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Artificial Intelligence-Based Extended Method for Estimating Richards' Growth Models for Three Bird Species

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Abstract
Artificial Intelligence Based Extended Method for Estimating Richards Growth Models for Three Bird Types was conducted, though, many researchers of several bird type have provided vital and valuable scientific information especially on the use of statistical models. However, this research is based on reviewing the model performances and adequacy of the Richards model and the modified Richards model. The original model was applied while the other was modified from the original model to compare their adequacies and behaviors. The data set of the three birds used are Bird type 1 (Broilers), Bird type 2 (Layers) and Bird type 3 (Dual-Purpose) were generated from body weight and feed consumption of 150 birds reared on station on the Teaching and Research Farm of Ignatius Ajuru University of Education Ndele Campus. The method of nonlinear least square estimate by a modified version of the Levenberg-Marquardt algorithm and a simulated method of the simple linear regression model using the ordinary least squares method (OLS) by the assumed value method were also adopted. The process of parameter estimates also took the method of Artificial Intelligence (AI) Learning machine programming system was also adopted. The results from the estimated parameters displayed in Table 2, and the fitted plot in Fig. 1, shows that both Richards model and modified Richards model did not perform well on bird type 1 (Broilers). Table 2 and Fig. 2, respectively shows that modified Richards model performed better than the Richards model on bird type 2 (Layers) while Richards model also performed better than the modified on bird type 3 (Dual-purpose). The simulation results displayed in Table 3 shows that modified Richards model performed efficiently than Richard model on bird type 1(Broilers) and bird type 3 (Dual-Purpose) while Richards model performed effectively on bird type 2 (Layers).

Keywords: Nonlinear, Model, Richards, Modified, Birds, Broilers, Layers, Dual-Purpose

Introduction

In the context of growth modelling, approaches have been widely used in the modelling of several growth phenomenon especially in animal and plant growth of different parts of the living things which are normally nonlinear. Scientists and researchers have made several contributions towards selective breeding to actually improve the performances of economic existence and importance on both plants and animal growth. Growth models have provided needful and vital information towards the understanding of biological phenomenon of growth .Growth models plays significant role in understanding the development of organisms, particularly in ecological and biological studies .The Richards growth model , an extension of modified Richards model provides flexibility in depicting different growth patterns due to its additional shape parameter , which allows for a more accurate description of biological growth process. Traditional method for estimating the parameters of Richards model include nonlinear regression and least square estimation, but these approaches often encounter difficulties due to local minima entrapment and computational inefficiencies. However, this research is based on modifying the Richards growth model from the original model and apply the idea of AI to extend the model which will assist in reviewing the model performances and its adequacy .The results were installed in the AI for effective interpretation and outcome .The two models used in this research are the Richards growth model and modified Richards growth model and the three sets of data from the Broilers, Layers and Dual purpose. The research compared the performances of the AI learning machine and the two nonlinear growth models using the model adequate measures which exhibits sigmoid pattern over time were also in consideration to justify the best fit model.

Several equations in statistical modeling has been used for parameter estimate in the nonlinear growth models in connection with the poultry farm industry towards the production of birds in Nigeria and other part of the country. However, Antonio et al. (2021), used local birds and its various breeds to study the growth and performances of the Gompertz model, Richards model, Lopez model, Bertalanffy model, and Weibull model. A technique of Kruskal-Wallis H test was used for the estimation and the results were obtained, the Richards and Gompertz described better to analyze the growth performance of the local bird breeds and variety. Raji et al. (2014) used seven nonlinear growth models to determine the best fit model to describe some Japanise quails, some model accuracy measures such as AIC, MSD, SD, R^2 and MSE were applied to measure the outperformed models. However, the results show that Weibull model performed better and follow by Richards model. Firat el al. (2016) used Bayesian techniques and a Nonlinear Least Square (NLS) to analyze three nonlinear growth models using some Japanise quails. The fitted plots series were also considered to determine their respective model performance, thereafter results were obtained and compared with the fitted plots and conclusion were made that Gompertz model and Richards model performed better than Logistic model.

Materials and Methods

Statistical analysts have described bird growth as a gradual process involving morphological changes towards breeding, hatching to maturity. However, this research is practically conducted at the experimental poultry industry at the university practical poultry farm of Ignatius Ajuru University of Education, Ndele Campus. Chicken breeds are randomly selected at 0-24 weeks (6 months) under the natural conducive environment (temperature, light and humidity). The birds are of three types namely; the bird type 1(broilers), bird type 2 (layers) and bird type 3 (dual-purpose) and each bird type contain 24 pieces for field experiment in the poultry farm. A good environmental temperature between 18.0C to 30.0C were provided for the different bird types during the experiment and 72 field experimental data items were generated through the measurement of feed consumed and weighted weekly. Feeding methodology commenced as the bird types arrived with starter diet from 0-18 days. The Gretl software, AI learning machine and Micro-Excel were used in the analysis of the two nonlinear growth models. The parameter estimation of the nonlinear least square estimation by the method of modified version of the Levenberg-Marquardt algorithm were used

The Richard Growth Model

The Richard growth model is given by

$$G_t(w) = \propto_{0i} \left(1 - \propto_1 e^{-\propto_3 x}\right)^{-\propto_2} \quad (1)$$

$$\theta_2 = (\propto_0, \propto_{1,} \propto_2, \propto_3) \quad (2)$$

i =1,.3 for bird type

$G_t(w)$ = Body weight / dependent variable (y).

