standard deviation for an integrated system are presented in Fig. 2. Genetic change for a trait, which relative economic value is near to zero, had little effect on system profit. Among investigated traits, body weight had the highest relative economic value. Genetic change of body weight was led to get more profit of system. This trait had more genetic variance and absolute economic value than other traits. Body weight, carcass weight, breast weight and feed consumption had higher relative economic values than hatching egg number, hatchability and mortality traits. The relative economic values show affirmation of traits to breeding goal, generally.

Table 6. Absolute economic values ($\$US \cdot$marketable bird$^{-1}\cdot$unit^{-1}) for the traits with changes in prices for different levels of inputs and outputs along with system profit under modified conditions in an integrated broiler enterprise

Input/output[1]	Price lev. (%)	Multiplier traits					Commercial traits		
		Profit[2]	Hatching egg	Feed cons. laying	fertility	Hatchability	Finishing weight	Feed consumption	Mortality
PS chicks	+20	0.4323	0.0014	-0.0019	0.0031	0.0034	0.2317	-0.2036	-0.0068
	-20	0.4474	0.0013	-0.0019	0.0029	0.0032	0.2317	-0.2036	-0.0067
PS feed R[€]	+20	0.4071	0.0016	-0.0023	0.0034	0.0038	0.2318	-0.2896	-0.0069
	-20	0.4561	0.0014	-0.0015	0.0029	0.0032	0.2318	-0.2035	-0.0066
PS feed L	+20	0.4194	0.0015	-0.0022	0.0032	0.0036	0.2317	-0.2035	-0.0069
	-20	0.4643	0.0013	-0.0014	0.0028	0.0031	0.2318	-0.2035	-0.0066
Comm. feed	+20	0.0685	0.0014	-0.0018	0.0031	0.0034	0.1470	-0.1768	-0.0078
	-20	0.8111	0.0014	-0.0018	0.0030	0.0033	0.3165	-0.1618	-0.0058
Fin. weight	+20	1.0092	0.0014	-0.0018	0.0030	0.0034	0.3618	-0.2035	-0.0068
	-20	-0.1296	0.0014	-0.0018	0.0030	0.0034	-0.0278	-0.2035	-0.0068

[1] Average price for integrated broiler enterprises

[2] Profit in this way resulted from final product output (bird finished)

[€] the abbreviations: PS = Parental Stock, R = Rearing, L = Laying, Comm = Commercial, Fin = Finishing

Table 7. Absolute economic value ($\$US \cdot product^{-1} \cdot unit^{-1}$) for the traits with changes in prices for different levels of inputs and outputs along with system profit under modified conditions in a non-integrated broiler enterprise

Input/output[1]	Price lev. (%)	Multiplier traits					Commercial traits		
		Profit[2]	Hatching egg	Feed cons. laying	fertility	Hatchability	Finishing weight	Feed consumption	Mortality
PS chicks	+20	0.1572	0.0009	-0.0014	-	-	-	-	-
	-20	0.1684	0.0009	-0.0013	-	-	-	-	-
PS feed R€	+20	0.1463	0.0010	-0.0016	-	-	-	-	-
	-20	0.1792	0.0008	-0.0010	-	-	-	-	-
PS feed L	+20	0.1502	0.0009	-0.0017	-	-	-	-	-
	-20	0.1754	0.0009	-0.0010	-	-	-	-	-
Comm. feed	+20	-0.1181	-	-	-	-	0.1491	-0.2443	-0.0089
	-20	0.6058	-	-	-	-	0.3144	-0.1628	-0.0068
Fin. weight	+20	0.8132	-	-	-	-	0.3618	-0.2035	-0.0078
	-20	-0.3212	-	-	-	-	0.1028	-0.2035	-0.0078

[1] the abbreviation: PS = Parental Stock, R = Rearing, L = Laying, Comm = Commercial, Fin = Finishing.

