Growth Data of Broiler Chickens Fitted to Gompertz Function

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ABSTRACT : This study describes the growth of broiler chickens to the two forms of Gompertz function for application in broiler production models. The first form is based on the estimated mature weight (W_A), while the second is based on the estimated hatch weight (W_O). Both equations gave identical estimation because they are mathematically identical. To fit the growth curve of commercial broilers that marketed at 35-42 days, it is unnecessary to keep broilers to near maturity (> day 140) to obtain growth data for deriving the Gompertz function. This data does not improve the curve fitting of the early growing period. Additionally, a high mortality and health problem occurred to this type of chicken after day 105. *(Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 8 : 1177-1180)*

Key Words : Broilers, Growth Curve, Gompertz Function

INTRODUCTION

Gompertz function has been reported to represent the growth of chickens accurately (Wilson 1977, Ricklefs 1985, Talpaz et al., 1986, Stilborn et al., 1994, Emmans, 1995, Gous et al., 1996, and Handcock et al., 1996, Tzeng and Becker, 1981, Pasternak and Shalev, 1983) with the best fit when compared to other non-linear and polynomial function (Tzeng and Beaker, 1981). The function may be used in 2 forms, one bases on the mature weight (W_A), and the other applies the *initial* weight or hatch weight (W_O).

The W_A form based on the knowledge of mature weight of broilers where such data is not readily available for *ad lib.* fed broilers because of high mortality and leg weakness encountered at heavier body weight (Handcock et al., 1996; Gous et al., 1996 and Stilborn, 1994). The W_A growth curves have therefore relied mostly on the early part of growing period and assumed a mature weight value using regression analysis. The W_O form of the Gompertz function that does not rely on the mature weight may be more suitable for the commercial broilers which are commonly marketed well before maturity. The W_O form may uses data of the commercial growing period and therefore is a more reliable and convenient descriptor for modelling broiler production.

The objectives of this study were to describe the growth of broilers and to compare the usefulness and limitation of the two forms of Gompertz function for application in broiler production models.

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MATERIAL AND METHODS

Ninety broilers from commercial strains (C, R, and I) available in Australia were used in this study. At day 1, broilers were identified with wing bands and each strain was unsexed kept in the wire cages as a group of 10 and at a density of 14/m^2. After 35 days old, they were randomly selected and assigned to single cages to avoid the aggressive interaction.

Commercial starter diet (26.7% protein, 11.7 MJ/kg) was fed for the first 21 days, grower diets (23.8% protein, 12.5 MJ/kg) for the next 14 days, and finisher diet (20.7% protein, 13.1 MJ/kg) until the end of trail (day 175). Feed and water were supplied *ad lib.* for the broilers to express the growth potential. The broilers were housed under a 24 hours light regime. Individual body weights of the broilers were measured weekly.

The growth functions were carried out from the mean weekly body weight. The two forms of Gompertz equations were fitted to the data

$$W_t = W_A \exp(-\exp(-B(t-t^*))) \qquad (1)$$
$$W_t = W_O \exp((L/K)(1-\exp(-Kt))) \qquad (2)$$

Where, W_t = body weight (g) at time t
W_A = mature weight (g)
W_O = initial or hatch weight (g)
B or K = growth rate constant (/d)
t^* = time (d) when broilers reach the maximum growth rate
L = the initial specific growth rate or slope of the growth curve when t=0

Both equations rely on three parameters, W_A, B, and t^* for equation 1, W_O, L, and K for equation 2. The parameters were estimated using nonlinear procedures, Gauss-Newton method in the SAS (1993) statistical package.