$\propto_{0i}$ = Initial growth rate for bird type

$\propto_1$= Environment (feeding, temperature, pressure and humidity etc.)

$\propto_2$= Biosecurity (treatment or medication)

$\propto_3$ = Genetic make-up (Genotype) for bird type

x = Feed consumption

t = time scale

e = the Euler number i.e. e= 2.71828

N/B, $\propto_{0i}, \propto_1, \propto_2$ and $\propto_3$ estimated parameters.

Modified Levenberg-Marquardt Iteration

By applying the method of Nonlinear Least Squares Estimation using a modified version of Levenberg-Marquardt Algorithm. These processes obtained the partial derivative of each of the nonlinear growth model with respect to each of the parameters such as $\propto_0$, $\propto_1$, $\propto_2$, and $\propto_3$. The process also substituted the second-order model coefficient ($\propto_0^{(0)}$, $\propto_1^{(0)}$, $\propto_2^{(0)}$, and $\propto_3^{(0)}$ and the process also contributes to the data and initiate some guess values on the AI machine learning program and the iteration are ran to obtain some results. The research used the modified version of Levenberg-Marquardt method as follows to:

(1) attain differential calculus of the model with respect to the four parameters ($\propto_{0i}, \propto_1, \propto_2, \propto_3$)

(2) To develop a package in the Gretl software using the six nonlinear models and input the initial values by fitting second order models.

(3) Then substitute the second order model coefficient ($\propto_{0i}^{(0)}$, $\propto_{1}^{(0)}$, $\propto_{2}^{(0)}$, and $\propto_{3}^{(0)}$,) as first guess value for iteration process.
(4) Contributes the field experimental data set and initiate guess values on the developed program. Then run the iteration accordingly to obtain the results.
Let $\propto = (\propto_{0i}^{(0)}, \propto_{1}^{(0)}, \propto_{2}^{(0)}$, and $\propto_{3}^{(0)}$,) represent the initial parameter. Thus, we take logarithm transformation of each of the six nonlinear growth models.
The Richard growth model are subjected is subjected into Gretl technique as follows

$$G_t(w) = \propto_{0i} (1 - \propto_1 e^{-\propto_3 x})^{-\propto_2} \quad (3)$$

Positioning the Richard growth model in logarithm form and we obtain

$$\text{In } G_t(w) = \text{In}\propto_{0i} - \propto_2 \text{ In } (1 - \propto_1 e^{-\propto_3 x}) \quad (4)$$

Take the partial derivative with respect to each of the parameter.

$$\frac{\partial G_t(w)}{\partial \propto_{0i}} = 1$$

$$\frac{\partial G_t(w)}{\partial \propto_{1}} = \propto_2 (1 - \propto_1 e^{-\propto_2 x})$$

$$\frac{\partial G_t(w)}{\partial \propto_{2}} = -\text{In } (1 - \propto_1 e^{-\propto_3 x})$$

$$\frac{\partial G_t(w)}{\partial \propto_{3}} = -\propto_1 \propto_2 + e^{-\propto_3 x} (1 - \propto_1 e^{-\propto_3 x})^{-1}$$

Then the nonlinear least square estimation using a modified version of Levenberg-Marquardt, we substitute $\propto_{0i}^{(0)}$, $\propto_{1}^{(0)}$, $\propto_{2}^{(0)}$, and $\propto_{3}^{(0)}$ the initial guess vectors for iteration process into the equation.

$$\text{In } G_t(w) = \text{In}\propto_{0i} - \propto_2 \text{In } (1 - \propto_1 e^{-\propto_3 x}) \quad (5)$$

modified Richard growth model is given by

$$G_t(w) = \propto_{0i} \left[1 - \propto_{0i} e^{-\propto_2 (x + S/\bar{x})}\right]^{-\propto_3} \quad (6)$$

Transforming the model into logarithm form

$$InG_t(w) = In \propto_{0i} - \propto_2 In(1 - \propto_1 e^{-\propto_3 (x + S/\bar{x})}) \quad (7)$$