[2] profit is per unit of product

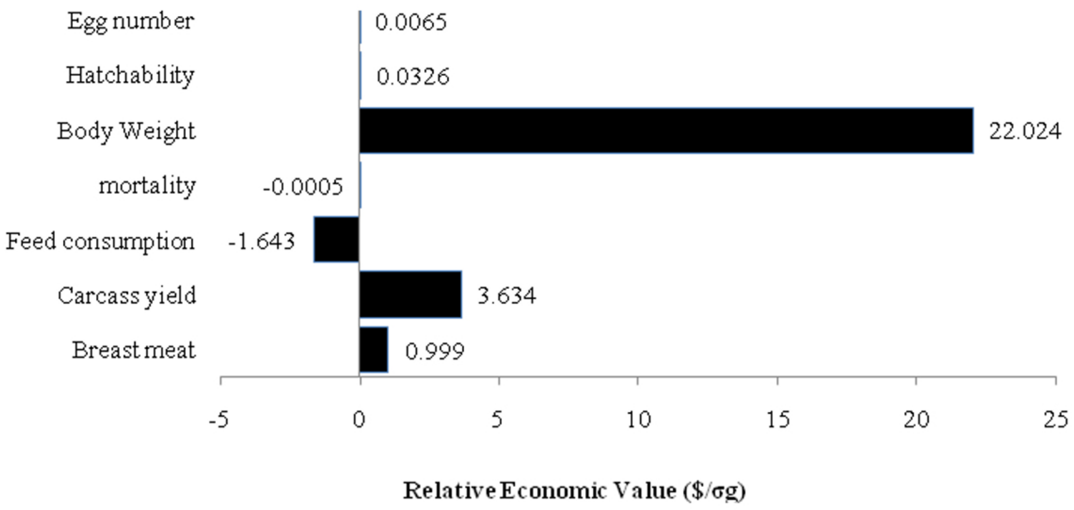

Figure 2. Relative economic values per genetic standard deviation ($US/) for significant traits in an integrated broiler enterprise

The relative economic values of important traits in an integrated turkey company were investigated by Wood (2009). The results showed that traits of commercial tom and hen had less economic importance than multiplier breeder traits.

For the integrated system, the values were expressed per marketable bird. In non-integrated system, the base of evaluation was per unit of product, i.e., per hatching egg (multiplier breeder stage), per day-old chick (hatchery stage), and per marketable bird (commercial grower and processor stages). The most important trait after finishing weight was feed consumption (-0.2035 US$/kg). Higher feed consumption would only result in raising feed cost. The economic importance of mortality is related to more needed chicks, feed and variable costs. Late and laying mortality were of less economic importance than mortality (Shalev and Pasternak, 1983).

The estimated economic values based on non-integrated system were higher than those of integrated system except for hatching egg number, mortality and wings yield. It was not in accordance with the results of Jiang et al. (1998). They calculated the economic values from both integrated and non-integrated perspectives by determining the change in returns at the level of the multiplier breeder, hatchery, commercial grower and processing plant.

