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Economic Values for Production Systems of Quality Chicken in China

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Abstract: The objectives of this study were to derive economic values of objective traits in quality chicken, and to determine the influence of production and market factors on economic values. Economic values were derived using a deterministic economic model based on profit equations with a fixed amount of broiler meat output of the production system. Especially, economic value of meat quality was derived by an optimum range model. As the result shows that the relative importance of the feed conversion ratio is the most, reach 36.10%, then finishing weight and meat quality trait, reach 29.94% and 22.95%, respectively. On the other hand, the relative importance of reproductive traits is smaller. This study shows that, in an integrated broiler enterprise, the economic returns of selection for reproduction traits are much smaller than those of production traits. Economic values of traits in the integrated system were also derived for situations where technical parameters or prices of productive factors were changed (10% increase or decrease). A general conclusion from these sensitivity analyses is 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.

Key words: broiler chicken, breeding objectives, economic values, quality chicken

1. Introduction

In the past decades, the poultry breeding has achieved exciting progress. For example, broiler chickens have been improved in many traits such as daily weight gain, feed efficiency and resistance to disease. But now, the high selection intensity for growth rate has caused many problems, especially the decreasing trend for meat quality [1]. At present, close attention is being paid to the chicken meat quality and the quality chicken industry is mushrooming all over the country in China [2]. As the major poultry industry in china, more than 4.5 billion quality chickens are put to market per year. The quality chicken have a slower growth rate, its 13-week-aged weight is about 2.5 kilogram, which is roughly equivalent to 7-week-aged weight of Dutch broiler. However, the meat quality of quality chicken is superior to that of broiler chicken. Meat quality of chicken is stressed by Chinese consumers, which refers to the sensory attributes of cooked product, i.e., tenderness, flavor, juiciness and color [3], and the internal properties of quality chicken is regard as its meat quality [4, 5].

The general aim of genetic improvement of farm animals is the increase in efficiency of production, and definition of the breeding objective is the key step in the development of breeding programs [6, 7]. Choice of traits to be included in the breeding goal should be based on the relative contribution of each trait to the overall efficiency of production usually evaluated from an economic perspective [8]. The breeding goal is formally defined by setting up an aggregate genotype to be improved, that is a function of individual genetic merit weighted by economic values of traits, i.e. their

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relative economic importance [9]. Bio-economic models, describing biological and economic aspects of livestock production systems, have been used extensively to derive economic values in beef cattle [10, 11], dairy cattle [12, 13] and poultry [14].

In the poultry breeding, only few sets of economic values have been presented in the scientific literature, Hogsett and Nordskog (1958) obtained economic values in layer chicken breeding by simple marginal cost and marginal revenue functions (per bird) [15]. Akbar et al (1986) and Pang (1989) developed profit functions to describe bio-economic objectives in broiler and layer chicken respectively [16, 17]. They derived economic values considering maximization of the profitability per broiler as the objective. Shalev and Pasternak (1983) derived economic values using a single profit function describing production cost per unit of marketable broiler body weight in a fully integrated broiler enterprise [18]. Jiang et al. (1998) derived economic values of traits in broiler breeding for both integrated and nonintegrated production systems. In the breeding program of quality chicken, there is no related study in previous scientific literature, especially about the meat quality trait, so the formal definition of the breeding goal and an economic selection index in broiler are lacking for this breed [14].

As pointed out by Dickerson (1970) [19] and it is important to consider the whole production-marketing system, rather than only part of it. Based on this reason we draw lessons from Jiang (1998), whose model used the broiler production system that including multiplier breeder, hatchery, commercial grower, and processor. The aim of the present study was to derive economic values of objective traits in quality chicken, and to determine the influence of production and market factors on economic values.

2. Materials and Methods

2.1 General Aspects of the Model

In this study a bio-economic simulation model is developed to describe an integrated quality chicken enterprise. The model is deterministic and simulates inputs and outputs of production system that starting with the primary breeder and finally the market. This model focuses on the multiplier breeder, hatchery, commercial grower, and process. In practice, different stages may be fully or partly integrated, the primary breeder is not modeled in detail and the exogenous parameters are used to define production costs of PS eggs, the hatchery is included to define specific costs associated with hatching eggs, the processor is included to determine relationships for the price per kilogram of live weight and the quality of the carcass, the consumer stage is represented by exogenous parameters for market prices of chicken meat products, eggs will be transferred between multiplier breeder and hatchery; chicks (aged 0 wk) will be transferred between hatchery and commercial grower (Fig. 1).