Table 1. Mean body weight±SE of three strains broiler as data source to derive the Gompertz functions

Day	Strain×Sex[1]					
	CF	CM	RF	RM	IF	IM
0	45± 0.3	45± 0.4	41± 1.4	42± 1.1	34± 0.5	35± 0.5
7	161± 0.9	166± 6.6	148± 7.7	158± 5.2	145± 3.9	153± 8.7
14	404± 1.2	425± 21.4	379± 11.0	419± 12.9	389± 12.5	421± 9.2
21	748± 2.8	806± 18.3	714± 7.1	822± 20.8	748± 17.7	826± 14.6
28	1152± 14.5	1263± 24.1	1110± 41.2	1302± 43.8	1177± 17.6	1327± 59.8
35	1473± 54.6	1737± 59.3	1487± 58.9	1825± 58.5	1710± 44.4	1922± 50.5
42	1789± 14.1	2188± 58.9	1834± 69.6	2311± 58.4	2070± 48.9	2414± 30.6
49	2223± 58.0	2802± 71.9	2203± 82.3	2845± 83.9	2389± 87.1	3065± 63.5
56	2567± 54.6	3237±154.0	2546±117.4	3326±131.2	2558± 38.8	3392± 68.6
63	2806± 98.4	3694±135.5	2855±132.6	3779±196.5	2974± 20.8	3685±134.2
70	3094±117.7	4115±139.4	3004±159.2	4105±205.6	3290±109.1	3914±287.5
77	3320±167.0	4467± 87.5	3264±213.6	4476±256.4	3400±205.1	4377±295.6
84	3676±213.1	4789±163.2	3549±189.5	4793±293.8	3762±208.4	4793±326.1
91	3996±199.4	5091±152.8	3824±195.5	5158±284.7	3924±301.6	4990±341.2
98	4353±220.3	5385±145.4	4032±210.7	5360±337.1	4193±320.5	5069±362.0
105	4607±241.2	5623±116.0	4256±231.1	5613±432.0	4385±334.3	5239±377.4

[1] C, R, and I = Strain; F, M = Sex

Table 2. Estimated parameters of the two forms of Gompertz functions based on two time periods, day 0-35 and day 0-105

Strain×Sex[1]	W_A form			W_O form		
	W_A	B	t*	W_O	L	K
based on day 0-35 data						
CF	2428	0.061	24	37	0.256	0.061
CM	3643	0.051	29	45	0.223	0.051
RF	2808	0.055	27	38	0.236	0.055
RM	4016	0.050	30	42	0.229	0.050
IF	4484	0.045	34	45	0.206	0.045
IM	4897	0.046	34	44	0.218	0.046
based on day 0-105 data						
CF	5640	0.026	48	177	0.089	0.026
CM	6410	0.032	44	111	0.129	0.032
SF	4755	0.031	42	131	0.111	0.031
SM	6282	0.033	42	111	0.133	0.033
IF	4760	0.033	39	132	0.118	0.033
IM	5649	0.037	38	93	0.152	0.037

[1] C, R, and I = Strain; F, M = Sex

RESULTS AND DISCUSSION

The growth data of each strain are presented in table 1. Male regardless of strain showed a higher observed body weight than female. Among strains, there was no consistent relation between hatch weight and subsequent growth. Strain I with the lowest hatch weight showed the highest body weight at the marketing period (day 35 to 42) while strain C showed the highest body weight at day 105 consistent to the heaviest hatch weight.

Although measurement were made until day 175, the mean body weights are presented up to day 105 only. After 105 days, the number of birds remaining was less than 50% in most groups. At the same time, female broilers started to lay and males suffered from leg weakness which caused the weight loss and data became very variable. Growth functions were therefore analysed up to only day 105 (table 2).

The growth function parameters (table 2) were derived over two time periods; day 0~35 and day 0~105, based on the weekly mean body weight. The W_A and W_O forms gave the same predicted W_t when developed from the same set of observed weight and are in fact mathematically identical (see Appendix).

Although both equations gave the same growth curve, the parameters within equations changed according to the time period selected for analysis. Parameters derived from the 0~35 day time period when used to predict the 0~105 day weight, there was a higher mean absolute error (MAE) compared to using 0~105 days parameter (418.5 vs. 71.5, table 3). In contrast, the 0-105 days parameters was not suited for predicting the commercial short growth period of 0~35 days compared to using 0~35 days parameters (MAE, 73.0 vs. 5.6). The early growth data alone was not sufficient to reliable describe the mature phase of the growth curve. Similarly, when data points from older ages were used to derive the growth curve, the reliability of the early period decreases. It is therefore unnecessary to keep broilers as long as possible to get the closest mature weight. The data from the later part of growth does not improve the curve fitting of the conventional growing period.

