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Comparative Study on Growth Patterns of 25 Commercial Strains of Korean Native Chicken

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ABSTRACT Prediction of growth patterns of commercial chicken strains is important. It can provide visual assessment of growth as function of time and prediction body weight (BW) at a specific age. The aim of current study is to compare the three nonlinear functions (i.e., Logistic, Gompertz, and von Betalanffy) for modeling the growth of twenty five commercial Korean native chicken (KNC) strains reared under a battery cage system until 32 weeks of age and to evaluate the three models with regard to their ability to describe the relationship between BW and age. A clear difference in growth pattern among 25 strains were observed and classified in to the groups according to their growth patterns. The highest and lowest estimated values for asymptotic body weight (C) for 3H and 5W were given by von Bertalanffy and Logistic model 4629.7 g for 2197.8 g respectively. The highest estimated parameter for maturating rate (b) was given by Logistic model 0.249 corresponds to the 2F and lowest in von Bertalanffy model 0.094 for 4Y. According to the coefficient of determination (R^2) and mean square of error (MSE), Gompertz and von Bertalanffy models were suitable to describe the growth of Korean native chicken. Moreover, von Bertalannfy model was well described the most of KNC growth with biologically meaningful parameter compared to Gompertz model.

(Key Words : growth pattern, Gompertz, von Bertalanffy, Logistic, Korean native chicken)

INTRODUCTION

Growth of an animal can be defined as irreversible increase in live weight or dimension for given period of time. Longitudinal increase of growth trajectory can be well defined by using different mathematical procedures (Darmani Kuhi et al., 2003). Therefore, characteristics of growth curve over age with its functional parameters can help to predict the animal production and provide data for the decision making process regarding the animal husbandry and management (Grossman et al., 1985; Gang and Zhen, 1997). Through the analysis of poultry growth curve, we can learn growth trajectory, and forecast the poultry growth patterns. In addition, the data from growth curve analysis can provide information for the programs of feeding management to improve the efficiency of selective breeding program (Darmani Kuhi et al., 2010).

Many studies have been reported that the shape of growth curve is dynamic due to species, environmental conditions and genetic background (Brisbin et al., 1987; Sengül and Kiraz, 2005; Ngeno et al., 2013; Mignon-Grasteau et al., 2000). Since it is not appropriate to use linear mathematical functions for describing growth trajectory, a number of nonlinear function has been investigated as alternatives (Sengül and Kiraz, 2005). Thereby, several nonlinear models (NLM) to describe the chicken growth pattern have been proposed (Gompertz, 1825; Grossman et al., 1982; Porter et al., 2010; Tompić et al., 2011). Among those models, Logistic, Gompertz, von Bertalanffy and Richards are often used to fit the growth curve of poultry breeds (von Bertalanffy, 1957; Yakupoglu and Atil, 2001a; Ali and Brenoe, 2002;Yang et al., 2006; Topal and Bolukbasi, 2008).

Well established few fast growth layer and broiler strains play vital roles in producing the demanded chicken meat and egg for the world population (Thiruvenkadan et al., 2011). Although Korean native chicken (KNC) has inferior growth rate, body weight and egg production compared to commercial

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broilers and layers, KNC has become popular among consumers due to own characteristics as a native livestock species in Korea (Kim et al., 2014). Selective breeding strategies with improved rearing condition has been applied to establish the commercial KNC to overcome their disadvantages such as retared growth (Kim et al., 2012). Literature reports provide information on previous attempts on comparison of few KNC growth performance (Cho et al., 2001; Kim et al., 2014). Therefore, this study is designed to compare the three nonlinear functions (Logistic, Gompertz and von Betalanffy), for modeling the growth of twenty five commercial KNC strains reared under a battery cage system and evaluating three models with regard to their ability to describe the relationship between BW and age.

MATERIALS AND METHODS

1. Animals, Diets and Management

The present study was conducted using twenty five strains of Korean native chicken (KNC) (Table 1). One day-old female chicks were obtained from a commercial hatchery (i.e., Hanhyup Breeder Inc.) and wing-tagged when they arrived. In each strain, chicks were individually weighed and randomly allocated into the wire floor brooder cages (0.75×0.61×0.40 m^3) with 12 birds per cage. These chicks were not subjected to the beak trimming. Nevertheless, proper vaccination procedure was followed during the experimental period. At the end of brooding stage, grower birds were transferred to the battery cages (0.6×0.54×0.45 m^3) in an environmentally controlled house. Feed and water were supplied *ad libitum* throughout the experiment period. Starter feed was included 22% CP, 3,120 kcal ME/kg for 14 days of their age. Thereafter, birds were fed with diet containing 18% CP, 2,900 kcal ME/kg as grower. After 20th week of age, birds were fed with diet containing 15～16% CP and 2,800 kcal ME/kg. 22/2 h light/dark cycle was maintained at first weeks, thereafter 16/8 h for 2nd weeks, 9/15 h up to 16th week and changed accordingly afterwards.

Table 1. Number of birds in twenty five strains of Korean native chicken.

Strains	Number of individuals
1F	43
2F	22
3F	42
4F	36
5F	45
Sub total	188
1G	48
2G	18
3G	40
4G	41
5G	39
Sub total	186
1H	41
2H	23
3H	42
4H	24
5H	48
Sub total	178
1W	43
2W	17
3W	46
4W	26
5W	39
Sub total	171
1Y	48
2Y	33
3Y	46
4Y	30
5Y	44
Sub total	201
Total	924

2. Data Collection

Individual body weight was measured every two weeks of interval until 20th weeks of age, followed by four weeks interval until 32nd weeks of age. Mortalities were corrected from data set before growth curve parameter estimation. All the experiments were performed at the research farm affiliated to Chungnam National University, Chungyang.

3. Statistical Analysis

The three nonlinear growth models, Gompertz (GP), Logistic (L) and von Bertalanffy (VB) were used to estimates parameters of the growth curves in KNC. Each model was compared to select the best fitted model to describe the growth trajectory of twenty five commercial KNC strains. The growth functions and their respective mathematical symbols are presented in Table 2.

