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Comparision of Four Sigmoidal Models to Describe Growth Curves of Cihateup Local Ducks in West Java

Limai Lan*), Asep Anang**) Iwan Setiawan**) and Heni Indrijani**
*)Papua New Guinea University of Natural Resources and Environment, Private Mail Bag, Kokopo,East New Britain, Papua New Guinea
**)Department of Animal Reproduction and Biometrics, Faculty of Animal Science, Universitas Padjadjaran, Jalan Raya, Bandung-Sumedang Km21, Jatinangor 45363

Abstract:- This study compares four sigmoidal models using 770 weekly body weights data of Cihateup duck male n=14 and Cihateup Female n=21 collected over 22 weeks. Four sigmoidal models, Richards, Gompetz, Logistic and Morgan-Mercer-Flodin (MMF) were fitted to determine the best model curve. R^2 and SE values were used for model determination. The R^2 values for these models were; 0.9956, 0.9956, 0.9955 and 0.9928 respectively in males, and 0.9982, 0.9964, 0.9979 and 0.9970 for females respectively. The SE values for the respective models were 41.0852, 41.0852, 40.3999 and 52.4300 in males while 23.0558, 31.7047, 24.3066 and 29.9865 in females. Richards function was suitable for the Cihateup breed better than the other three models based on higest R^2 and lowest SE values.

Keywords:- *Sigmoidal Models, Body Weights, Cihateup Duck, Richards.*

I. INTRODUCTION

Indonesian local ducks including Cihateup (Ismoyojati et al., 2001;Suswono, 2013) breeds in West Java have contributed meat and egg to the household during the recent past. These ducks are mostly layers with small body size and lower meat production (Irma *et al*., 2014; Suryana *et al*., 2010; Purba, 2004; Suparyanto, 2005) and can adopt to local environmental conditions at temperature range of 19-26ºC at higher altitude and 25-35ºC at lower altitude (Sabrina *et al*., 2013). They are raised under free range over the years for food and cash. Despite farming these ducks, breeding and genetic knowledge for improvements on desired traits still remains the major constrain. Genetic improvement of local ducks under suitable breeding system is crucial to assist selection of the genetically improved birds with desired economic characters such as body weight and growth rates. Growth is an important selection trait in poultry industry and is measured interms of body weight gain related to breed, sex, age and feed conversion rates (Sengul and Kiraz, 2005; Yang *et al*., 2006; Balcioglu *et al*., 2005). Body weights are predicted using mathematical growth curves (Golimytis *et al*., 2003; Kinizetova et al., 1991;Vitezica *et al*., 2010; Yang, 2006) such as; Gompetz (Winsor, 1932), Logistic (Nelder, 1961), Richards (Richards, 1959), and MMF (Sengul & Kiraz, 2005). These mathematical functions have frequently been used in the past studies for growth modeling; sheep (Tariq *et al*; 2013), chickens (Michalchuk *et al*., 2016; Ereloglu *et al*., 2014; Narushin & Takma, 2005), turkeys (Sengul & Kiraz, 2005) and qails (Raji *et al*., 2014). They have mathematical limitations (Noris *et al*., 2007) and are used to assisst predict results of biological changes in animals.

It is observed that variations exist in mature weights and age at maximum gain of breeds and sexes in polutry species like in Venda and Naked Neck breeds (Noris *et al*., 2007). Breeds contribute largely towards variations on growth of birds and declines at certain ages after reaching platue. Identifying the breed of such effects would help reduce economic losses in the production cycle.The present study compares four growth functions to predict growth using body weights. Non-linear sigmoidal functions; Logistic, Richards, Gompetz and MMF were used to predict the body weights of Cihateup Duck Breed.

II. MATERIALS AND METHODS

- *Birds*

The data was collected from randomly mated F1 birds at the Padjadjaran University local duck breeding center from April 4-October 10, 2015. The parent ducks were randomly housed in a mating pen at a mating ratio of 4 males to 15 dams. A total of 40 ducklings were hatched after 30 days incubation into two hatces at 6 weeks interval. F2 ducklings were placed in brooding pens of 10 birds for two weeks, transfered to 60cm x 110 cm cages for four weeks and reared in 80cm x 150cm pens beded with rice hulls deep litter for 16 weeks.The birds were fed a starter ration 20% protien /3, 000kcal ME /kg from hatch to 14days. A finisher 16% protien/2, 600kcal ME/kg was fed after 14 days to 600 days (Table 1). All birds were sexed and weighed at hatch. The birds were weighed weekly for 614 days.

