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COMPARING POST-PARTUM GROWTH BY BODY WEIGHT BETWEEN SEX AND LITTER SIZE OF AGOUTI (*Dasyprocta Leporina*) OFFSPRING FROM BIRTH TO 360 DAYS OLD

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ABSTRACT

Thirty (30) offspring were weaned at 7 days old and 12 weights were taken every 30 days from the date of birth until 360 days old. The objectives of this study were: 1) to observe any dimorphism by live weight gain between agouti males and females at each 30 day interval, 2) to see if there was any difference in growth rate between litter sizes, and 3) to observe of there was a point where growth plateaued and to decide on an average age and weight for utilization (meat). Results suggested that: 1) Offspring can be weaned as early as 7 days, 2) Single born offspring grew faster than double or triple born initially in the earlier periods of life (< 6 months old) (18.89 g/d vs.17.61 g/d, 17.57 g/d) 3) Compensatory growth took place for offspring that came from larger litters in the latter stages of life (> 6 months old) (1.25 g/d, 1.21 g/d vs. 0.87 g/d) and had no major disadvantage by weight when compared to single born offspring (2750.8g 2770.0g and 2784.1g,), 4) Male and female offspring grew at the same rate from day 0 to 360, hence no sexual dimorphism by live weight was seen at day 360, 5) The average weight for optimum utilization (harvest) by live weight is no less than 2600g which can be achieved by 8 months of age, 6) The Gompertz growth model best describes the growth of Agouti offspring as compared to the Logistic and Von Bertalanffy models.

Contribution/Originality: This study is one of very few studies which have investigated the growth and development of agouti offspring along a 360 day period and compared the growth rates of sexes and litter sizes to the Gompertz , Logistic and Von Bertalanffy growth models.

1. INTRODUCTION

Brown-Uddenberg [1] reported new born agouti females weighing between 210g-355g while male offspring weighed 225g- 308g. At 8 weeks of age, female offspring weighed 1088.9g- 1306.6 g and males at 8 weeks old were 723.5g- 1298.8g Brown-Uddenberg [1]. Meritt [2] reported Agouti (Dasyprocta sp.) to weigh 3.5 kg (males) and 4 -5 kg (females) while Nowak [3] reported adults to weigh between 3.4 and 5 kg. There has been no record in the literature of how the agouti grows from birth (day old) to juveniles to adulthood or market weight. The three most common growth curves used to measure rodents and mammals were the Gompertz, Logistic and Von Bertalanffy. Gompertz and Logistic curves both shared the similar "S- shaped" form while the Gompertz function is symmetric and the Logistic is asymmetric [4]. The reproduction of wild fauna in ex situ conditions play a critical role in animal conservation, production and utilization [5]. Hence this study lends itself to securing food for rural communities, creating employment and generating new information for science. The purpose of this study is to sustainably produce the Neo tropical agouti in captivity for sustainable utilization by intensive production. This will be achieved by adjusting the Gompertz ($W(t) = Ae^{-Be^{-Kt}}$), Logistic ($W(t) = \frac{A}{1+Be^{-Kt}}$) and Von Bertanlaffy ($W(t) = A(1 - Be^{-Kt})^3$) nonlinear models to the growth data of male and female agouti of different litter sizes for a 360 day period.

These growth curves were done to observe if:

1) There is any dimorphism between agouti males and females at day 360.
2) There is any difference in growth rate in litter sizes throughout the 360 day period.
3) There is a point where growth plateaued to decide on an average age and weight for utilization (meat).

2. METHODOLOGY

2.1. Location and Time Frame

The experiment took place at the University of the West Indies Field Station located at Mt. Hope (Latitude 10.6468 and Longitude -61.4228), Trinidad. The temperatures within the unit ranged from 22.1^{0}C to 33.3^{0}C. The unit was established on July 31st, 1986. The unit had a total head count of approximately 150 Agouti, of different physiological states in 2016. The observations were carried out from May 2016 to December 2017.

2.2. Animals

Data was collected from 30 offspring (10 single from born, 10 from double, 10 from triple) born within a 6 week period in the dry season. Of the 10 single born, there were 6 males and 4 females, of the 10 double born, there were 5 males and 5 females and of the triple born, there were 6 males and 4 females. Offspring were chosen in a systematic way as they were born within the 6 week period.