The estimation of the growth model parameters was performed using SAS NLIN procedure (SAS Institute Inc., 2015). A total of 924 birds out of 1000 were survived until the end of experiment (i.e., at 32 weeks of age). However, a total of 758 individual body weight data were used to estimate the parameter after remove the extreme values from the data set. Goodness of fit for each model was determined. The goodness of fit criteria such as coefficient of determination (R^2) and mean square error (MSE) were obtained by using functions describe in Table 3. The model with lowest MSE and highest R^2 is considered as the best fit to the data.

RESULTS

1. Parameter Estimation of Three Growth Curve Models

Estimation results of parameters of the three non-linear growth models for 25 commercial KNC strains are summarized in Tables 4 to 8. The highest C value (i.e., asymptotic final body weight) was shown by von Bertalaffy model for all the strains of F, G, H, W and Y followed by Gompertz and Logistic model. Furthermore, the highest estimated C value was shown in von Bertalanffy model for strain 3H (4,629.7±33.30 g) and the lowest value in logistic model for strain 5W (2,197 ±20.60 g). The values of parameter C estimated by the Logistic model were closer with observed mean final body weights of all strains than Gompertz and von Bertalanffy models.

Table 2. Functions for modeling the growth curves.

Model	Equation
Gompertz	$W_t = Ce^{-ae^{-bt}}$
von Bertalanffy	$W_t = C\,(1-ae^{-bt})^3$
Logistic	$W_t = C\,(1+ae^{-ae^{-bt}})^{-1}$

W_t: is the corresponding weight at time t, C: asymptotic final body weight: the parameter for asymptotic limit of the weight when age (t) approaches infinity, a: the log- function for the proportion of the asymptotic mature weight to be gain after birth, b: the parameter for maturating rate, a function of the ratio of maximum growth rate to mature size, t: time by weeks.

Table 3. Goodness of fit criteria.

Criteria	Equation
R^2	$1-(SSE/SST)$
MSE	$SSE/(n-k)$

SSE: Sum of squared errors, SST: Total sum of squares, k: The number of parameters, n: Sample size.

The a value (i.e., the log function for the proportion of the asymptotic mature weight to be gained after birth) was different among the growth models. Nevertheless, the a value from given model was not obviously different among the strains. The highest a value shown in Logistic model for 4Y and the lowest by von Bertalanffy model for 3F were 14.85 and 0.73 respectively. The highest estimated parameter for maturating rate (b) was 0.25 in logistic model which corresponds to the 2F and lowest in von Bertalanffy model 0.09 for 4Y.

Based on the goodness of fit criteria, the highest coefficient of determination (R^2) value and the lowest MSE value can be used to determine the best fit model to the longitudinal body weight data. Provided higher R^2 value and lower MSE, von Bertalanffy model was best fitted for all the strains of F, G, H and 1W. As for all other strains of W (i.e., 2W, 3W, 4W, 5W) and Y, Gompertz model was best fitted with body weight data with lower MSE and higher R^2 value, followed by von Bertalanfy model. As proportion, 64% (16) of strains were best fitted to von Bertalanffy model where as 36% (9) were best fitted with Gompertz model. The coefficient of determination (R^2) values ranged from 0.94~0.98, were not obviously varied among the strains and models.

2. Growth Patterns of KNC

In Fig. 6, the average body weight and age relationship of 25 strains of KNC are presented. Interestingly, three clustered

Table 4. Estimated parameter, calculated goodness of fit criteria for five strains of F line using three growth model, from hatch to 32 weeks.

Function		n	Model parameter				
			C^*	a^{**}	b^{***}	Goodness of fit	
			Mean±S.E. (g)	Mean±S.E.	Mean±S.E.	MSE	R^2
Gompertz	1F	25	4,414.0±68.0	3.30±0.120	0.13±0.0048	33,019,847	0.9519
	2F	17	3,788.4±46.4	3.53±0.150	0.16±0.0058	12,705,795	0.9664
	3F	32	4,315.5±46.5	3.23±0.080	0.13±0.0035	26,805,799	0.9677
	4F	30	3,668.3±42.6	3.39±0.090	0.13±0.0033	14,797,329	0.9723
	5F	38	3,655.2±32.2	3.49±0.070	0.13±0.0026	14,606,801	0.9789
von Bertalanffy	1F	25	4,600.1±84.0	0.74±0.020	0.10±0.0042	32,288,468	0.9530
	2F	17	3,885.5±54.0	0.79±0.027	0.13±0.0051	12,540,275	0.9668
	3F	32	4,488.6±56.2	0.73±0.014	0.11±0.0030	25,464,769	0.9693
	4F	30	3,849.9±53.0	0.75±0.014	0.01±0.0029	14,037,179	0.9737
	5F	38	3,831.2±40.9	0.77±0.012	0.10±0.0023	14,412,495	0.9789
Logistic	1F	25	4,166.3±51.2	11.8±0.820	0.21±0.0070	37,596,433	0.9453
	2F	17	3,644.7±39.7	12.5±1.000	0.25±0.0090	15,128,127	0.9600
	3F	32	4,082.1±37.1	11.2±0.570	0.21±0.0050	33,402,174	0.9597
	4F	30	3,430.7±32.9	12.5±0.640	0.21±0.0050	18,958,128	0.9645
	5F	38	3,424.7±24.4	13.3±0.540	0.21±0.0040	18,005,715	0.9736

F: line F. 1F, 2F, 3F, 4F, 5F: strains of line F, n: number of animals.

[*] Asymptotic final body weight: the parameter for asymptotic limit of the weight when age (t) approaches infinity.

[**] The logfunction for the proportion of the asymptotic mature weight to be gain after birth.

[***] The parameter for maturating rate, a function of the ratio of maximum growth rate to mature size, MSE: mean square error of nonlinear model, S.E: standard error, R^2: coefficient of determination.