Table1. Nutient Compositon of Feeds rations fed to the ducks

Starter Feed	Composition	Finisher Feed	Composition
Protein	20%	Protein	16%
Energy	3000kcl/kg	Energy	2600kcal/kg
Corn	59%	Corn	55%
Rice bran	7%	Rice bran	22.25%
Soya bean meal	14%	Soya bean meal	7%
Fish meal	11%	Fish meal	7%
Copra meal	5.7%	Copra meal	6%
Bone meal	1.25%	Bone meal	2.25%
Coconut oil	1.5%	Coconut oil	1.5%
Premix	0.5%	Premix	0.5%

➢ *Growth Models*

The four sigmoidal models ; Logistic,Richards, Gompetz Relations and MMF were fit to estimate the mean BW data collected at the respective ages for 22 weeks.Table 2 indictaes the four functions and their parameters (a) asymptotic weight at maturity, (b) scale parameter related to initial weight response, (c) intrinsic growth rate for all functions and (d) Shape parameters.

	Function
Logistic	$y = \frac{a}{1+b^{-cx}}$
Richards	$y = \frac{1}{\left(A + B.e^{C.x}\right)^{D}}$
Gompetz	$y = Ae^{BeCx}$
MMF	$y = \frac{ab+cx^{d}}{b+x^{d}}$

Table 2. Growth functions and their parameters

Y= body weight
X=age in weeks
a= asymptotic weight at maturity
b=scale parameter related to initial weight response
c=intrinsic growth rate for functions
d=shape parameters
e=exponential decay
The four growth curve parameters were compared for each bird using Curve Expert Professional 2.3. Goodness of fit crietria were R^2 , and standard error (SE) and correlation between observed and predicted.

Table 3.The criteria for Goodness of fit for functions

Criteria	Equation
R	$\frac{\sum xy}{\sqrt{(\sum x^2)(\sum y^2)}}$
R^2	$1\text{-}SS_{res}/SS_{tot}$
SE	SS/df

SS_{res}= sum of square of the residuals
SS_{tot}=sum[(y- y)^2]
SS=Sum of Squres
Df=degrees of freedom

III. RESULTS AND DISCUSSIONS

➢ *Observed and Predicted Body Weights of Four models*

Table 4 explains the obesrved and predicted values of Gompetz, Richards, Logistic and MMF sigmoidal functions. Coefficient of correlation (R) values (Table 5) indictaes 99% correlation between observed and predicted body weights in all models. However, based on four figure (R) values, higher (R) were observed in females of all models; Richards (0.9991), Logistic (0.9989), Gompetz (0.9985) and MMF (0.9982). Richards, Gompetz and Logistic had the same (R) predictions (0.9978) but MMF had (0.9964).

Predictions were better for Richards and Logistic most of the time. Richards function predicted better during the early growth stages (week0-week2) in Cihateup male and Cihateup Female at week (0, 2-3). Than Logistic function.Predictions in Richards was randomly distributed during the growth stages of Cihateup ducks except in Cihateup Female where predictions at weeks18-21 were better than Logistic. Logistic function predictions were better than Richards at weeks (3,6,8,10,12,13,17 and 21) in Cihateup male, weeks (2,4,6,10,12 and 18) in Cihateup Female.

Gompetz and MMF functions were unable to precisely explain the predicted values in Cihateup ducks despite their random predictions.Logistic function was able to predict better than Richards compared to observed values in Cihateup male and Female observed values. Predicted body weights of four models are represented in Figures 1 and 2. The fit lines appeared close to the observed values, indicating that the observed and predicted body weights are closely related. Sengul and Kiraz, (2005) had simmilar observations on male and female Turkey using the same four growth functions stating that fit lines for all models were very close to the observed value. Table (5) explains R values in four models of body weight predictions.