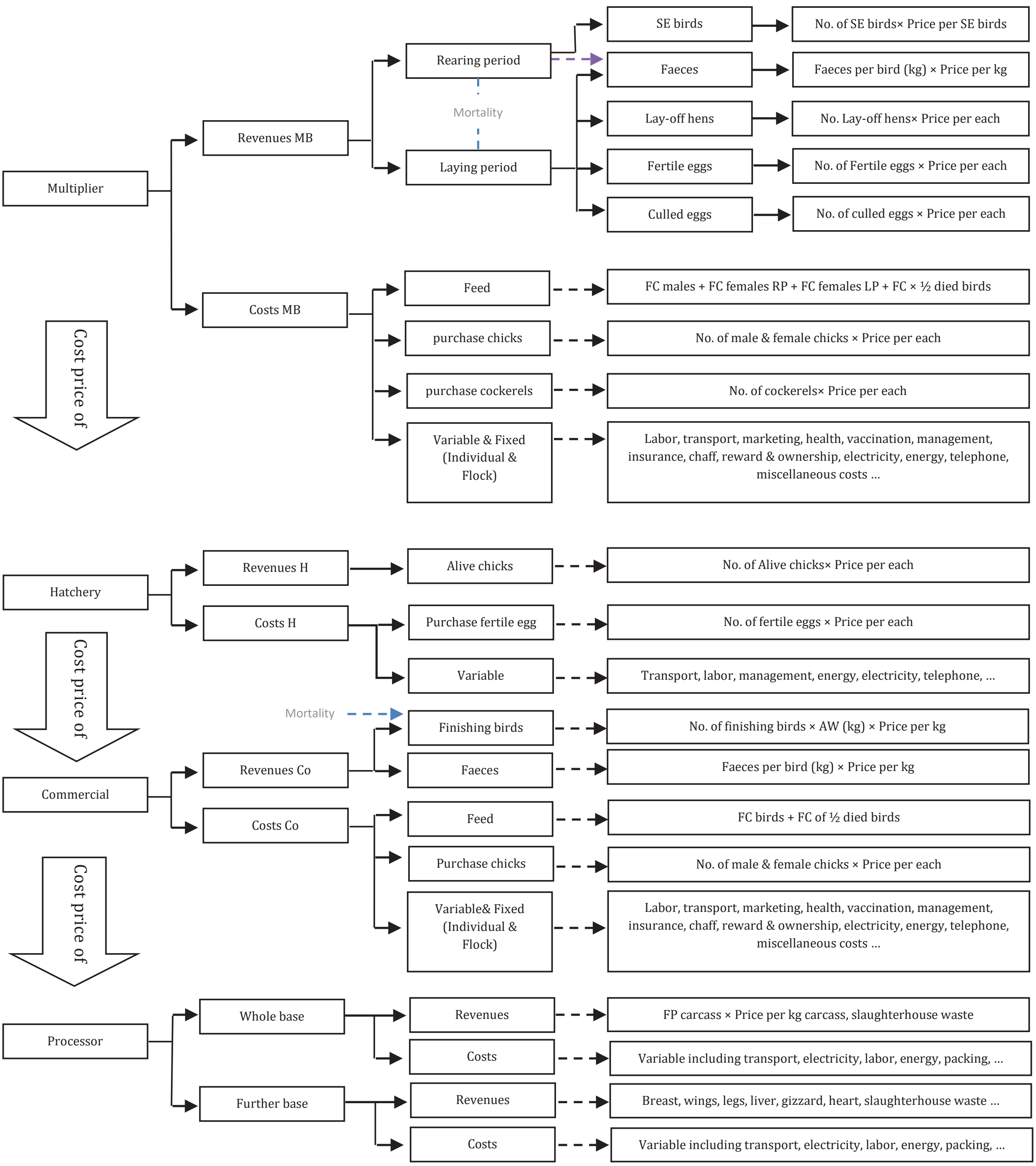

Figure 3. The scheme of the simulation model. (MB: Multiplier Breeder, SE: Sexual Error, FC: Feed Cost, RP: Rearing Period, LP: Laying Period, H: Hatchery, Co: Commercial)

Increasing the mean of hatching egg number leads to increase of its economic value, and applies to hatchability trait (Von Rohr et al., 1999; Wood, 2009; Fallah-Khair et al., 2009). Increased hatching egg number results in additional feed consumed, increased feed cost, and followed by decreasing the economic value of laying feed.

Economic importance for laying feed increased when the price of feed decreased. Changes in the price PS chicks don not influence the economic value of laying feed. Also, changes in PS chicks, rearing feed and laying feed only result in changes of multiplier breeder traits not commercial grower traits. In an integrated turkey company, Wood (2009) showed that when the price of feed increased, the economic value of feed consumption deceased. Also, increasing the mean of hatching egg would result in a decrease for economic values of hatching egg, fertility and hatchability. These results were in accordance to those obtained by Jiang et al. (1998) and Wood, (2009).