Table 5. Estimated parameter, calculated goodness of fit criteria for five strains of G line using three growth model, from hatch to 32 weeks.

Function		n	Model parameters				
			C^*	a^{**}	b^{***}	Goodness of fit	
			Mean±S.E.	Mean±S.E.	Mean±S.E.	MSE	R^2
Gompertz	1G	31	4,226.4±39.9	3.27±0.079	0.14±0.0030	18,809,684	0.9750
	2G	17	3,772.4±44.6	3.42±0.121	0.15±0.0050	8,265,973	0.9754
	3G	30	3,987.6±47.0	3.27±0.096	0.14±0.0040	23,711,716	0.9638
	4G	36	3,324.8±31.8	3.60±0.094	0.14±0.0030	17,003,779	0.9704
	5G	34	3,118.8±32.6	3.48±0.100	0.14±0.0040	16,553,362	0.9653
von Bertalanffy	1G	31	4,380.2±47.6	0.74±0.014	0.11±0.0029	18,009,942	0.9760
	2G	17	3,893.3±52.7	0.77±0.021	0.12±0.0041	7,964,949	0.9763
	3G	30	4,144.2±57.1	0.74±0.017	0.11±0.0035	23,104,640	0.9647

Table 5. Continued.

Function		n	Model parameters				
			C^{*}	a^{**}	b^{***}	Goodness of fit	
			Mean±S.E.	Mean±S.E.	Mean±S.E.	MSE	R^2
von Bertalanffy	4G	36	3,458.5±39.9	0.79±0.016	0.11±0.0029	16,727,646	0.9709
	5G	30	3,236.3±40.2	0.77±0.017	0.11±0.0033	16,548,985	0.9653
Logistic	1G	31	4,015.7±33.1	11.38±0.550	0.22±0.0050	24,111,848	0.9679
	2G	17	3,602.7±38.1	12.07±0.840	0.23±0.0070	10,668,613	0.9683
	3G	30	3,772.5±36.7	11.54±0.650	0.22±0.0060	27,970,602	0.9573
	4G	36	3,144.1±23.8	13.97±0.680	0.23±0.0050	18,667,391	0.9675
	5G	30	2,958.7±25.1	12.93±0.700	0.22±0.0050	18,740,274	0.9607

G: line G. 1G, 2G, 3G, 4G, 5G : strains of line G, n: number of animals.

[*] Asymptotic final body weight: the parameter for asymptotic limit of the weight when age (t) approaches infinity.

[**] The log function for the proportion of the asymptotic mature weight to be gain after birth.

[***] The parameter for maturating rate, a function of the ratio of maximum growth rate to mature size.

MSE: mean square error of nonlinear model, S.E: standard error, R^2: coefficient of determination.

Table 6. Estimated parameter, calculated goodness of fit criteria for five strains of H line using three growth model, from hatch to 32 weeks.

Function		n	Model parameter				
			C^{*}	a^{**}	b^{***}	Goodness of fit	
			Mean±S.E. (g)	Mean±S.E.	Mean±S.E.	MSE	R^2
Gompertz	1H	36	4,297.8±34.5	3.44±0.728	0.14±0.0030	19,791,873	0.9790
	2H	16	4,202.5±42.8	3.49±0.113	0.15±0.0040	8,216,943	0.9806
	3H	40	4,456.9±28.3	3.32±0.054	0.14±0.0020	16,407,257	0.9851
	4H	19	3,389.9±43.6	3.44±0.118	0.14±0.0050	8,746,689	0.9718
	5H	43	3,397.7±33.2	3.43±0.078	0.13±0.0030	20,688,123	0.9694
von Bertalanffy	1H	36	4,466.1±41.9	0.77±0.012	0.11±0.0024	19,037,751	0.9798
	2H	16	4,329.4±50.8	0.78±0.020	0.12±0.0037	8,091,814	0.9809
	3H	40	4,629.7±33.3	0.75±0.009	0.11±0.0018	15,002,155	0.9864
	4H	19	3,522.3±53.0	0.77±0.020	0.11±0.0039	8,467,512	0.9727
	5H	43	3,556.4±41.8	0.76±0.013	0.10±0.0026	20,309,966	0.9700
Logistic	1H	36	4,071.4±28.4	12.52±0.530	0.22±0.0040	25,977,767	0.9725
	2H	16	4,023.3±36.9	12.55±0.800	0.24±0.0070	10,684,062	0.9748
	3H	40	4,223.3±25.0	11.74±0.410	0.22±0.0040	24,650,328	0.9777
	4H	19	3,209.2±35.1	12.47±0.840	0.22±0.0070	10,933,473	0.9648
	5H	43	3,188.4±24.8	12.82±0.570	0.21±0.0040	24,474,751	0.9638

H: line H, 1H, 2H, 3H, 4H, 5H : strains of line H, n: number of animals.

[*] Asymptotic final body weight: the parameter for asymptotic limit of the weight when age (t) approaches infinity.

[**] The log- function for the proportion of the asymptotic mature weight to be gain after birth.

[***] The parameter for maturating rate , a function of the ratio of maximum growth rate to mature size.

MSE: mean square error of nonlinear model, S.E: standard error, R^2: coefficient of determination.

Table 7. Estimated parameter, calculated goodness of fit criteria for five strains of W line using three growth model, from hatch to 32 weeks.