The scale of the system is defined by a fixed output of carcass of final product chickens, scales of subsequent system stages are derived from this fixed output. The number of parental stock female chicks required to produce the fixed output depends on

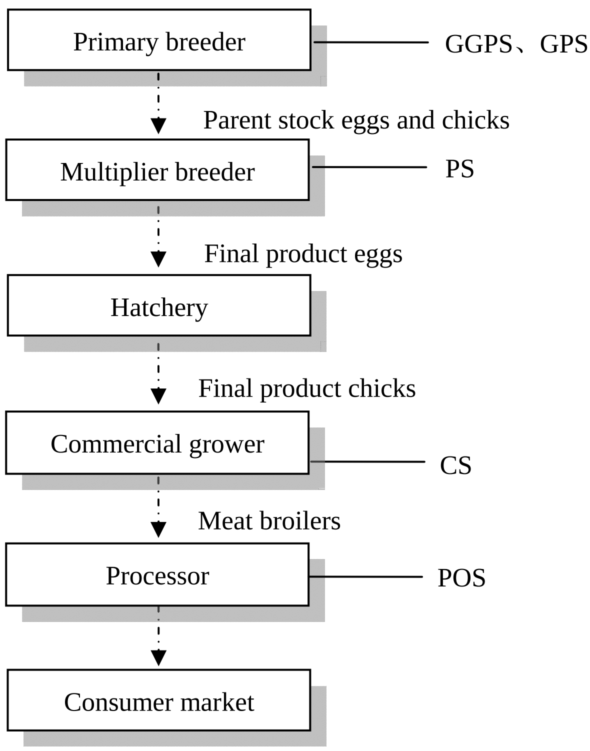

Fig. 1 Structure of the quality chicken production system.

performance levels of parental stock (i.e., hen-housed egg production) and final product (i.e., live weight and carcass yield), as well as on rates of involuntary culling of chickens and eggs.

2.2 Derivation of Economic Values

Breeding objective traits considered in the model are meat quality index (MQI), annual egg production (EN), fertility rate (FR), hatchability rate fertile eggs (HR), body weight aged 13 wk (FW), feed conversion ratio(FCR) and dressing percentage (DP). Performance data and economic parameters used in the model and assumed as representative for the base situation are summarized in Table 1 and Table 2.

Profits originate from the flowing of products and the market prices in each stage, in general, the economic value of a trait is defined as "the change in profitability of an enterprise expressed per unit product

Table 1 Performance and management data for quality chicken production.

Stage	Performance data and management parameters	Unit	Abbreviation	Value
PS	Ratio of males to females at starting rearing period	/	SR1	15
	Ratio of breeder males selected to females housed	/	SR	10
	Survival rate of female chicks during early stage	%	CSRF	99.000
	Survival rate of male chicks during early stage	%	CSRM	97.000
	Survival rate of female in rearing stage	%	BSRF	96.000
	Survival rate of male in rearing stage	%	BSRM	92.000
	Survival rate of female during laying period	%	LSRF	91.000
	Survival rate of male during laying period	%	LSRM	86.000
	Feed consumption during early stage	Kg/bird	CFC	0.750
	Feed consumption of female in rearing stage	Kg/bird	BFCF	7.800
	Feed consumption of male in rearing stage	Kg/bird	BFCM	9.120
	Feed consumption of female during laying period	Kg/bird	LFCF	38.600
	Feed consumption of male during laying period	Kg/bird	LFCM	44.500
	Body weight of female end rearing	Kg/bird	BWHF	2.300
	Body weight of male end rearing	Kg/bird	BWHM	3.000
	Body weight of female end laying	Kg/bird	BWF	2.800
	Body weight of male end laying	Kg/bird	BWM	3.900
	Number of eggs per female housed	/	EN	175.000
	hatching egg weight	g	EW	58.000
HS	Qualified rate of hatching eggs	%	HER	90.000
	Fertility rate of hatching eggs	%	FR	90.000
	Hatchability rate of fertile eggs	%	HR	90.000
CS	Feed consumption of female	Kg/bird	MFCF	6.160
	Feed consumption of male	Kg/bird	MFCM	7.000
	Feed consumption to gain weight of female	/	FCRF	2.800
	Feed consumption to gain weight of male	/	FCRM	2.500
	Body weight of female aged 13 wk	Kg/bird	FWF	2.200
	Body weight of male aged 13 wk	Kg/bird	FWM	2.800
	Survival rate of female chicks during early stage	%	SRF1	99.000
	Survival rate of male chicks during early stage	%	SRF2	99.000
	Survival rate of female ending 13 wk	%	SRF	95.000
	Survival rate of female ending 13 wk	%	SRM	95.000
POS	Carcass yield of female	%	DPF	88.600
	Carcass yield of male	%	DPM	90.800