Take the partial derivative with respect to their respective parameters

$$\frac{\partial G_t(w)}{\partial \propto_{0i}} = 1$$

$$\frac{\partial G_t(w)}{\partial \propto_{1}} = \propto_2 \left(1 - \propto_1 e^{-\propto_2 (x + S/\bar{x})}\right)^{-1} e^{-\propto_3 (x + S/\bar{x})}$$

$$\frac{\partial G_t(w)}{\partial \propto_{2}} = In(1 - \propto_1 e^{-\propto_3 (x + S/\bar{x})}$$

$$\frac{\partial G_t(w)}{\partial \propto_{3}} = \propto_1 \propto_2 \left(x + S/\bar{x}\right) e^{-\propto_3 (x + S/\bar{x})} \left(-\propto_1 e^{-\propto_3 (x + S/\bar{x})}\right)^{-1}$$

Substituting the initial guess vector (${\propto_{0i}}^{(0)}, {\propto_1}^{(0)}, {\propto_2}^{(0)}$ *and* ${\propto_3}^{(0)}$) to the equation.
$InG_t(w) = In \propto_{0i} - \propto_1 In\left(1 - \propto_1 e^{-\propto_3 (x + S/\bar{x})}\right)$ and the results were obtained

Simulation of Assumed Value Method

The assumed mean value method was applied in the analysis of the two nonlinear growth models to calculate and estimates the best model to fit the field experimental simulation data set.
We take n = 500 and assume that $x \sim \bar{x}\ (\bar{x}, s) and\ x \sim \bar{x}\ [a, b]$
If a = $\bar{x}\ amd\ b = s$ .Then the assumed mean value is written thus $\bar{x} = \frac{a+2}{2}\ and$
S = $\frac{b+2}{2}$. Again, assuming$x \sim \bar{x}\ \left(x + S/\bar{x}\right), and\ x \sim \bar{x}\ [a, b]$ as a = x and b $S/\bar{x}$ then
$x = \frac{a+2}{2}$, $S/\bar{x} = \frac{b+2}{2}$ as $x \sim \bar{x}$ ($\bar{x}$,s) and n = 500 [$\propto_{0i}\ \propto_1 \propto_2$, and $\propto_3$] ≈ [2,1,5,0,5,0,3]
$(x + S/\bar{x})$. $x \sim \bar{x}$ [a, b]

$$\bar{x} = \frac{a+2}{2} \quad (8)$$

$$s = \frac{b+2}{2} \quad (9)$$

Richards Growth Model.

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Assumed value using ordinary least square method

$G_t(w) \quad = \propto^{i}{}_0 (1 - \propto_1 \ e^{-\propto_3 x})^{-\propto_2}$ (10)

Take log of both sides

In $G_t(w)$= in$\propto_0$ $^-\propto_2$ in $(1 - \propto_1 \ e^{-\propto_3 x})$ (11)

So, to fit the transformed method, we assumed value for $\propto_1$ & $\propto_3$. Then, approach orderly leapt square estimation (OLS). $\propto_1$ = [-0.10; 0.10] at an increase of 0.02 and $\propto_3$ = [-1.00, 1.00] at an increase of 0.2. Therefore, we fit $y_t = \beta_0 + \beta_2 \ x_t$ (simple regression)

Where $y_t = In \ G_t(w)$ (12)

$x_t = In \ (1 - \propto_1 \ e^{-\propto_3 x})$ (13)

Also $\propto_0 = \beta_0$ and $\propto_2 = -\beta_2$ as $\propto_0 = e^{\beta_0}$

$\propto_3$	$\propto_1$
-0.10	-1.0
-0.08	-0.8
-0.06	-0.6
-0.04	-0.4
-0.02	-0.2
0.02	0.2
0.04	0.4
0.06	0.6
0.08	0.8
1.00	0.10

Modified Richards Growth Model.

Assumed value using ordinary least square method

$G_t(w) \quad = \propto_{0i} (1 - \propto_1 \ e^{-\propto_3 (x + S/\bar{x})})^{-\propto_2}$ (14)

Take log of both sides

In $G_t(w)$= in$\propto_{0i}$ $^-\propto_2$ in $(1 - \propto_1 \ e^{-\propto_3 (x + S/\bar{x})})$ (15)

So, to fit the transformed method, we assumed value for $\propto_1$ and $\propto_3$. then, approach orderly leapt square estimation (OLS). In the study, we let $\propto_1$ = [-0.10; 0.10] at an increase of 0.02 and $\propto_3$ = [-1.00, 1.00] at an increase of 0.2. Therefore, we fit

$y_t = \beta_0 + \beta_2 \ x_t$ (simple regression) (16)

$y_t = In \ G_t(w)$ (17)