2.3. Housing and Environment

The animals were housed in an intensive type system in steel cages (15" length, 18" width and 15" high) and supplied with water and food on a daily basis [1]. Pens were cleaned and washed while animals were fed, watered and observed daily. Pre-weaned data collection required offspring to stay with their mothers for only 1 week. Post-weaned data collection required for all young to be separated into different cages with a feeder bowl and water container in each. All cages were of the same size (18" long, 15" width and 15"high). Weights were collected from the day of birth and every 30 days after until they were 360 days old. This meant that each offspring had 13 weights, their birth weight and 12 (30) day interval weights.

2.4. Feeding and Nutrition

Offspring were fed 1000g of fresh fruit per day, usually the fruit in season or abundance (farm grown). The fruits fed were mangoes (*Mangifera indica*), pumpkin (*Cucurbita*), cucumbers (*Cucumis sativus*) and papaya (*Carica papaya*). Tropical forages such as Trichanthera (*Trichanthera gigantea*) and Leucaena (*Leucaena leucocephala*) were also fed when fruits were not available.

2.5. Analysis

2.5.1. Non-Linear Curve Fitting of Agouti Data

- Comparison of growth curves (Gompertz, Logistic, Von Bertanlaffy) for the agouti by sex (male, female) and litter size (single, double, triple – born).
- Fitted polynomial equations of curves for each sex and litter-size for agouti.

The non-linear growth functions, in mathematical forms described by Gbangboche, et al. [6] are as follows:

Gompertz: $W(t) = Ae^{-Be^{-Kt}}$

Logistic: $W(t) = \frac{A}{1+Be^{-Kt}}$

Von Bertalanffy: $W(t) = A(1 - Be^{-Kt})^3$

Where $W(t)$ represents the weight (grams) of the animal at age t (days), A represents the asymptotic value of the weight (mature weight), B represents the proportion of asymptotic mature weight to be gained post birth (using initial values of the weights $W(t)$ and time, t), K provides a function of the ratio of the maximum rate of growth to the mature weight (called the maturation rate) and the larger the K value, the earlier the maturation of the animal.

Each model was fitted to the mean body weights of the agouti by sex (male, female) and litter size (single-born, double-born, triple-born) respectively using Non-Linear Least Squares curve fitting procedures in MATLAB R2017b. Parameter estimates were obtained for each of the curves and a 95% Confidence Interval for each estimate was constructed Table 1.

The models were also evaluated based on the Goodness of Fit. The statistics used were the co-efficient of determination (R^2), adjusted co-efficient of determination (R^2_{adj}), the root mean square error (RMSE). The adjusted R-squared statistic is a good indicator of the quality of the model fit when additional coefficients are added to the model.

The RMSE metric which provides an absolute measure of fit compared to the R^2 values which gives a relative measure of fit. Lower values of the RMSE indicate a better fit. Different curves provided the best fit compared to the other growth curves based on the highest values of the R^2_{adj} and lowest RMSE values in each case, compared to the Logistic and Bertalanffy curves see Table 1.

Sex and Litter size were also fit to polynomial curves respectively. In each case, a non-linear equation was obtained with estimates for the regression co-efficients. The form of this equation was:

$$W(t)_{fitted} = a_n x^n + \cdots + a_2 x^2 + a_1 x + a_0$$

where a_k represents the fitted model co-efficient of x^k, the variable age (each sex or litter size respectively), for $k = 0,1, \dots, n$. The value of k is based on the highest power in the fitted model polynomial, for instance, a cubic polynomial has the value of $k = 3$.

3. RESULTS

Table-1. Live weight gains by litter size from day 0 to day 360.