Table 2 Representative price for quality chicken production.

Stage	Performance data and management parameters	Unit	Abbreviation	Value
PS	Market price of female chick	RMB/bird	PPSF	3.700
	Market price of male chick	RMB/bird	PPSM	0.000
	Market price of early feed	RMB/Kg	PGF	2.500
	Market price of rearing feed	RMB/Kg	PBF	2.500
	Market price of laying feed	RMB/Kg	PLF	2.300
	Variable cost during early stage	RMB/bird	FOCC	2.960
	Variable cost during rearing stage	RMB/bird	FOCB	9.850
	Variable cost during laying period	RMB/bird	FOCL	38.000
	Fixed cost	RMB	PPSF	600.000
	Market price of chicken finished laying	RMB/Kg	PRC	8.300
	Market price of hatching egg	RMB/egg	PHE	1.700
	Market price of unqualified egg	RMB/Kg	PRE	7.600
HS	Variable cost per hatching egg	RMB/egg	PHV	0.350
	Fixed cost	RMB	PHF	2000.000
CS	Market price per chick	RMB/bird	PHC	2.500
	Market price of feed	RMB/Kg	PMF	2.500
	Variable cost	RMB/bird	FOCM	7.130
	Fixed cost	RMB	PCSF	92100
	Market price of quality chicken	RMB/Kg	PRB	12.000
POS	Processing cost	RMB/bird	PCS	1.5000
	Further processed base	RMB/bird	PDP	3.5000
	Market price of carcass	RMB/Kg	PRM	20.300
	Price of remainder yield	RMB/Kg	PRR	3.000

output as a consequence of one unit of change in performance of the trait considered, without changing performance of other traits", in an integrated quality chicken enterprise, the unit product output is a marketable final product bird. Economic values in principle are derived by computing cost price for the base level of the trait concerned and for a level that is marginally higher in integrated system. It has been shown by Jiang (1998) that in the case of fixed product output, which is the case here, economic values equal the average variable cost minus the marginal costs. That is, the economic value of an increase in egg number per parent stock female will be positive when the marginal cost of an additional egg per female is lower than the average variable cost per egg before genetic improvement. An exception is that the economic values of breast meat, legs, and wings are determined by marginal revenues, as they are affected by market price.

The defined representative market prices and performance levels influence average variable cost in the representative situation, and will, therefore, influence economic values. These influences are illustrated by giving underlying aspects of quantification and valuation of changes in cost or profit of the system. Moreover, the sensitivity of economic values is illustrated by results from alternative performance levels and price elements (product prices and feed prices).

3. Results

3.1 Model for Deriving the Economic Value

For working out the economic values of the objective traits in an integrated broiler enterprise, assuming an arbitrarily chosen scale of 1000000 Kg FP carcass output (TC) at the processor stage, to obtain this production, $TS = TC/[(DPF+DPM)/2]$ Kg live weight of FP finished birds is required, corresponding to $TN = TS/[(FWF+FWM)/2]$ FP birds finished, $TNC = TN/[(SRF+SRM)/2]$ FP chicks started by the commercial grower. To produce these FP chicks, $TNE = TNC/(FR \times HR)$ FP eggs are hatched, $TNPE = TNE/(EN \times HER)/[1\text{-}(1\text{-}LSRF)/2]$ PS hens are housed, $TPCN = TNPF/CSRF/(CSRF \times BSRF)$ PS female chicks and TPCM =TPCF×SR1/[CSRM×(CSRM×BSRM)] male chicks are purchased at the multiplier breeder stage.