Function		n	Model parameter				
			C^*	a^{**}	b^{***}	Goodness of fit	
			Mean±S.E. (g)	Mean±S.E.	Mean±S.E.	MSE	R^2
Gompertz	1W	36	3,449.1±34.1	3.41±0.078	0.13±0.0030	14,926,057	0.9740
	2W	16	2,962.5±41.1	3.61±0.176	0.16±0.0060	8,678,847	0.9608
	3W	44	3,276.8±31.2	3.46±0.085	0.14±0.0030	22,630,382	0.9661
	4W	24	2,470.1±36.5	3.63±0.127	0.13±0.0040	7,347,710	0.9637
	5W	33	2,360.0±30.0	3.53±0.099	0.12±0.0040	8,630,914	0.9650
von Bertalanffy	1W	36	3,610.8±43.0	0.76±0.013	0.10±0.0026	14,696,380	0.9744
	2W	16	3,043.6±48.7	0.80±0.031	0.13±0.0057	8,686,902	0.9608
	3W	44	3,415.0±39.1	0.77±0.014	0.11±0.0028	22,679,021	0.9660
	4W	24	2,594.2±47.6	0.79±0.021	0.10±0.0039	7,495,546	0.9629
	5W	33	2,487.9±39.5	0.77±0.017	0.10±0.0032	8,790,001	0.9644
Logistic	1W	36	3,236.4±25.7	12.70±0.570	0.21±0.0040	17,967,765	0.9687
	2W	16	2,843.8±33.8	13.16±1.170	0.25±0.0090	9,870,564	0.9555
	3W	44	3,090.9±23.3	13.01±0.600	0.22±0.0050	25,466,570	0.9619
	4W	24	2,309.6±25.4	14.55±0.940	0.21±0.0060	7,871,458	0.9611
	5W	33	2,197.8±20.6	13.91±0.730	0.21±0.0050	9,342,105	0.9621

W: line W. 1W, 2W, 3W, 4W, 5W : strains of line W, n: number of animals.

* Asymptotic final body weight: the parameter for asymptotic limit of the weight when age (*t*) approaches infinity.

** The log- function for the proportion of the asymptotic mature weight to be gain after birth.

*** The parameter for maturating rate, a function of the ratio of maximum growth rate to mature size.

MSE: mean square error of nonlinear model, S.E: standard error, R^2: coefficient of determination.

Table 8. Estimated parameter, calculated goodness of fit criteria for five strains of Y line using three growth model, from hatch to 32 weeks.

Function		n	Model parameter				
			C^*	a^{**}	b^{***}	Goodness of fit	
			Mean±S.E. (g)	Mean±S.E.	Mean±S.E.	MSE	R^2
Gompertz	1Y	39	3,518.8±31.7	3.36±0.072	0.13±0.0028	16,638,730	0.9747
	2Y	23	3,167.4±27.8	3.59±0.094	0.14±0.0033	6,144,404	0.9819
	3Y	42	3,623.8±34.2	3.61±0.088	0.13±0.0030	23,553,622	0.9700
	4Y	22	2,645.7±45.5	3.63±0.135	0.12±0.0046	8,148,133	0.9661
	5Y	39	2,488.9±27.1	3.55±0.089	0.13±0.0031	10,532,937	0.9679
von Bertalanffy	1Y	39	3,675.7±39.8	0.75±0.012	0.10±0.0025	16,476,696	0.9750
	2Y	23	3,280.1±34.2	0.79±0.016	0.12±0.0030	6,184,999	0.9818
	3Y	42	3,785.2±43.6	0.79±0.015	0.11±0.0027	23,838,978	0.9696

Table 8. Continued.

Function		n	Model parameter				
			C^{*}	a^{**}	b^{***}	Goodness of fit	
			Mean±S.E. (g)	Mean±S.E.	Mean±S.E.		R^2
von Bertalanffy	4Y	22	2,800.4±61.0	0.78±0.022	0.09±0.0041	8,292,532	0.9599
	5Y	39	2,618.0±35.6	0.77±0.015	0.10±0.0028	10,747,599	0.9673
Logistic	1Y	39	3,310.7±24.0	12.39±0.52	0.21±0.0040	19,780,556	0.9700
	2Y	23	3,011.3±22.8	13.58±0.69	0.23±0.0050	7,714,502	0.9773
	3Y	42	3,410.4±25.2	14.16±0.65	0.22±0.0040	26,503,272	0.9662
	4Y	22	2,451.2±30.3	14.85±1.02	0.21±0.0070	8,664,134	0.9581
	5Y	39	2,322.8±18.8	14.07±0.66	0.21±0.0050	11,417,126	0.9652

Y: line Y. 1Y, 2Y, 3Y, 4Y, 5Y : strains of line Y, n : number of animals.

[*] Asymptotic final body weight: the parameter for asymptotic limit of the weight when age (*t*) approaches infinity.

[**] The log- function for the proportion of the asymptotic mature weight to be gain after birth.

[***] The parameter for maturating rate , a function of the ratio of maximum growth rate to mature size.

MSE: mean square error of nonlinear model, S.E: standard error, R^2: coefficient of determination.

growth trajectories can be clearly observed in this plot. Descending order of low body weight group was consisted of 4Y>5Y>4W>5W strains respectively, and their average body weight of this group ranged between 2,434~2,171 g at 32 weeks of age. For medium weight group (i.e., 4F>5F>3Y>1Y>4H>1W>5H>4G>3W>2Y>5G>2W), the average body weight of this group ranged between 2,870~3,520 g at 32 weeks of age. For the heaviest group (i.e., 3H>1F>3F>1H>1G>2H>3G>2F>2G), average body weight ranged between 4,284~3,634 g respectively at the last week. Based on the results of the body weight curve and estimated *C* value, 3H strain was the highest body weight strain, whereas 5W strain was the lowest body weight strain. The results from growth curve were concordant with the observed average body weight data (i.e., observed the 3H and the 5W strains were the highest and the lowest body weight strains, respectively) in Fig. 1~5.

DISCUSSION

In this study, we identified that the growth curves of KNC strains showed clear tendency of difference among the 25 strains. Based on their body weight gain and mature body weight, three body weight groups can be divided (Fig. 6).

Gompertz model has been used as a model of choice for describing growth in broilers and layers in many reports, although growth curves of the similar or different species are not well described by the same model (Ricklefs, 1967). However, Gompertz model has the possible mathematical limitation which might cause in its overestimation of parameters in the model. Therefore, in this study, Bertalanffy model, was also evaluated with regard to their ability to describe the relationship between body weight and age in KNC and compared with two other functions (i.e., Gompertz and Logistic).