Cihateup Male						Cihateup Female				
		Logistic	Richards	Gompetz	MMF		Logistic	Richards	Gompetz	MMF
Age	Observed	Predicted				Observed	Predicted			
0	43.87	77.47	67.92	16.28	106.93	43.77	77.46	60.70	19.56	103.83
1	80.75	119.97	110.42	54.43	111.41	125.17	117.16	100.74	57.88	108.35
2	176.17	182.98	175.23	132.67	144.18	158.96	174.57	161.62	130.38	139.02
3	302.47	272.98	269.24	256.12	229.79	245.27	254.63	248.52	239.45	215.60
4	420.77	394.90	396.56	416.21	375.28	353.78	360.82	363.42	377.44	342.12
5	553.42	548.73	555.18	595.65	563.55	514.42	492.66	502.62	530.63	503.60
6	706.73	726.32	734.55	776.08	763.61	649.77	643.56	656.20	684.75	674.67
7	935.92	911.49	917.58	943.50	948.41	810.50	801.00	810.60	828.76	833.84
8	1043.76	1085.14	1086.55	1089.86	1103.98	961.28	950.15	952.98	956.05	969.48
9	1230.70	1232.53	1229.21	1212.28	1227.84	1058.66	1079.10	1074.80	1063.97	1079.04
10	1361.04	1347.41	1341.09	1311.39	1323.54	1182.18	1182.04	1172.81	1152.66	1164.99
11	1427.41	1431.13	1423.95	1389.72	1396.58	1230.93	1259.12	1247.98	1223.86	1231.52
12	1535.99	1489.22	1482.79	1450.53	1452.19	1326.33	1314.11	1303.60	1280.01	1282.86
13	1582.17	1528.15	1523.35	1497.12	1494.72	1380.49	1351.99	1343.68	1323.73	1322.60
14	1453.77	1553.65	1550.75	1532.47	1527.48	1371.69	1377.48	1372.02	1357.43	1353.55
15	1498.42	1570.09	1568.99	1559.10	1552.96	1350.15	1394.35	1391.81	1383.21	1377.86
16	1618.42	1580.59	1581.04	1579.05	1572.98	1403.54	1405.39	1405.50	1402.84	1397.12
17	1549.42	1587.25	1588.94	1593.95	1588.86	1399.43	1412.57	1414.90	1417.71	1412.53
18	1619.10	1591.46	1594.08	1605.04	1601.59	1373.82	1417.21	1421.38	1428.94	1424.97
19	1624.62	1594.12	1597.46	1613.27	1611.88	1428.32	1420.21	1425.73	1437.41	1435.11
20	1619.93	1595.79	1599.65	1619.37	1620.29	1434.02	1422.14	1428.72	1443.78	1443.43
21	1588.74	1596.84	1601.07	1623.90	1627.21	1444.31	1423.38	1430.75	1448.57	1450.33
22	1604.59	1597.5.0	1602.00	1627.24	1632.95	1475.61	1424.18	1432.14	1452.13	1456.08