Economic Value of Annual Egg Production: As hatching egg number per hen housed increases from175 (Table 1) to 176, for getting the same output, the number of PS female in every production period are reduced. The reduction in PS female number also decreases the number of PS males, as they are set proportional to those of females. Here, the reduction of cost for purchasing PS chicks and feed consumption of PS chicken defined as *CSE*1 and *CSE*2, decrease of variable costs for PS chicken as *CSE*3, revenue decrease as the number of hens and cocks at the end of laying as *CSE*4. So, the economic value of an additional hatching egg is W_{EN} = (CSE1+CSE2+CSE3-CSE4)/TNE.

Economic Value of Fertility and Hatchability: At the hatchery stage, the base of evaluation is per unit of product, i.e., per day-old chick. Fertility and hatchability of fertile have the same economic value. With an additional percentage in fertility or in hatchability, the number of hatching eggs needed to produce the constant output is reduced from $TNC/(FR \times HR)$ to TNC/[(FR+1%)×HR]. Thus, cost of hatching egg is decreased by $CSH1 = \{TNE\text{-}TNC/[(FR+1\%) \times HR]\} \times PHE$, the variable cost of the hatchery is reduced by $CSH2 = [TNE\text{-}TNC/[(FR+1\%) \times HR]] \times PHV$, Thus, the economic value of fertility or hatchability is W_{FR}= (CSH1+CSH2)/TNC per percentage per chick.

3.1.1 Economic Value of Finishing Weight

As an additional 1 kg increasing in finishing weight of FP chicken, for getting the constant FP carcass output, the cost of feed consumption is increased for per FP chicken, meanwhile, the costs for purchasing FP chicks and total feed consumption decreasing with the FP birds number decreased at the commercial grower stage, and leading to a decrease in cost of purchasing PS hatching eggs and in variable cost at the hatchery stage. At the PS stage, cost of purchasing day-old PS chicks and feed consumption decreased, and then, the revenue reduced as the number of hens and cocks at the end of laying stage. Here, assuming the extra profit due to an additional 1 kg increasing in finishing weight of FP chicken as *CSH*3, *CSH*4, and *CSH*5 at the PS, HS and CS stage, respectively. The economic value of an additional 1 kg body weight of FP chicken is derived by $W_{FM} = (CSH3 + CSH4 + CSH5) / TS / (FWF +1 +FWM+1)/2]$.

3.1.2 Economic Value of Feed Conversion Ratio

As the feed conversion ratio increase one unit, increasing feed consumption only increases feed cost by *CSF*, and the economic values of *FCR* is $WFCR = CSF/TN$, where

$CSF=\{TN/2+TNC \times (1\text{-}SRF)/2\}/2\} \times [(FCRF+1)\text{-}FCRF] \times PMF\{TN/2+TNC \times (1\text{-}SRM)/2\}/2\} \times [FCRM+1\text{-}FCRM] \times PMF$

3.1.3 Economic Value of Dressing Percentage

As the feed dressing percentage increase an additional percent, maintaining the fixed output, i.e., 1000000 Kg FP carcass, that need $TN2 = TC/(DPM+SPF)/2+1\%)/(UWF+UWM)/2)$ FP birds in the commercial grower stage. Here, assuming the extra profit due to an additional percent increasing in DP as *CSF*1, *CSF*2 and *CSF*3 at the PS, HS and CS stage, respectively. The economic value of dressing percentage is derived by $W_{DP} = (CSF2+CSF3+CSF4)/TN2$.

3.1.4 Economic Value of Meat Quality Trait

The deriving for economic value of meat quality trait following Hovenier's theory [19]. Meat quality traits are assumed to be truncated normal distribution, when the trait value is within the optimum range, meat quality is optimum, on the contrary, when the trait value is outside the optimum range, meat quality is lower, that is the meat quality is bad when the trait value is outside the biological limit. The meat quality performance was reflect by meat quality index (MQI) [5, 20], the economic value of meat quality traits is derived by $EV(\mu)=\frac{p\times M}{\delta\sqrt{2\pi}}\times[e^{-\frac{1}{2}(\frac{MQI_L-\mu}{\delta})^2}-e^{-\frac{1}{2}(\frac{MQI_U-\mu}{\delta})^2}]$, where p represent a price difference between products within and outside the optimum range, MQI_u and MQI_i represent the upper and lower boundary of the optimum range respectively, and M represents the meat weight produced per chicken, δ =standard deviation of the trait.