$x_t = In \ (1 - \propto_1 \ e^{-\propto_3 (x + S/\bar{x})})$

Also $\propto_0 = \beta_0$ and $\propto_2 = -\beta_2$ $\propto_0 = e^{\beta_0}$

$\propto_3$	$\propto_1$
-0.10	-1.0
-0.08	-0.8
-0.06	-0.6
-0.04	-0.4
-0.02	-0.2
0.02	0.2
0.04	0.4
0.06	0.6
0.08	0.8
1.00	0.10

$\propto_3$ = (-0.10, -0.08, -0.06, -0.04, -0.02,0.02,0.04,0.06,0.08,0.10)

$\propto_1$ = (-1.0, -0.8, -0.6, -0.4, -0.2,0.2,0.4,0.6,0.8,0.10)

Table 1: Represents the Field Experimental Data Set and the Modified Field Experimental Data Set of The Three Bird Types in Gramm

BROILER C FEED CONSUMED (g)	BROILER C BODY WT (g)	LAYERS C FEED CONSUMED (g)	LAYERS C BODY WEIGHT (g)	DUAL P. C FEED CONSUMED (g)	DUAL P. C. BODY WEIGHT (g)	Mod. BROILER C FEED CONSUMED (g)	Mod. LAYERS C FEED CONSUMED (g)	Mod. DUAL P. C FEED CONSUMED (g)
0.00	42.20	0.00	40.50	0.00	42.10	0	0	0
805.71	70.62	40.20	150.10	880.20	56.46	805.316	39.786	879.874
990.20	92.40	42.70	320.00	1001.30	71.10	989.806	42.286	1000.974
985.60	108.20	48.40	520.80	1102.40	90.70	985.206	47.986	1102.074
1109.22	122.22	50.60	620.40	1210.40	107.80	1108.826	50.186	1210.074
1216.00	228.40	60.30	710.80	1320.22	122.90	1215.606	59.886	1319.894
1102.62	239.30	66.40	1000.00	1400.00	184.60	1102.226	65.986	1399.674
1367.10	308.22	61.90	1020.80	1428.40	279.22	1366.706	61.486	1428.074
1562.32	386.72	65.80	1240.50	1448.10	385.20	1561.926	65.386	1447.774
1749.20	407.72	70.30	1500.00	1460.40	496.10	1748.806	69.886	1460.074
1908.32	500.11	73.40	1600.70	1562.00	586.00	1907.926	72.986	1561.674
1936.42	601.12	78.70	1720.20	1584.82	690.10	1936.026	78.286	1584.494
1962.21	682.41	82.30	1820.00	1709.62	864.40	1961.816	81.886	1709.294
2000.10	716.82	85.60	1900.30	1722.62	1020.00	1999.706	85.186	1722.294
2120.40	880.13	90.40	2120.50	1794.24	1181.17	2120.006	89.986	1793.914
2144.48	1002.20	100.20	2270.50	1840.20	1422.30	2144.086	99.786	1839.874
2202.20	1170.72	103.40	2348.70	1878.31	1510.14	2201.806	102.986	1877.984
2302.10	1210.62	108.70	2478.30	1920.00	1700.00	2301.706	108.286	1919.674
2401.22	1218.72	110.60	2575.02	1992.40	1910.40	2400.826	110.186	1992.074
2303.00	1223.20	114.80	2876.20	2010.41	2102.00	2302.606	114.386	2010.084
2440.12	1242.10	122.70	2895.10	2082.10	2260.20	2439.726	122.286	2081.774
2602.42	1362.82	125.80	3035.05	2165.20	2400.09	2602.026	125.386	2164.874
2706.24	1530.45	132.60	3195.80	2247.75	2490.26	2705.846	132.186	2247.424
2800.10	1702.42	140.20	3355.52	2326.10	2443.00	2799.706	139.786	2325.774

Artificial Intelligence (AI) Programming Based Richards Growth Model. AI is a characteristic of a self-aware machine, while the former feeling is a characteristic of a theory-of-mind machine. Artificial Intelligence (AI) uses a wide range of techniques and approaches that enable machines to simulate human-like intelligence and perform tasks that traditionally require human assistance. AI systems work through a combination of algorithms, data, and computational power: Algorithm Process: Modified Levenberg-Marquardt Algorithm: Applying the non-linear least squares method or performing non-linear square (NLS) estimation using a modified version of the Levenberg-Marquardt algorithm. Non-linear regression modelling is similar to linear regression modelling in that both seek to graphically track a particular response from a set of variables. Non-linear model is more complicated than a linear model to develop because the function is created through a series of approximations (iteration) that may start from trial and error.