Tabel 4. Observed and predicted body weights of four sigmoidal curves

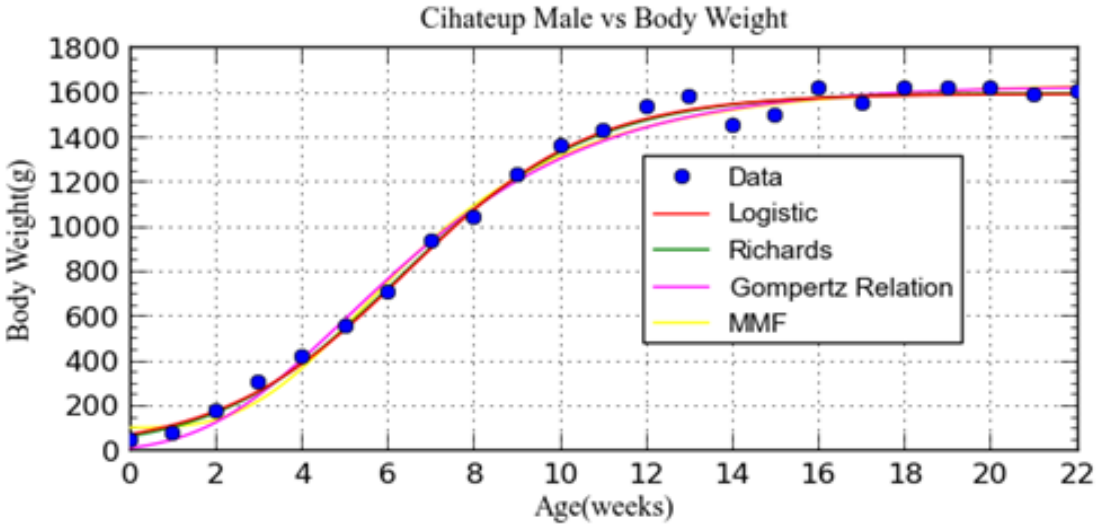

Fig 1. Four Growth Curves of Cihateup Male

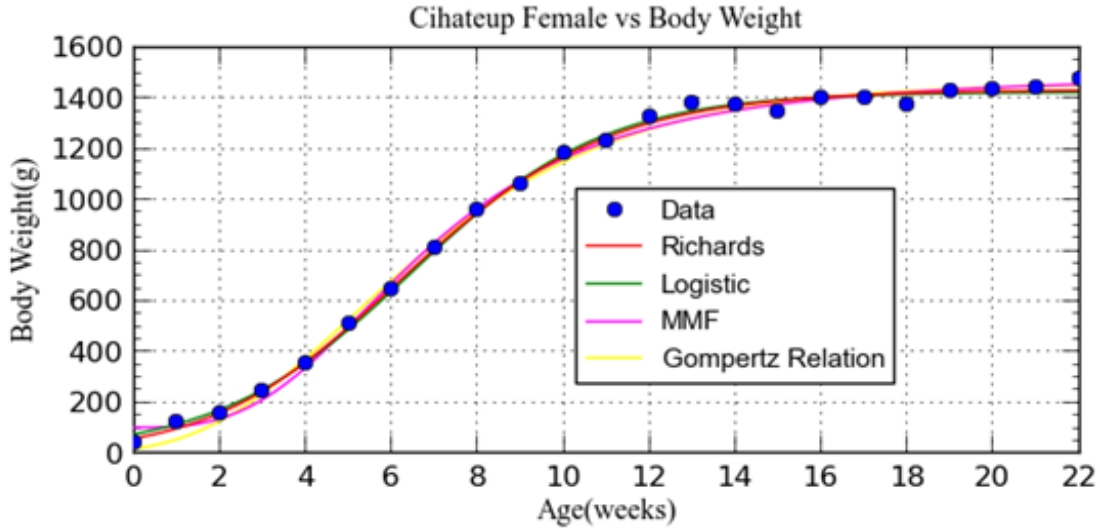

Fig 2. Four Growth Curves of Cihateup Female

➢ *Parameters and Goodness of fit criteria results for models*

Table 5 shows the parameters of Gomeptz, Logistic, Richards and MMF growth curve functions, correlations among the parameters, assymptotic mature weight, scale parameter, growth rate values and shape parameters of Cihateup ducks. Gompetz had the higher male and female mature weight (a) values (1.64E+03; 1.46E+03) followed by Richards (1.60E+03; 1.44E+03), MMF (1.07E+02) 1.04E+02) and Logistic (1.06E+03; 1.43E+03 in males and female respectively.This agrees with Michalczuk et al. (2016) that Gompetz had the highest 'a' parameter value (5900g:400g) followed by Richards (5700g:3800g) and Logistic (4000g:2900g) respectively in males:females of experimental line CCPG chickens. Sengul and Kiraz, (2005) firmly confirmed the 'a' parameter values in same models; Gompetz, Ricahrds, Logistic and MMF in males of turkey ; 14,628.90, 10,198.75, 10.468.42 and 49.77 respectively. The current mature body weight values in females agrees with the past studies for Gompetz and Richards functions, but Logistic was lower than MMF in male values. Zhao et al.(2015) also reported Gompetz as the second to Bertalanfy for 'a' parameter values in Shaobo,Huaixiang and Youxi chickens while Logistic had the least. Raji *et al*., (2014) reported in Japanese quail that the highest 'a' parameter was recorded in Monomolecular model (160.227g), followed by assymptote regression model (160.093g) while the least values were recorded by Logistic (115.227g) and Exponential (70.517g).