Time period (Days)	Litter size			F value	p-value
	1 Mean (SD)	2 Mean (SD)	3 Mean (SD)		
0	211.2 (7.48)	198.4 (7.71)	189.0 (5.25)	33.597	p < 0.001
30	1227.2 (17.57)	862.3 (10.58)	671.7 (26.21)	3815.87	p < 0.001
60	1668.0 (13.42)	1275.3 (10.87)	1175.0 (13.43)	8791.85	p < 0.001
90	1930.1 (13.56)	1673.0 (16.29)	1646.1 (23.41)	1321.38	p < 0.001
120	2266.8 (28.68)	1954.9 (15.54)	1918.4 (16.28)	948.21	p < 0.001
150	2397.6 (25.80)	2230.3 (9.45)	2170.7 (14.65)	423.40	p < 0.001
180	2516.7 (21.17)	2401.6 (8.64)	2375.8 (14.24)	227.41	p < 0.001
210	2621.7 (10.76)	2547.0 (9.15)	2542.2 (16.94)	200.78	p < 0.001
240	2663.7 (15.03)	2642.1 (8.47)	2635.7 (10.00)	19.41	p < 0.001
270	2701.5 (12.96)	2689.9 (37.31)	2664.4 (20.21)	12.93	p < 0.001
300	2746.5 (19.48)	2717.2 (43.92)	2679.7 (17.43)	20.58	p < 0.001
330	2771.1 (18.14)	2745.9 (41.15)	2697.5 (20.90)	22.78	p < 0.001
360	2784.1 (14.07)	2754.4 (37.23)	2749.1 (17.96)	30.70	p < 0.001

Table-2. Percentage weight change by sex from day 0 to day 360.

Time period intervals (Days)	F value	p-value
0-30	1.451	0.239
31-60	6.416	0.018
61-90	0.389	0.538
91-120	1.447	0.240
121-150	0.550	0.465
151-180	0.044	0.835
181-210	4.238	0.050
211-240	0.587	0.450
241-270	19.314	p < 0.001
271-300	0.519	0.478
301-330	1.173	0.289
331-360	3.116	0.089

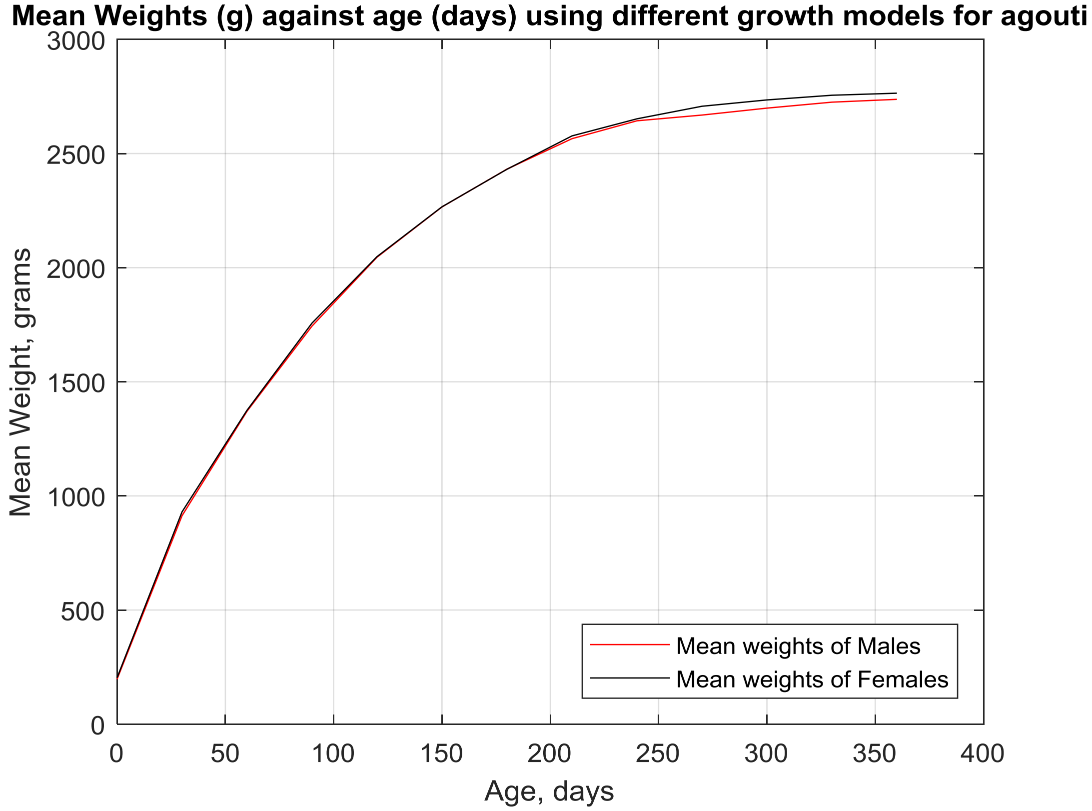

Figure-1. Mean live weights from day 0 to day 360 by sex.