Comparison of the models based on asymptotic body weight (*C*), von Bertanffy model showed highest value 4,629 g, while Logistic model showed lowest 2,197 g. This finding were supported by similar trend of result showed by Choo et al. (2012); Zhao et al. (2015) and Fatten (2015). For maturating rate (*b*) and growth ratio (*a*), the highest values were obtained by Logistic model whereas the lowest were found in von Bertalanfy model. The range of maturating rate (*b*) value for all strains in Logistic and Bertalanffy were 0.09~0.25, which was lower than values, 0.12, 0.35 for those of Chinese indigenous chicken breeds determined by same model (Zhao et al., 2015; Choo et al., 2012). Grossman et al., (1985) and Aggrey (2002) obtained higher growth rate value in female chicken using Logistic model.

To make a comparison using coefficient of determination

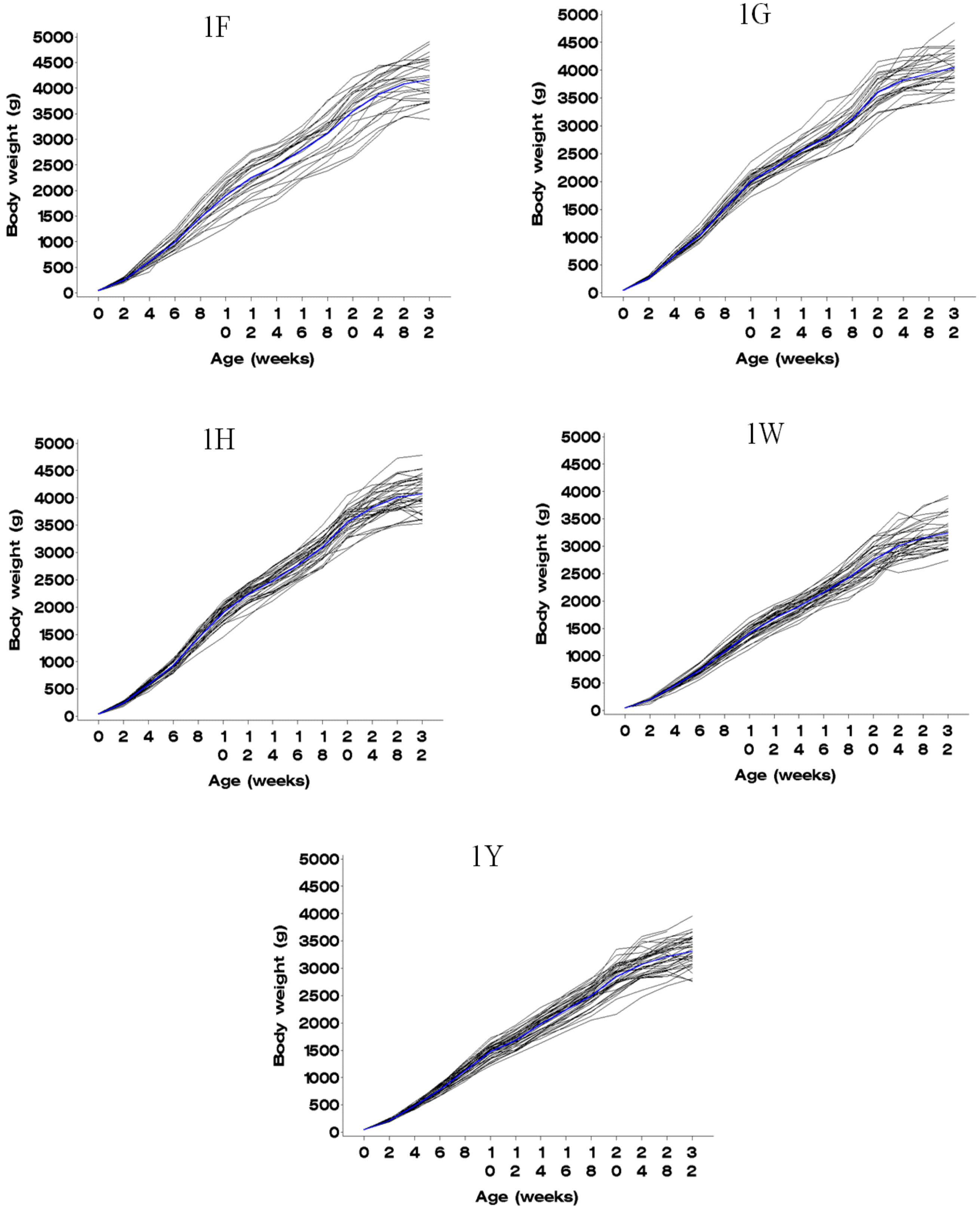

Fig. 1. Individual growth curves of female 1F, 1G, 1H, 1W, 1Y Korean native chicken strains from hatch to 32 weeks of age.