Steps

genr alpha =5
genr beta = 2
genr gamma =1

```
genr omega =0.2
l_BROILER_C_BOD = alpha - gamma*log(1-beta*exp(-BROILER_C_FEED*omega))
deriv alpha = 1
deriv beta = exp(-BROILER_C_FEED*omega)*gamma*(1-beta*exp(-BROILER_C_FEED*omega))^-1
deriv gamma = - log(1-beta*exp(-BROILER_C_FEED*omega))
deriv omega = -gamma*beta*BROILER_C_FEED*exp(-BROILER_C_FEED*omega)*(1-beta*exp(-BROILER_C_FEED*omega))^-1
genr alpha =3.1
genr beta = 0.89
genr gamma = 0.4
genr omega = 0.0012
l_ LAYERS _C_BOD= alpha - gamma*log(1-beta*exp(-LAYERS_C_FEED_C *omega))
deriv alpha = 1
deriv beta = exp(-LAYERS_C_FEED_C *omega)*gamma*(1-beta*exp(-LAYERS_C_FEED_C *omega)^-1)
deriv gamma = - log(1-beta*exp(-LAYERS_C_FEED_C *omega))
deriv omega = -gamma*beta* LAYERS_C_FEED_C *exp(-LAYERS_C_FEED_C *omega)*(1-beta*exp(-LAYERS_C_FEED_C *omega)^-1)

genr alpha =5.5
genr beta = 0.86
genr gamma = 0.3
genr omega = 0.001
l_DUAL_P__C__BO = alpha - gamma*log(1-beta*exp(-DUAL_P__C_FEED*omega))
deriv alpha = 1
deriv beta = exp(-DUAL_P__C_FEED*omega)*gamma*(1-beta*exp(-DUAL_P__C_FEED*omega)^-1)
deriv gamma = - log(1-beta*exp(-DUAL_P__C_FEED*omega))
deriv omega = -gamma*beta*DUAL_P__C_FEED*exp(-DUAL_P__C_FEED*omega)*(1-beta*exp(-DUAL_P__C_FEED*omega)^-1)
```

Table 2: Illustrates the Estimates of the Richard Growth Model and the Modified Richard Model

BIRD TYPE 1 (BROILER BIRD) OF FIELD EXPERIMENTAL

Model	Parameter	Estimated Existing Model	Estimated Modified Richards Model
Richard	Alpha	$\propto_0$ = 6.13219 (0.8988)*	$\propto_0$ = 6.13189 (0.8987)**
	Beta	$\propto_1$ = -3.09284 (0.7459)**	$\propto_1$ = -3.09136 (0.7462)*
	Gamma	$\propto_2$ = 1.67811 (0.8908)	$\propto_2$ = 1.67696 (0.8909)
	Omega	$\propto_3$ = 0.00306549 (8.35e-026)**	$\propto_3$ = 0.00306653 (8.56e-026)**
	SSE	18.67600	18.20100
	AIC	39.46409	39.47120
	BIC	44.17630	44.18341
	R^2	0.332487	0.332289
	Adj R^2	0.332360	0.232132

BIRD TYPE 2 (LAYER BIRDS) OF FIELD EXPERIMENTAL DATA

Model	Parameter	Estimated Existing Model	Estimated Modified Richards Model
	Alpha	$\propto_0$ = 7.52334 (0.9999)	$\propto_0$ = 7.97477 (0.5379)*
	Beta	$\propto_1$ = -6.73237 (0.9723)*	$\propto_1$ = -13.1290 (8.13e016)***
	Gamma	$\propto_2$ = 65.9554 (0.9729)	$\propto_2$ = 1.75866 (0.0064)**
	Omega	$\propto_3$ = 0.126591 (171e-083)***	$\propto_3$ = 0.0437215 (3.01e-056)***
	SSE	2.125904	0.239521
	AIC	26.58867	44.939168
	BIC	31.13065	54.701383
	R^2	1.786728	0.952968
	Adj R^2	1.753054	0.945913

BIRD TYPE 3 (DUAL-PURPOSE BIRDS) OF FIELD EXPERIMENTAL DATA		
Alpha	$\propto_0$ = 6.38.905 (0.8372)**	$\propto_0$ = 6.39982 (0.8344)*
Beta	$\propto_1$ = -1.13116 (0.9261)***	$\propto_1$ = -1.12544 (0.9236)
Gamma	$\propto_2$ = 2.60436 (0.9571)**	$\propto_2$ = 2.68747 (0.0178)**
Omega	$\propto_3$ = 0.00181949 (0.0184)***	$\propto_3$ = 0.00180481 (0.0178)***
SSE	29.99696	29.99696
AIC	81.46207	61.46207
BIC	86.17428	66.17428
R^2	0.291638	1.291638
Adj R^2	0.185383	0.985383