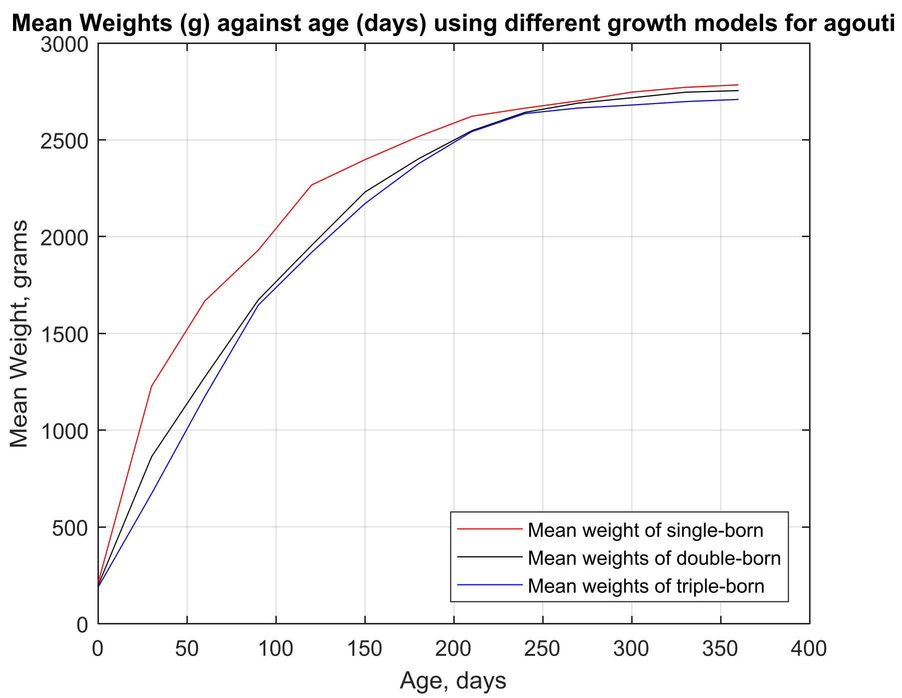

Figure-2. Mean live weights from day 0 to day 360 by litter size.

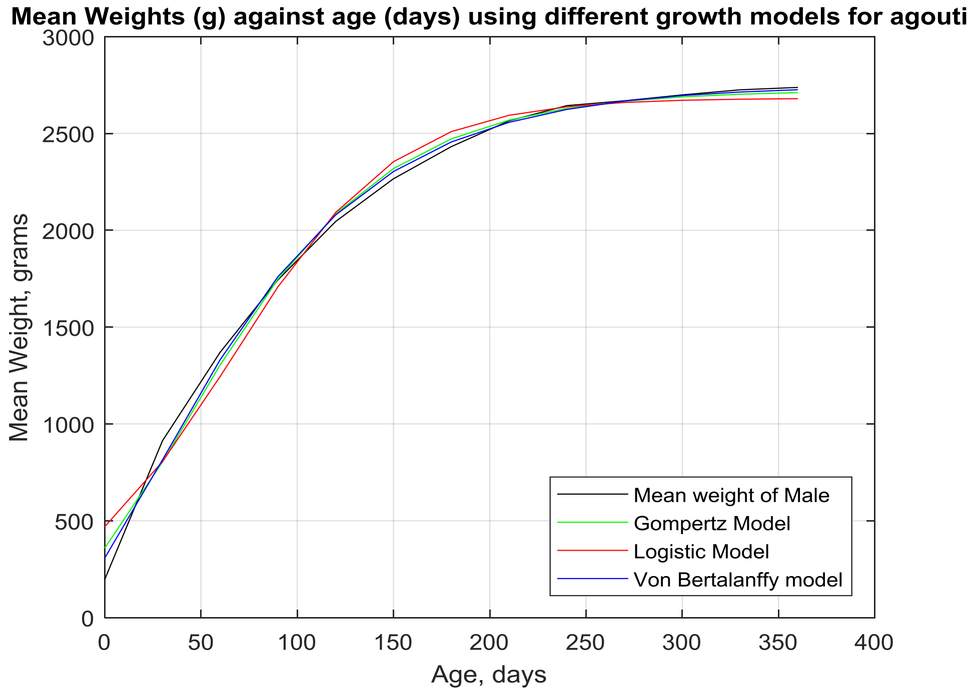

Figure-3. Mean live weight of males from day 0 to day 360 using gompertz, logistic and von bertalanffy models.