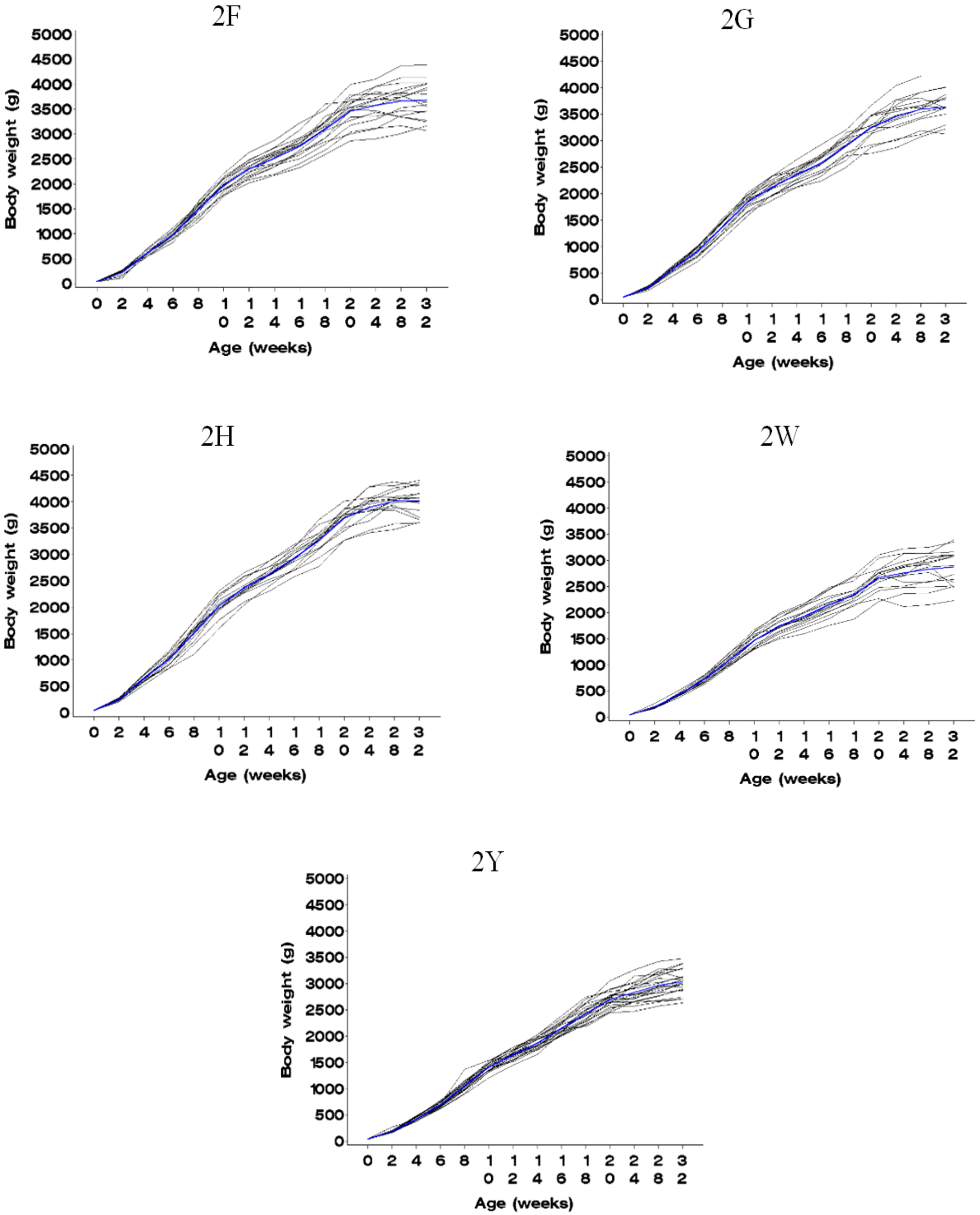

Fig. 2. Individual growth curves of female 2F, 2G, 2H, 2W, 2Y Korean native chicken strains from hatch to 32 weeks of age.