In broiler breeding, production level and market are changing; also, altering the market make the price changed, changing the evaluation process for the economic value occurred. Therefore, the cost-benefit analysis of system and economic values of important traits must be calculated repeatedly for the new market condition. In present study, the deterministic model was written as a program code by MATLAB programming package. The model written can also be extended to use in other meat-type poultry and used for systems without output limitation by changing the source code of the program in MATLAB programming package.

Conclusions

To design breeding program for broilers in Iran, economic values of important traits based on a given parameters were estimated. A fixed amount carcass output at the processor stage was considered. The estimated economic values based on non-integrated system were higher than those of integrated system except for hatching egg number, mortality and wings yield. Trait ranking for both systems was the same. The results of sensitivity analysis showed that traits of hatching egg number, fertility, hatchability and laying feed were sensitive to changes in the price of rearing and laying feed. When the price of feed increased, the economic values of considered traits increased except for laying feed. These changes did not influence the economic values of finishing weight, feed consumption and mortality. On the other hands, changes in the price of finishing weight and feed would not result in changes of multiplier breeder traits.

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Appendix

Number of birds existing at various stages

$$NFPC = \frac{CARCASS}{\left(\frac{CY}{100}\right) \times FINWEI \times \left(\frac{100 - MORTLG}{100}\right)}$$

$$NBF = \left(\frac{100 - MORTLG}{100}\right) \times NFPC$$

$$NEH = \frac{NFPC \times 100^2}{FERT \times HATCH}$$

$$NFH = \frac{NEH}{EPS}$$

$$NFC = \frac{NFH \times 100}{(100 - MORTEFPS - MORTLFPS)}$$

$$NFL = NFH \times \left(\frac{100 - MORTLAFPS}{100}\right)$$

$$NML = NBM \times \left(\frac{100 - MORTLAMPS}{100}\right)$$

$$NBL = NFL + NML$$

$$NMC = NFC \times RATIOR$$

$$NBM = NFH \times RATIOL$$

$$NMISPIK = 0.2 \times NBM$$

Where NFPC, NBF, NEH, NFH, NFC, NFL, NMC, NBM, NML, NBL and NMISPIK are numbers of final product chicks, bird finished, egg hatched, parental stock females housed, parental stock female chicks, parental stock females at the end of laying period, parental stock male chicks, parental stock breeder males, parental stock males at the laying period, parental stock males and females at the end of laying period and males interspiking, respectively.

Multiplier breeder modeling

$$SV = (CE \times pec \times NFL) + (NML \times BWMLPS \times sfml) + (NFL \times BWFLPS \times sfml) + (\mathrm{SEXERROR} \times \mathrm{sesr}) + (\mathrm{MULPS} \times NBL \times pm)$$

$$FCFG = \left(NFH + NFC \times \frac{MORTLFPS}{100} \times 0.5 \right) \times FCFRPS \times prl$$

$$FCFEP = NFL \times FCFLPS \times prl$$

$$FeCM = \left(\left(NBM + NMC \times \frac{MORTLMPS}{100} \times 0.5 \right) \times FCMRPS \times prl \right) + \left(\left(NML + NBM \times \frac{MORTLAMPS}{100} \times 0.5 \right) \times FSMRPS \times prl \right)$$

$$CPCOCKEREL = MASPIK \times ppco$$

$$CPPSCHICKS = (NMC \times pmc) + (NFC \times pfc)$$

$$CM_{total} = VCM + FCM + FCFG + FCFEP + FeCM + CPPCCHICKS + CPCOCKEREL - (SV)$$

$$RM_{total} = NEH \times pe$$

$$\Pr ofitM = RM_{total} - CM_{total} \text{ , } PEH = \frac{\Pr ofitM}{NEH} \text{ , } CPEH = \frac{CM_{total}}{NEH}$$