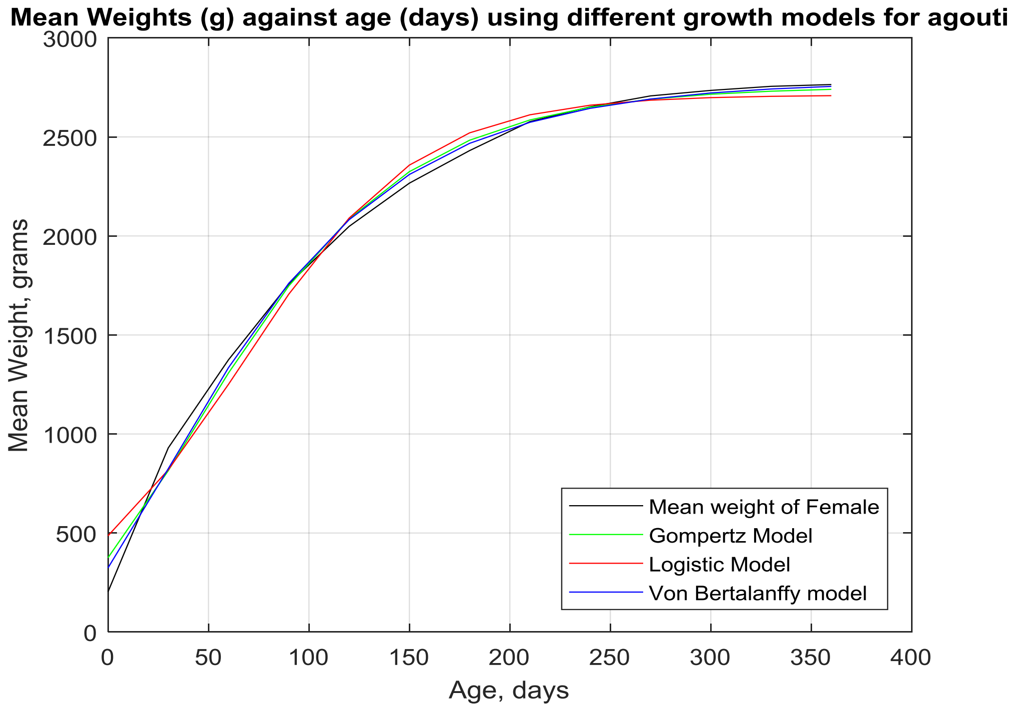

Figure-4. Mean live weight of females from day 0 to day 360 using gompertz, logistic and von bertalanffy models.

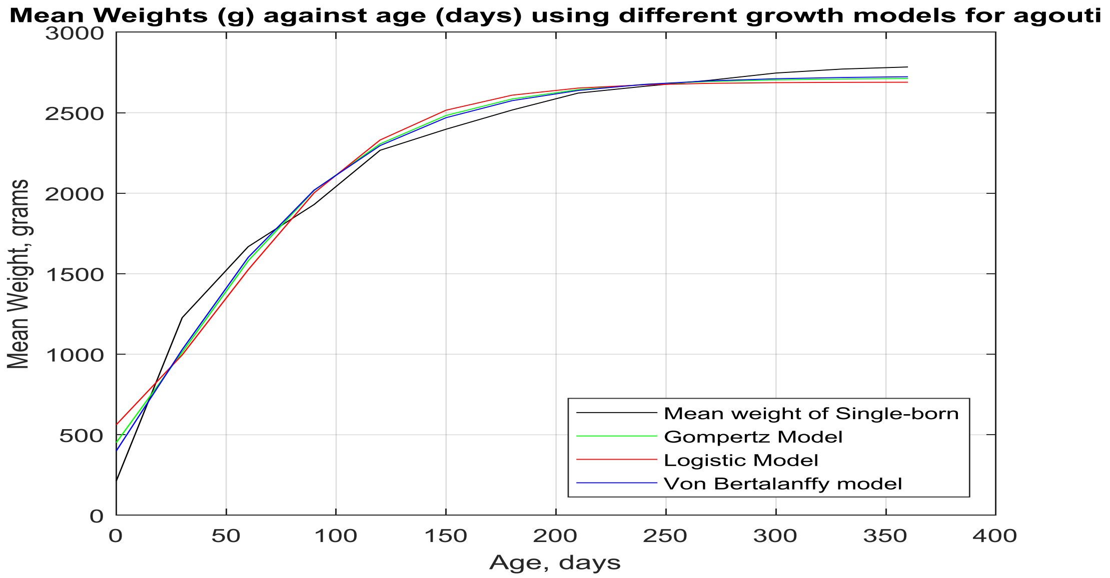

Figure-5. Mean live weight of single born offspring from day 0 to day 360 using gompertz, logistic and von bertalanffy models.