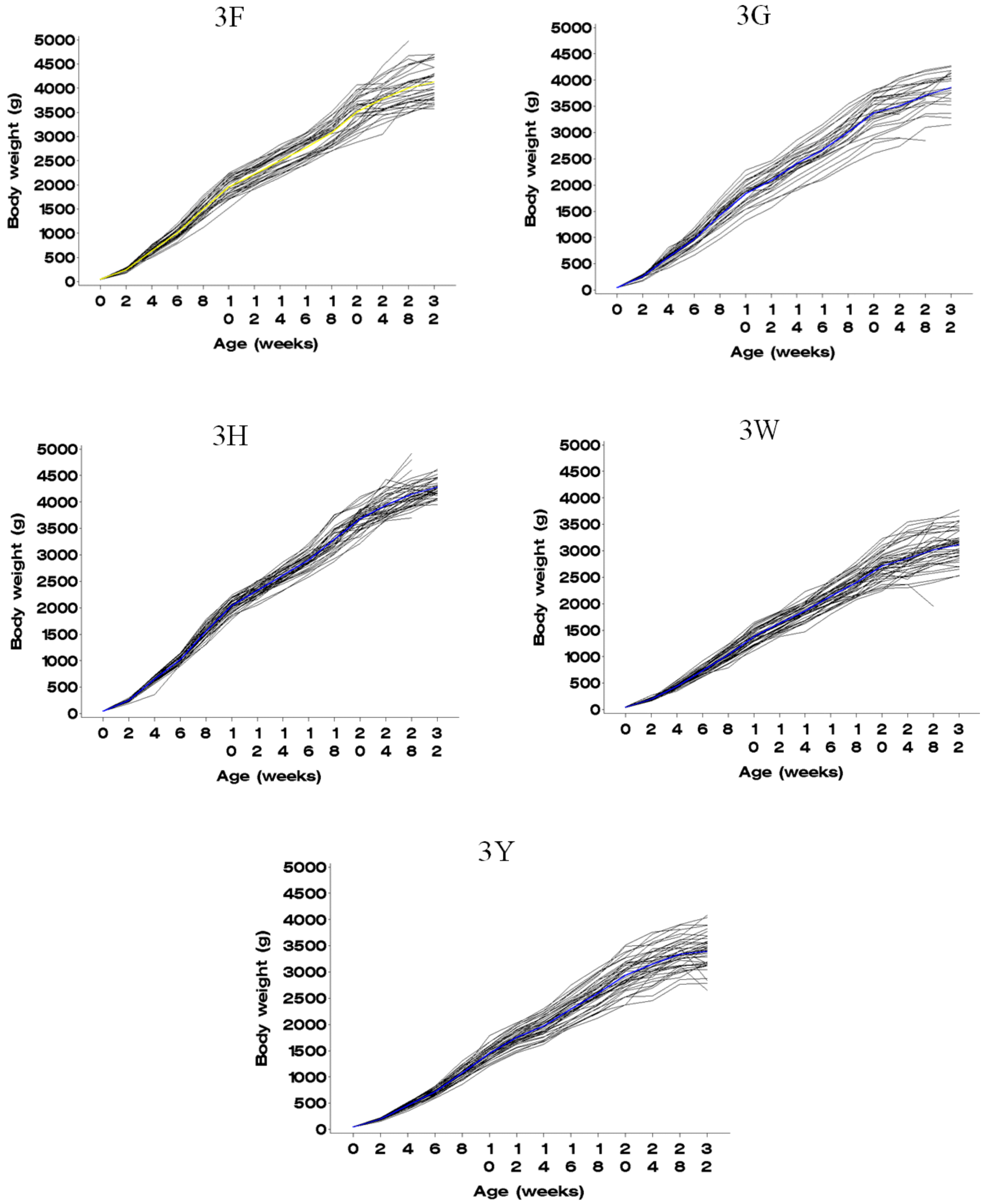

Fig. 3. Individual growth curves of female 3F, 3G, 3H, 3W, 3Y Korean native chicken strains from hatch to 32 weeks of age.

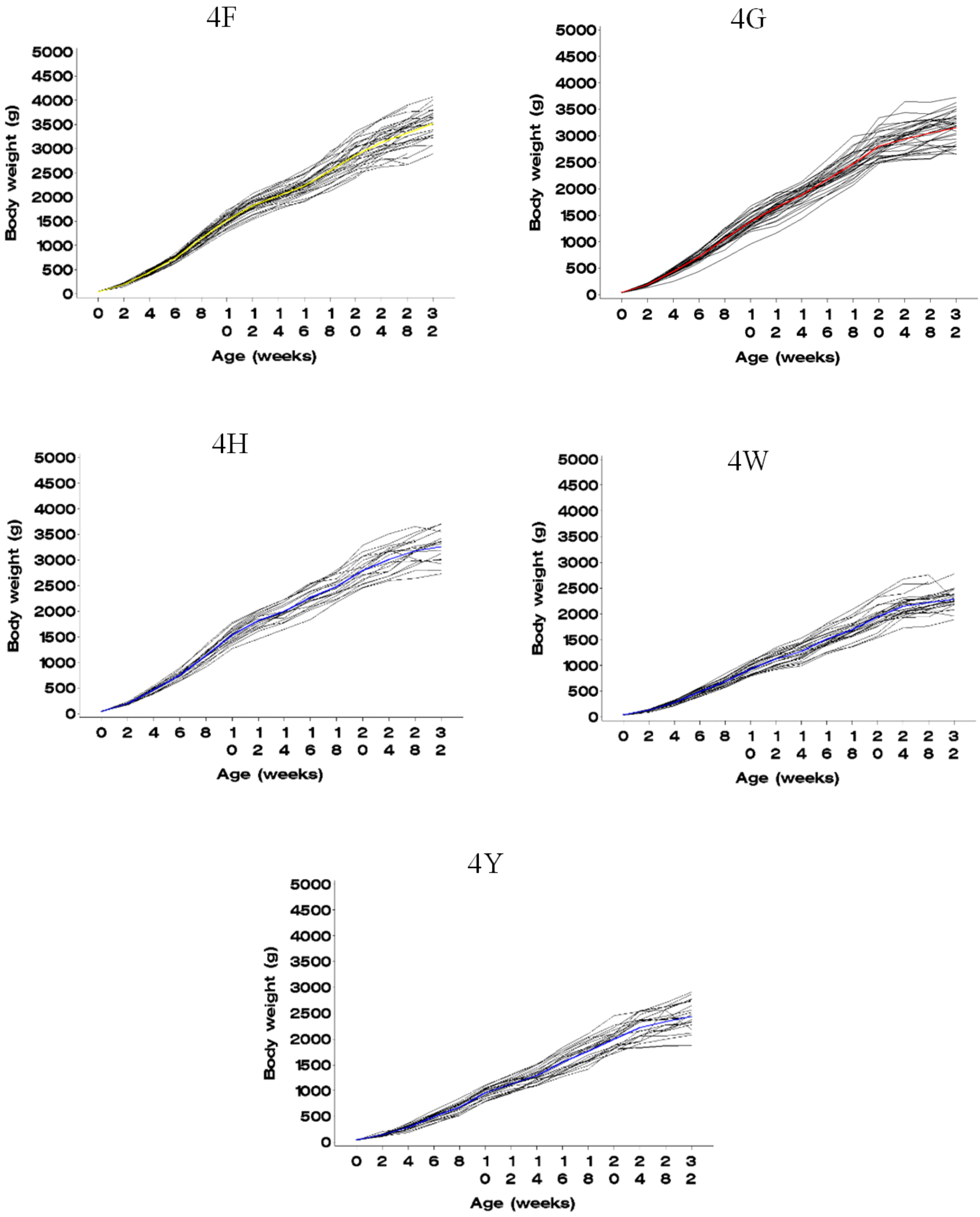

Fig. 4. Individual growth curves of female 4F, 4G, 4H, 4W, 4Y Korean native chicken strains from hatch to 32 weeks of age.