3.2 The Economic Value

The economic value each breeding objective traits are listed in Table 3. However, it's impossible to intercompare because of the different measurement units for the economic value each trait. In order to derived the relative weight of each traits for the aggregate selection index, the genetic standard deviation (σ_A) was used to multiply the economic value, by which the importance of genetic deviation for breeding is embodied, and the economic value are standardized. As the Table 3 shows, the relative importance of the feed conversion ratio is the most, reach 36.10%, then finishing weight and meat quality trait, reach 29.94% and 22.95%, respectively. On the other hand, the relative importance of reproductive traits is smaller.

Table 3 Economic values of the objective traits in relation to production levels in an integrated quality chicken enterprise.

Traits	EV	σ_A	σ_A *EV	%
EN	0.0061	13.100	0.0799	1.81
FR	0.0228	3.000	0.0684	1.55
HB	0.0228	3.000	0.0684	1.55
FW	7.2234	0.140	1.0113	22.95
FCR	-6.4145	0.248	-1.5908	36.10
DP	0.3163	0.850	0.2689	6.10
MQI	0.8607	1.533	1.3195	29.94

3.3 Alternative Production Levels

Influences of alternative production levels on the economic values in an integrated broiler enterprise are listed in Table 4. Table 4 shows that economic values of feed conversion ratio (FCR), carcass yield (DP) and meat quality (MQI) are sensitive to changes in finishing weight (FW); higher finishing weight gives higher economic values of carcass yield and meat quality, but leads to lower economic values of FCR. For example, a 10% increase in finishing weight leads to 0.7286 RMB lower in economic value of FCR. Changes in feed conversion ratio and meat quality only result in changes in the economic values of finishing weight.

It is worth noting that changes in reproduction traits of PS don't influence the economic values of traits at the commercial grower and the processor stage downstream, but only change those at the multiplier breeder and the hatchery stage. Changes in traits at the commercial grower influence economic values of traits at both the commercial grower and processor stage, but don't upstream change those of the multiplier breeder and hatchery stage.

3.4 Alternative Representative Prices

Economic values of production traits in relation to feed and product prices in an integrated broiler enterprise are listed in Table 5. It is worth noting that changes in feed prices only result in changes in the economic values of production traits in the corresponding stage, that is, changes in price of laying feed don't influence the economic values of traits at the commercial grower and the processor stage downstream, but only lead to the changes in the economic values of annual egg production (EN), fertility rate (FR) and hatchability (HR); and changes in price of feed at commercial grower stage don't influence those of the multiplier breeder and hatchery stage.

Table 4 Economic values of the objective traits for alternative the production performance.

Trait		EN	FR/HB（%）	FW（kg）	FCR（%）	DP（%）	MQI
EV（RMB）		0.0061	0.0228	7.2234	-6.4145	0.3163	0.8607
EN	-10%	0.0095	0.0271	7.2234	-6.4145	0.3163	0.8607
	+10%	0.0048	0.0190	7.2234	-6.4145	0.3163	0.8607
FR/HR	-10%	0.0071	0.0252	7.2234	-6.4145	0.3163	0.8607
	+10%	0.0053	0.0207	7.2234	-6.4145	0.3163	0.8607
FW	-10%	0.0061	0.0228	7.2234	-5.8546	0.2856	0.7126
	+10%	0.0061	0.0228	7.2234	-7.1431	0.3839	0.9655
FCR	-10%	0.0061	0.0228	8.5678	-6.4145	0.3163	0.8607
	+10%	0.0061	0.0228	5.3212	-6.4145	0.3163	0.8607
DP	-10%	0.0061	0.0228	6.8639	-6.4145	0.3163	0.8607
	+10%	0.0061	0.0228	7.3590	-6.4145	0.3163	0.8607
MQI	-10%	0.0061	0.0228	7.8790	-6.4145	0.3163	0.8607
	+10%	0.0061	0.0228	6.1265	-6.4145	0.3163	0.8607

Table 5 Economic Values of the objective traits for alternative the representative prices.