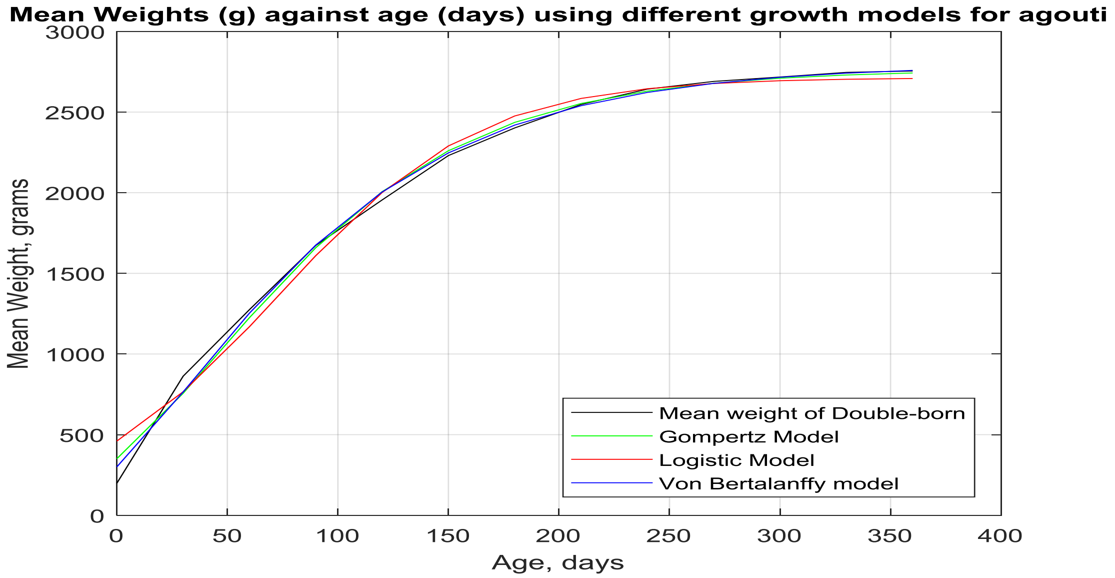

Figure-6. Mean live weight of double born offspring from day 0 to day 360 using gompertz, logistic and von bertalanffy models.