Footnote *sig. at 10%, ** Sig. at 5% *** Sig. at 1%

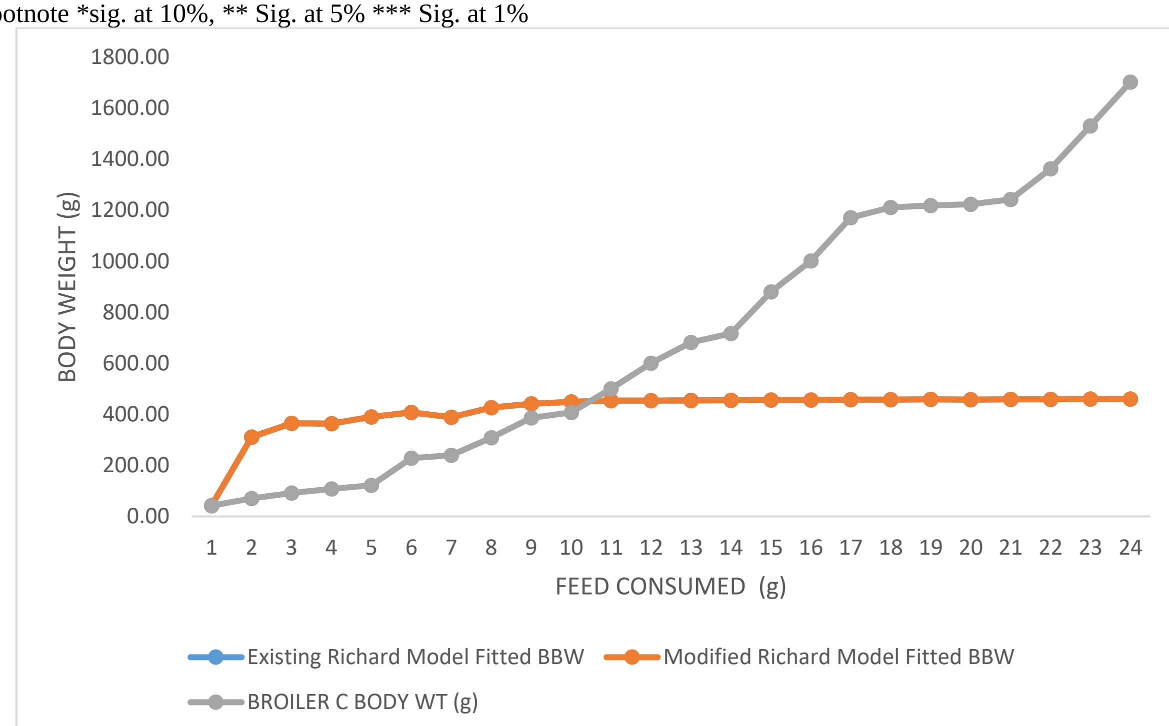

Fig. 1: Represents plot of Richard model, modified Richard model and bird type 1 body weight (Broiler Chicken) against body weight

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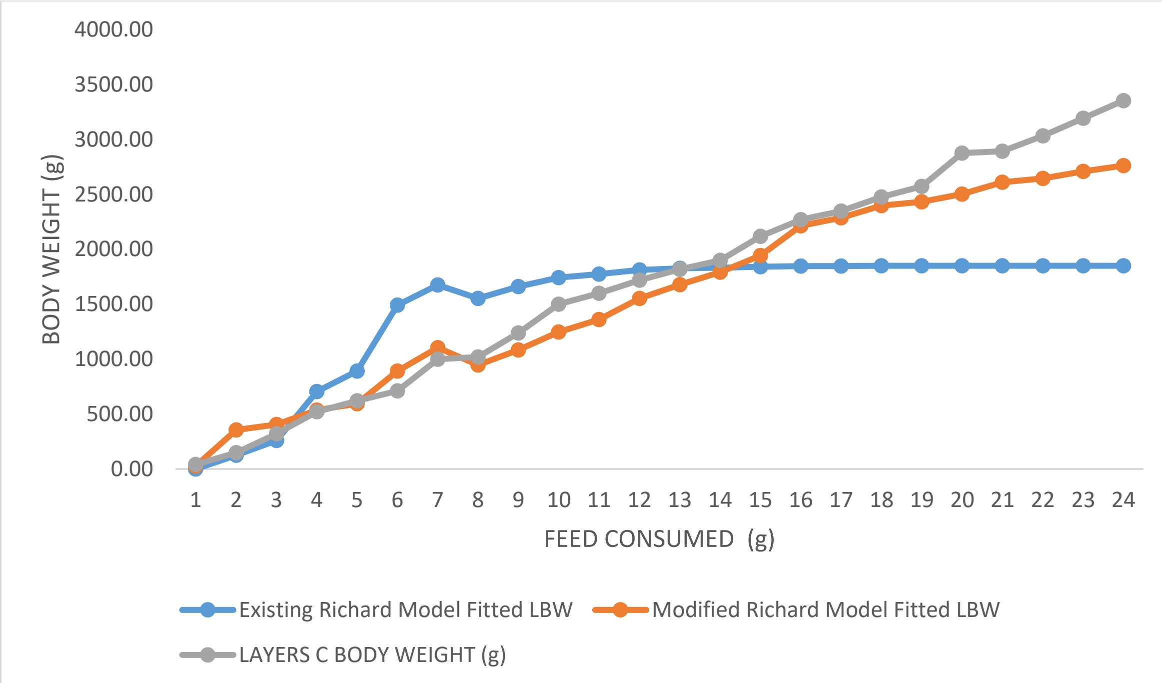