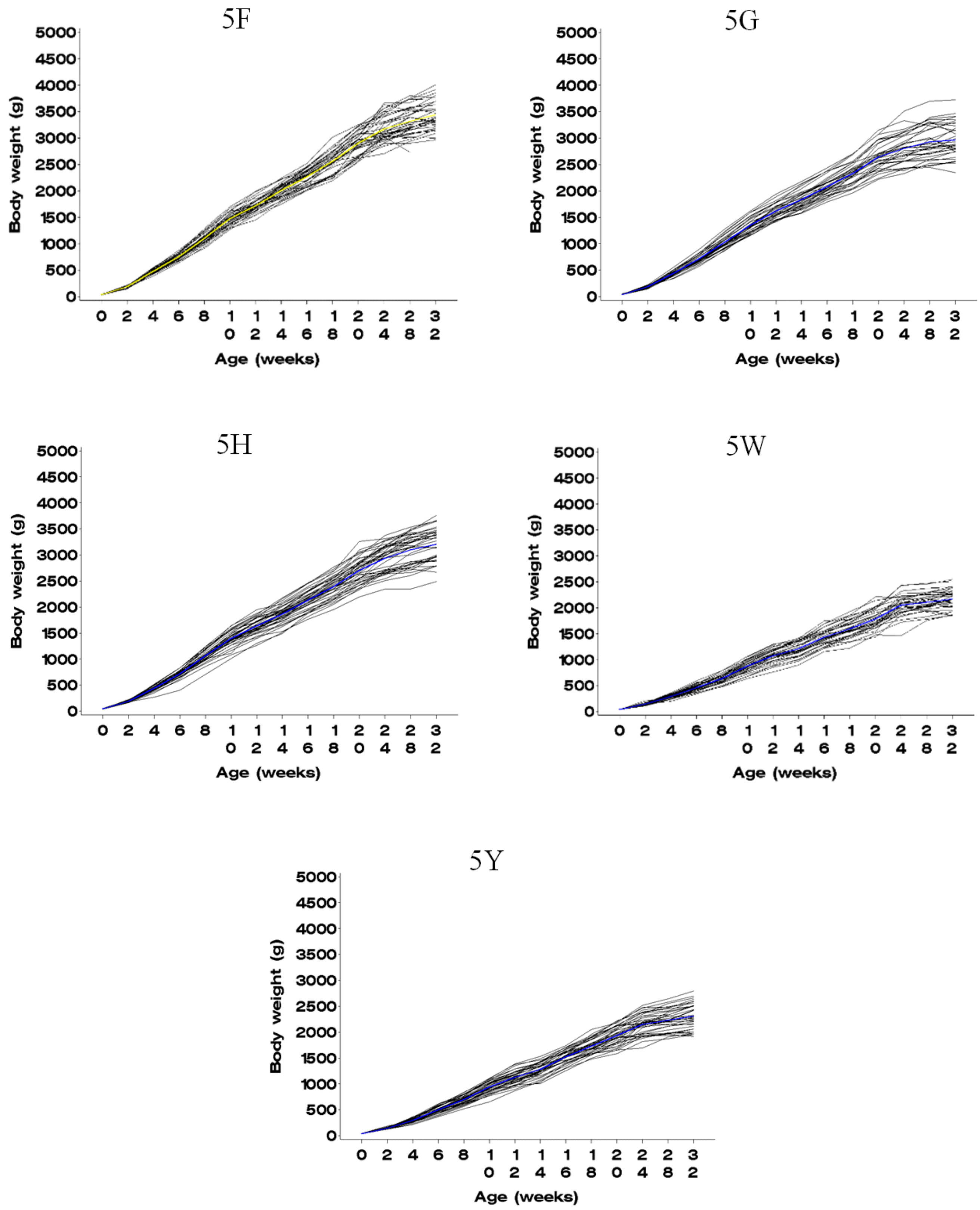

Fig. 5. Individual growth curves of female 5F, 5G, 5H, 5W, 5Y Korean native chicken strains from hatch to 32 week of age.

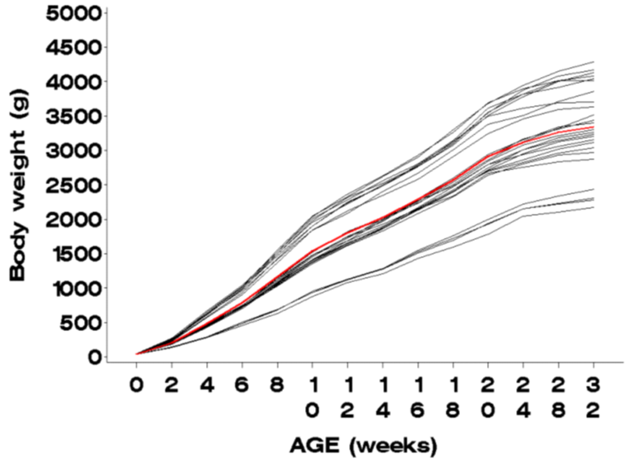

Fig. 6. Avarage body weight and age relationship of 25 strains of Korean native chicken. The strains can be divided by three groups: high group of strains (3H>1F>3F>1H>1G>2H>3G>2F>2G), medium group of strains (4F>5F>3Y>1Y>4H>1W>5H>4G>3W>2Y>5G>2W), and low group of strains (4Y>5Y>4W>5W).

(R^2) values, it was very difficult to identify obviously better than the others since each R^2 values were similar each other. However, the comparison between the models based on MSE values facilitated to make valid differences among the models. For 16 strains (i.e., 1F, 2F, 3F, 4F, 5F, 1G, 2G, 3G, 4G, 5G, 1H, 2H, 3H, 4H, 5H and 1W), von Bertalanffy model showed lowest MSE and highest R^2 values. However, Logistic model demonstrated highest MSE and lowest R^2 values for the same 16 strains. This findings found to be in agreement with those of similar study by Choo et al. (2012). Comparison between Gompertz and von Bertalanffy based on this criterion, von Bertalanffy was not superior to the Gompertz for all 25 strains. In this regards, nine KNC strains are best fit with Gompetz and worst fit with Logistic. Similar results for R^2 criteria were also observed. The results of goodness of fit in this study was inconsistent with several other researches which used similar growth curve model (Fatten, 2015; Zhao et al., 2015; Dharmani Kuhi et al., 2003; Dorgan et al., 2010).

In conclusion, different model can be used to evaluate the growth curves of poultry. Each model has mathematical limitations in estimation and data interpretation. Based on the goodness of fit criteria, Gompertz, and von Bertalanffy model were adequate to describe Korean native chicken growth. However, von Bertalannfy model is well described the most of KNC growth with biologically meaningful parameters. These results can provide useful information to improve the feeding standard of each KNC strains used in this study.

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