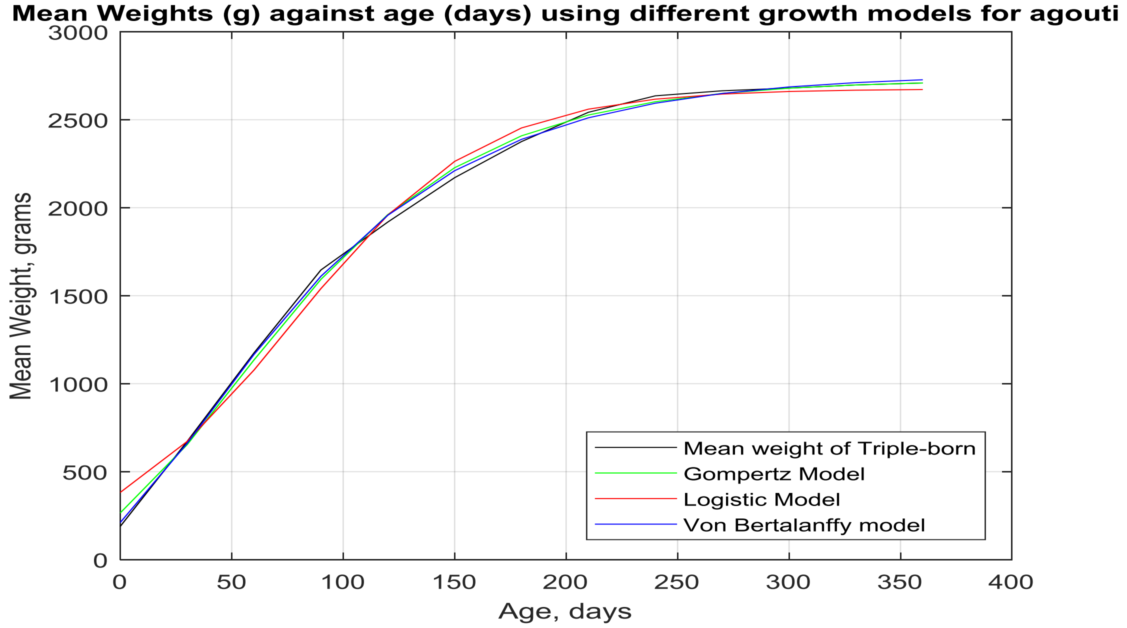

Figure-7. Mean live weight of triple born offspring from day 0 to day 360 using gompertz, logistic and von bertalanffy models.

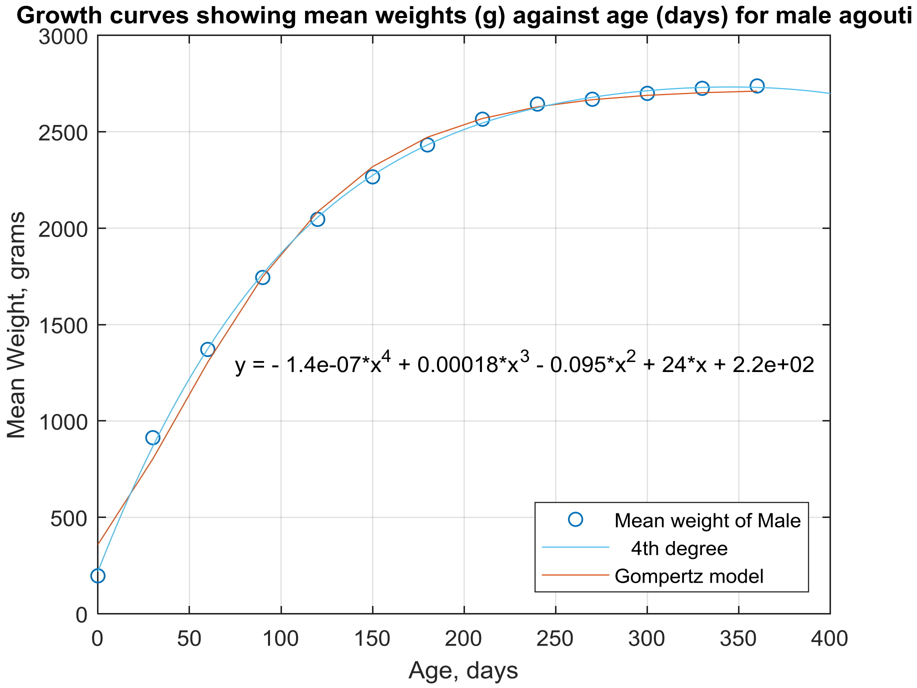

Figure-8. Gompertz model fitted to curve of mean live weight of male offspring from day 0 to day 360.

Table-3. Parameter estimates for the growth curves (Gompertz, Logistic, Bertalanffy) fitted to Agouti mean final live weight data by sex and litter-size.