Parameters	Trait	-20%	-10%	-5%	0	+5%	+10%	+20%
PLF	EN	0.0033	0.0048	0.0057	0.0061	0.0065	0.0075	0.0090
	FR	0.0211	0.0213	0.0221	0.0228	0.0236	0.0247	0.0259
	HB	0.0211	0.0213	0.0221	0.0228	0.0236	0.0247	0.0259
PMF	FW	9.8457	8.7693	7.8709	7.2234	6.6563	5.7649	4.6502
	FCR	-4.2058	-5.2302	-6.0543	-6.4145	-6.8409	-7.6302	-8.5361
PRB	FW	3.6299	5.5094	6.6420	7.2234	7.9962	9.1691	10.8264
PRM	DP	0.2150	0.2616	0.2917	0.3163	0.3476	0.3809	0.4386
PD*	FW	5.7787	6.5011	6.8523	7.2234	7.5845	7.9457	8.6681
	MQI	6.8885	0.7740	0.8544	0.8607	0.8650	0.9468	1.0371

*PD, price differentiation between quality chicken and ordinary broiler.

Changes in product prices would only change economic values of those traits that influence output of corresponding products. Increases in product price will lead to linear increases in the economic values of the traits considered (Table 5), for example, the increase in the product prices of FP or price differentiation between quality chicken and ordinary broiler will lead to increase of the economic values of finishing weight in commercial stage. As the product price increases, the increase in the economic values is faster for finishing weight and meat quality than for carcass yield and feed conversion ratio, implying that at different product price levels, relative values of traits would change.

4. Discussion

The implication of quality chicken is meat quality, which is the prime trait in the breeding goal, then reproduction and production traits. In the past decades, the poultry breeding has achieved exciting progress. For example, broiler chickens have been improved in many traits such as daily weight gain, feed efficiency and resistance to disease. But now, the high selection intensity for growth rate has caused many problems, especially the decreasing trend for meat quality [1]. Based on this fact, the current study advocated that the objective traits should include meat quality traits except for reproduction and production traits.

There are three methods to set the scale of model for deriving the economic values of objective traits by fixing the population size, investment cost and output, but the economic value is the same by different control strategy if the output from the system terminal is the single product, Conversely, it won't like this [21, 22]. No matter which method used, it is necessary to assume that the supply must meet the demand, in the present study, economic values derived by assuming an arbitrarily chosen scale of 1000000 Kg FP carcass output at the processor stage.

The economic value of meat quality was derived by the "optimum range model" [19, 20]. In general, profit functions include both returns and costs of production. In this paper, no costs are included, assuming that no extra costs are associated with the production of meet of various quality levels, which is only associated with the breed. The optimum range is set by curve fitting, reliable or not need further verified.

The main breeding objective traits considered in Chinese quality chicken breeding are meat quality traits, annual egg production fertility rate, hatchability rate fertile eggs, finishing weight, feed conversion ratio and carcass yield, which are different from those meat quality won't be considered as the breeding objective traits in broiler breeding [14].

The economic values show that the relative importance of the feed conversion ratio is the most, then finishing weight and meat quality trait in the second and third, however, compared with the broiler breeding, the economic value of finishing weight is the max, and then the feed conversion ratio and breast meat [14]. There is one same conclusion, that the relative importance of reproductive traits is much lower than that of production and meat quality traits in the two different breeds, the relative weight of reproduction traits is short of 10%, however, it don't mean the reproduction trait is unimportant for the enterprise, because reproduction traits is the key factor concerned with the cost of producing a broiler chick, in general, the breed that is of good production and meat quality performance but is not of better reproduction level will not be welcomed by breeding enterprise or organization [23]. Moreover, as commercial broilers are crossbreeds, the number of times traits are expressed in a population and the interval between selection and expression of these traits should be considered. The economic values should be weighted by the number of discounted expressions for each trait [24, 25]. The reason for the lower economic value of reproduction traits is that the economic values were calculated based on the whole breeding system, not on a certain line. These items leave room for further study.

This study further shows that the economic value of objective traits are affected by production level and market prices, changes in the production level or market price would result in the economic value of the related trait. The economic values were calculated by marginal profit method in the present production and market system, and the advantages of production level and the changes of market supply and demand in the future were not considered [26]. Actually, the production level and market are dynamic; a little changes of the market will result in changes of the price, which is the key factor to evaluation for the economic value. Therefore, the economic values must be calculated again for the new market circumstances. In this study, the model was written as a program code by Matrix Laboratory (version 6.5). The model and the method of deriving economic values can be extended, without changing the computer program, to apply in other meat-type poultry, e.g., turkeys and ducks, as the breeding method and production system are similar to that of broilers. The model can also be extended to apply to the situation without output limitation just by changing a few lines in the computer program.

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