Fig. 4.2: Represents plot of Richard model, modified Richard model and bird type 2 body weight (Layers Chicken) against body weight

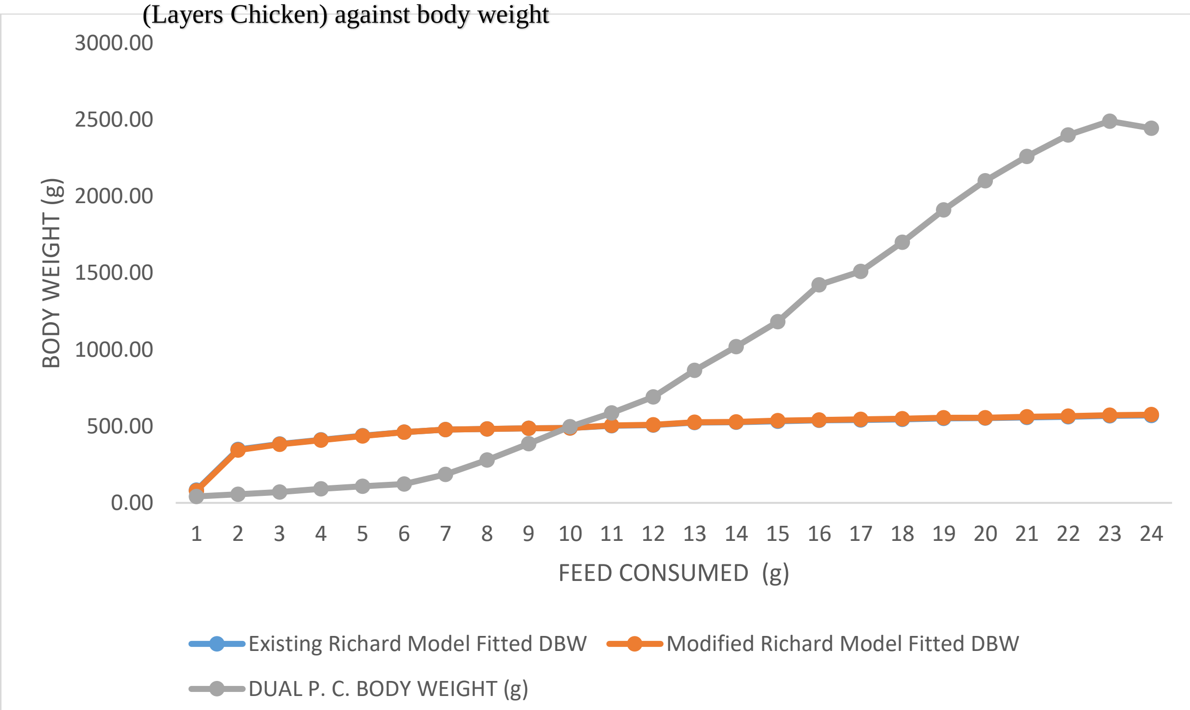

Fig. 4.3: Represents plot of Richard model, modified Richard model and bird type 3 body weight (Dual-Purpose Chicken) against body weight

Table 3: The Summary of the Two Nonlinear Models with Model Accuracy Measures

Bird Type 1 (Broilers)

Model	Growth Rate	SSE	AIC	BIC	R^2	Adj R^2
Modified Richards	0.10	0.0544	-61.8734	-57.1612	95.69%	95.49%
Existing Richards		0.0534	-62.3187	-57.6065	95.69%	95.49%
Modified Richards	0.08	0.0531	-62.4539	-57.7417	95.71%	95.52%
Existing Richards		0.0531	-62.4539	-57.7417	95.71%	95.52%
Modified Richards	0.06	0.0526	-62.2289	-57.51.67	95.76%	95.57%
Existing Richards		0.0526	-62.2289	-57.51.67	95.76%	95.56%
Modified Richards	0.04	0.0515	-63.1882	-58.4759	95.85%	95.66%
Existing Richards		0.0515	-63.1882	-58.4759	95.85%	95.66%
Modified Richards	0.02	0.049	-64.3824	-59.6702	96.05%	95.87%
Existing Richards		0.049	-64.3824	-59.6702	96.05%	95.87%

Bird Type 2 (Layers)