Higher values of scale parameter (b) were found in MMF in both males (3.48E+02) and females (3.07E+02). Gompetz had the lowest for males (1.53E+00) and females (1.46E+00). Sengul and Kiraz, (2005) had reported higher 'b' parameter values for MMF and lowest for Gompetz function in large white turkeys. Logistic had the highest inrtrinsic growth parameter values in males (4.66E-01) and (4.44E-01) in females. MMF had the least (c) values of males and females after Gompetz. Higher intrinsic values observed in current study for Logistic and the lowest in MMF contradicts the past study of Sengul & Kiraz, (2005). The opposite seem to exist for Logistic and MMF functions. Shape parameter (d) values were found higher in Richards function with males (8.05E-01) and females (6.51E-01 than

MMF whereas Gompetz and Logistic models failed to generate this parameter. Higher shape values were found in MMF than Richards in white turkeys (Sengul & Kiraz, 2005), which does not agree with the current study.Such contradictions in parameters of models may be due to species or use of different statistical softwares.

Table 5. Goodness of fit Criteria results for Growth Models

		Model Parameters						
Model	**Birds**	a	b	c	d	R	R^2	SE
Gompetz	CM	1.64E+03	1.53E+00	3.04E-01	-	0.9978	0.9956	41.0852
	CF	1.46E+03	1.46E+00	2.90E-01	-	0.9982	0.9964	31.7047
Logistic	CM	1.06E+03	1.96E+01	4.66E-01	-	0.9978	0.9955	40.3999
	CF	1.43E+03	1.74E+01	4.44E-01	-	0.9989	0.9979	24.3066
Richards	CM	1.60E+03	2.46E+00	4.33E-01	8.05E-01	0.9978	0.9956	41.0852
	CF	1.44E+03	1.92E+00	3.89E-01	6.51E-01	0.9991	0.9982	23.0558
MMF	CM	1.07E+02	3.48E+02	1.67E+03	3.09E+00	0.9964	0.9928	52.4300
	CF	1.04E+02	3.07E+02	1.50E+03	2.99E+00	0.9985	0.9970	29.9865

CM=Cihateup Male, CF=Cihateup Female, R=Coefficient of correlation, R^2=Coefficeint of determination, SE=Square Error

The Coefficient of Correlation (R) values in females of Richards, Logistic, MMF and Gompetz functions were; (0.9991,0.9989,0.9985 and 0.9982) respectively. Richards, Logistic and Gompetz had the same value of (0.9978) while in MMF was (0.9964) males. Predictions of four growth models were 99% near to observed body weights in both males and females.

The results of goodness of fit were (R^2) and (SE) in four sigmoidal models. R^2 values for Richards, Logistic, Gompetz and MMF were (0.9982, 0.9979,0.9970 and 0.9964) in female and (0.9956, 0.9955, 0.9956 and 0.9928) for male respectively. Sengul and Kiraz; (2015) derived closely related (R^2) values in chickens of Gompetz, Logistic, MMF and Richards (0.9975,0.9937,0.9993, 0.9966) in female and (0.9974, 0.9933, 0.9993 and 0.9969) for males respectively. Different (R^2) values of growth models in ducks and chickens may be due to species vaiations. Standard Error (SE) derives an alternative to determine which of the four models can best fit the duck growth. The SE values of female from the lowest were Richards (23.0558), Logistic (24.3066), MMF (29.9865) and Gompetz (31.7047) whereas Logistic, (40.3999), Richards and Gompetz (41.0852) and MMF (52.4300) in males. Richards is the accurate growth function for the Cihateup duck breed favorably in dams related to better predictions of (R) values, higher (R^2) values, lower (SE) values and had the ability to generate four parameters**.** Raji et al. (2005) reported that model with the smallest standard error is assumed to have the best fit to the data. Narushin and Takma, (2002) reported that among the four-parameter equations (Gompetz, Logistic, Richards and MMF), the Richards function was found to describe accurately the growth curves of major poultry species, chickens (Kinezotova *et al*., 1991b), ducks (Kinezotova *et al*, 1991a), geese (Kinezotova *et al*., 1994) and quail (Hayangkova *et al*., 2001) .

IV. CONCLUSION

Richards function best predicted the growth parameters of Cihateup ducks of higher (R) values, higher (R^2) values, lower (SE) values and had the ability to generate four parameters**.**

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