Where VCM and FCM are the variable and fixed costs multiplier breeder, number of parental stock females housed multiplied by variable and fixed costs per parental stock females housed. The SV is salvage value from cull eggs, produced faeces at rearing and laying periods, and males and females that are removed for sexual error or low productivity, respectively. In Iran, produced faeces from broiler farms are valuable, used for enrichment of agricultural lands. Taking into account its revenues, the revenues of selling faeces (RMM) are considered. Feed costs for females are considered separately as growing (FCFG) and laying periods (FCFEP). Also, FeCM is the feed cost males. On the other hands, CPFC, CPMC and $\mathrm{CM}_{\mathrm{total}}$ are the costs components for purchasing male and female chicks and all costs relation to multiplier breeder stage. However, the REH, $\mathrm{RM}_{\mathrm{total}}$, PEH and CPEH are revenues of fertile eggs produced, profit multiplier breeder, profit per fertile egg and cost price per fertile egg, respectively. The unit price and costs abbreviations are presented in Table 2.

Hatchery modeling

$$CH_{total} = (NEH \times pe) + VCH + FCH \text{ , } RH_{total} = NFPC \times psb \text{ , } \Pr ofitH = RH_{total} - CH_{total}$$

$$PDC = \frac{\Pr ofitH}{NFPC} \text{ , } \quad CPC = \frac{CH_{total}}{NFPC}$$

In which $\mathrm{CH}_{\mathrm{total}}$ is all costs related to hatchery, including variable (VCH), fixed (FCH) and purchasing final product fertile eggs costs. Otherwise, the abbreviations RV, PDC and CPC are revenues hatchery, profit per a day old final product chick and cost price per final product chick produced, respectively.

Commercial grower modeling

$$FCB = \left(NBF + NFPC \times \frac{MORTLG}{100} \times 0.5 \right) \times FINWEI \times FCR \times \mathrm{pf}$$

$$CPCCHICKS = NFPC \times psb$$

$$CC_{total} = VCC + FCC + FCB + CPCCHICKS$$

$$RC_{total} = (NBF \times FINWEI \times pfw) + (NBF \times pm \times MUG)$$

$$\mathrm{Pr}\,ofitC = RC_{total} - CC_{total}\,,\; PFPBF = \frac{\mathrm{Pr}\,ofitC}{NBF}\,,\; CPBF = \frac{CC_{total}}{NBF}$$

Where FCB is the feed costs related to birds at growing period, ignoring feed costs for chicks that died during week one. The CPCCHICKS is the costs of purchasing chicks and VCC and FCC are the variable and fixed costs per broiler farm, multiplying number of birds finished by variable and fixed costs per bird, in which variable cost per bird include vaccination, transportation, energy and the other costs except costs of purchasing chicks and feed costs. Hence, RMG, RCG, PCG, PFPBF and CPBF are revenues from selling final product faeces, commercial grower, profit margin commercial grower, profit per final product bird finished and cost price per final product bird finished, respectively.

Processor modeling

$$\mathrm{Pr}\,ofitCAR = (FINWEI \times CY \times pc) - wbb$$

$$EVB = \left(\frac{(FINWEI \times CY \times (pb - pr)/100)}{100} \right), \qquad EVL = \frac{(FINWEI \times CY \times (pl - pr)/100)}{100}$$

$$EVW = \frac{(FINWEI \times CY \times (pw - pr)/100)}{100}$$

$$CPCYwhole = (CPBF + wbb)/(FINWEI \times (CARCASS)/100)$$

$$CPCYfurther = (CPBF + fpb)/(FINWEI \times (CARCASS)/100)$$

In this way, ProfitCAR is the profit per kg carcass and EVB, EVL and EVW are economic values (per 1% increase) for breast, legs and wings yield, respectively. Also, CPCY whole and CPCY further are cost prices per kg carcass based on whole and further processed.