Model	Growth Rate	SSE	AIC	BIC	R^2	Adj R^2
Modified Richards	0.1	0.2959	-21.2256	-16.5134	75.30%	74.18%
Existing Richards		0.294	-21.3802	-16.668	75.46%	74.35%
Modified Richards	0.08	0.3399	-17.8985	-13.1863	71.62%	70.33%
Existing Richards		0.3377	-18.0543	-13.3421	71.81%	70.53%
Modified Richards	0.06	0.42	-17.8985	-13.1863	64.94%	63.35%
Existing Richards		0.4175	-18.0543	-13.3421	65.15%	63.56%
Modified Richards	0.04	0.5374	-6.9043	-2.1921	55.14%	53.10%
Existing Richards		0.5356	-6.9848	-2.2726	55.29%	53.26%
Modified Richards	0.02	0.5246	-7.4829	-2.7707	56.21%	54.22%
Existing Richards		0.5239	-7.5149	-2.8027	56.26%	54.27%

Bird Type 3 (Dual-Purpose)

Model	Growth Rate	SSE	AIC	BIC	R^2	Adj R^2
Modified Richards	0.1	0.2369	-26.5628	-21.8506	87.69%	87.14%
Existing Richards		0.237	-26.5527	-22.8405	87.69%	87.13%
Modified Richards	0.08	0.2343	-26.8277	-21.1155	87.83%	87.27%
Existing Richards		0.2344	-26.8174	-21.1052	87.82%	87.27%
Modified Richards	0.06	0.2298	-27.2931	-22.5809	88.06%	87.52%
Existing Richards		0.2299	-27.2827	-22.5704	88.05%	87.51%
Modified Richards	0.04	0.2201	-27.3284	-23.6155	88.56%	88.04%
Existing Richards		0.2202	-28.3173	-23.605	88.56%	88.04%
Modified Richards	0.02	0.1883	-32.0733	-27.361	90.22%	89.77%
Existing Richards		0.1884	-32.0605	-27.3483	90.21%	89.77%

Discussion

Many researchers, such as Azme et al. (2005) and Biu et al. (2020), etc., whose studies were based on the nonlinear growth models, used partial differentiation to obtain their respective results. However, the study used partial derivative method to determine the model parameters, estimation of $\propto_0, \propto_1, \propto_2, \propto_3$ and the fitted plots of the Richards model and modified Richards. Table 4.1 described the experimental data set and modified experimental data set used in the estimation. The Modified Levenberg Marquardt Algorithm of Richards and modified Richards model displayed the processes of Artificial Intelligence (AI) machine learning programming system as results were obtained. Table 4.2 also displayed the estimated results of Richards growth model and modified Richards growth model of bird type 1(Broilers), bird type 2 (Layers) and bird type 3 (Dual-purpose).The results, which displayed in Table 4.2, described that both the Richards model and modified Richards model on bird type 1 (Broiler) did not perform efficiently, but modified Richards model performed better than Richards model on bird type 2 (Layers) while Richards model performed better on bird type 3(Dual-purpose). Fig.1, Fig.2, and Fig. 3 display fitted plots of the Richards model and the modified Richards model of bird type 1 (Broiler), bird type 2 (Layers), bird type 3 (Dual-Purpose) and their respective body weight. The result of the fitted plots showed that both the Richards model and the modified Richards model did not capture the sigmoid shape on bird type 1 (Broiler), it also displayed that the modified Richards model captured bird type 2 (Layers) while the Richards model captured bird type 3 (Dual-Purpose). Table 3 displays the assumed mean simulation technique of parameter estimation of the bird type 1 (Broilers), bird type 2 (Layers) and bird type 3 (Dual-Purpose). The result shows that the modified Richards model was better than the Richards model at the respective rate and significant levels on bird type 1 (Broilers), bird type 3 (Dual-Purpose). The parameter estimation in Table 3, also displayed that the Richards model was better than the modified Richards on bird type 2 (Layers).

The two nonlinear growth models used in the study had their respective estimations with the three-bird type. The Gretl estimation was able to identify the model selection of the estimated parameter with its fitted plots. Table 1 illustrates the results of the estimation that both models did not perform efficiently on bird type 1 (Broiler), Modified Richards model performed efficiently on bird type 2 (Layers). Table 2, while Richards model performed effectively for bird type 3 (Dual-purpose) on Table. Table 3 displays the summary of the simulation techniques at various rates of parameter estimation. It shows that modified Richards model performed better than Richards model on bird type 1 (Broilers) and bird type 3 (Dual-Purpose) while Richards model performed better than modified Richards model on bird type 2 (Layers).

Conclusion

The Richards model and modified Richards model on bird type 1 did o displayed sigmoid trend shape and the parameter estimation did no performed adequately. Table 3. which displayed various parameter estimate is in of the simulation techniques shows that modified Richards perfumed better on bird type 1 and bird type 3 while Richards model performed better only on bird type 2.

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