Table 3. Mean absolute error (MAE) between observed and predicted body weight of broilers based on the Gompertz function using parameters derived over day 0~35 or day 0~105

MAE (observed vs. predicted data)	Based on parameters derived over	
	Day 0~35	Day 0~105
Day 0~35	5.6	73.0
Day 0~105	418.5	71.5

$$MAE = \frac{\sum|Observed - predicted\ data|}{n}$$

As indicated above, the number of survival birds beyond day 105 was less than 50%. These data are insufficient to reliably represent the group. Furthermore, after day 140, most survivors stopped growing or lost weight (figure 1). Females started to lay between day 130 and day 140. At this stage, males developed leg weakness which led to difficulty in reaching feed and water. For these reason, the data after day 105 was considered unsuitable for use in curve fitting. The poor fit during the final phase was consistent with the findings of Knizetova et al. (1991).

The present study illustrated the difficulty in obtaining a reliable growth curve in *ad-lib* fed broilers grown to maturity. However, such information is of little direct importance to the broiler industry as it is beyond the productive period. For breeder flocks, data of growth is obtained differently. Feeding is restricted to obtain satisfactory survival and reproductive performance. In this case, a multifunction is considered more appropriate to describe the growth of restricted fed birds as suggested by Grossman and Koops (1988).

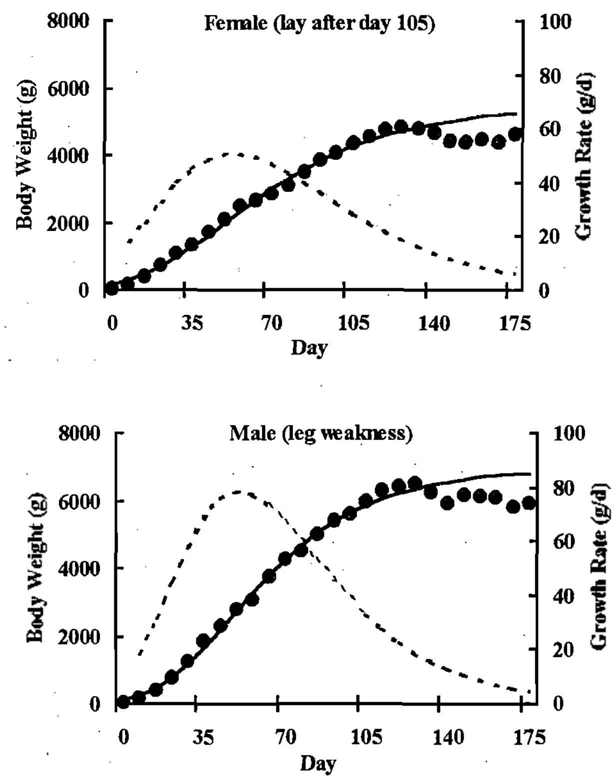

Figure 1. Observed body weights 0~175 days of female and males against Gompertz growth curve based on day 0-105 (● observe body weight, —— Gompertz function, ---- growth rate)

CONCLUSION

The W_A and W_O Gompertz functions gave the same estimated growth data. The Gompertz parameters derived from the early growing period were sufficient to describe the growth of commercial broilers. Parameters of W_O form were considered more related to the early growth since they rely on the early growth data rather than the mature weight.

APPENDIX

Starting from equation 2

$$\begin{aligned} W_t &= W_O \exp(L/K - L/K \exp(-Kt)) \\ &= W_O \exp(L/K) \exp(- L/K \exp(-Kt)), \\ &= W_O \exp(L/K) \exp(- \exp(\ln(L/K))).\exp(-Kt)), \\ &= W_O \exp(L/K) \exp(- \exp(\ln(L/K)-Kt)), \\ &= W_O \exp(L/K) \exp(- \exp((K/K).\ln(L/K)-Kt)), \\ &= W_O \exp(L/K) \exp(- \exp(-K(t-(1/K).\ln(L/K)))), \end{aligned}$$

Since W_O, L and K are constant for any growth curve, the following substitutions can be made

$$W_A = W_O \exp(L/K)$$

$t^* = 1/K.\ln(L/K)$

$B = K$

Thus

$W_t = W_A \exp(-\exp(-B(t-t^*)))$ which is equation (1)

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