Model	Factor	A	B	K	SSE	R^2	Adjusted R^2	RMSE
Gompertz	*Sex*							
	Male	2839 (2411, 3267)	2.149 (1.03, 3.269)	0.01345 (0.00573, 0.02118)	7.9471e+05	0.9155	0.8986	281.9064
	Female	2755 (2666, 2844)	1.993 (1.697, 2.289))	0.01642 (0.01391, 0.01892)	5.6876e+04	0.9928	0.9913	75.415
	Litter size							
	Single - born	2716 (2598, 2834)	1.795 (1.355, 2.236)	0.01997 (0.01499, 0.02496)	1.4319e+05	0.9796	0.9755	119.6613
	Double-born	2763 (2681, 2846)	2.064 (1.801, 2.328)	0.01553 (0.01348, 0.01758)	4.2557e+04	0.9948	0.9938	65.2356
	Triple-born	2727 (2674, 2779)	2.329 (2.116, 2.541)	0.01629 (0.0149, 0.01769)	1.8264e+04	0.9979	0.9975	42.7363
Logistic	*Sex*							
	Male	2760 (2434, 3085)	5.767 (0.5178, 11.02)	0.02024 (0.009703, 0.03078)	7.5836e+05	0.9194	0.9032	275.3840
	Female	2712 (2592, 2832)	4.579 (2.806, 6.353)	0.02279 (0.01747, 0.0281)	1.3712e+05	0.9827	0.9792	117.0962
	Litter size							
	Single - born	2690 (2547, 2833)	3.787 (1.77, 5.804)	0.02667 (0.01773, 0.03562)	2.4894e+05	0.9645	0.9574	157.7770
	Double-born	2713 (2601, 2825)	4.898 (3.196, 6.601)	0.02186 (0.01735, 0.02637)	1.1022e+05	0.9865	0.9938	104.9834
	Triple-born	2675 (2583, 2767)	6.002 (4.075, 7.93)	0.02331 (0.01929, 0.02733)	7.7768e+04	0.9910	0.9892	88.1862
Bertalanffy	*Sex*							
	Male	2885 (2392, 3377)	2885 (2392, 3377)	0.01136 (0.004449, 0.01827)	8.1156e+05	0.9137	0.8964	284.8787
	Female	2780 (2707, 2852)	0.5115 (0.4664, 0.5566)	0.01431 (0.01264, 0.01598)	3.2366e+04	0.9959	0.9951	56.8910
	Litter size							
	Single - born	2730 (2624, 2835)	0.4732 (0.3944, 0.552)	0.01778 (0.01402, 0.02153)	1.0410e+05	0.9851	0.9822	102.0318
	Double-born	2793 (2726, 2861)	0.5247 (0.4853, 0.5641)	0.01343 (0.01207, 0.01479)	2.4030e+04	0.9971	0.9965	49.0200
	Triple-born	2759 (2719, 2798)	0.5754 (0.5472, 0.6036)	0.01393 (0.01309, 0.01477)	8.6871e+03	0.9990	0.9988	29.4739

Polynomial equations of fitted curves by sex and litter size.

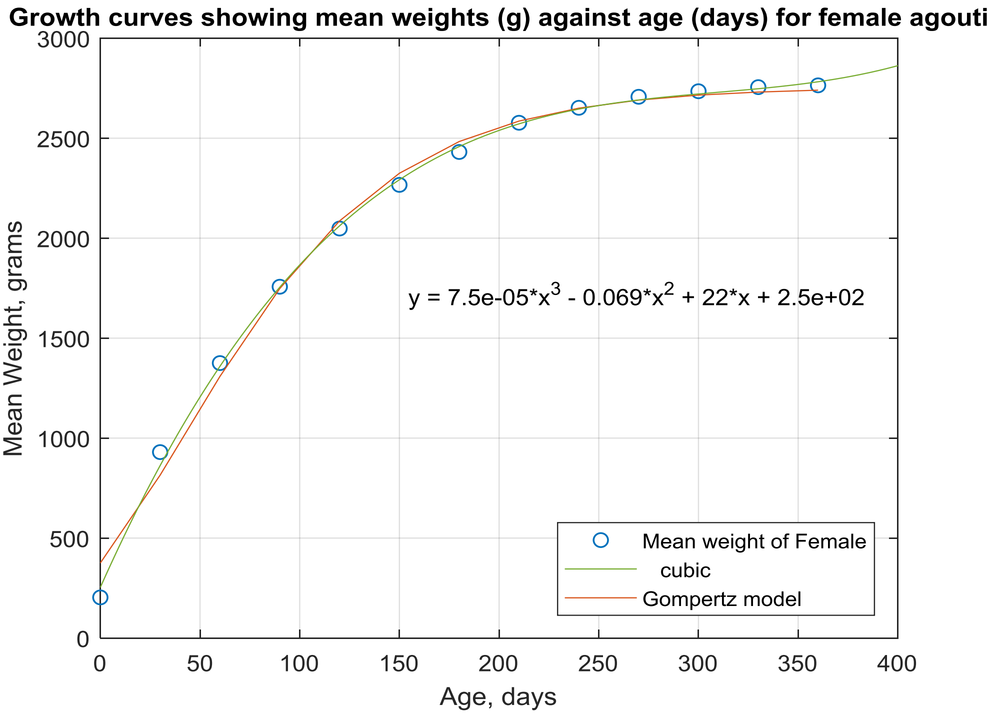

Figure-9. Gompertz model fitted to curve of mean live weight of female offspring from day 0 to day 360.

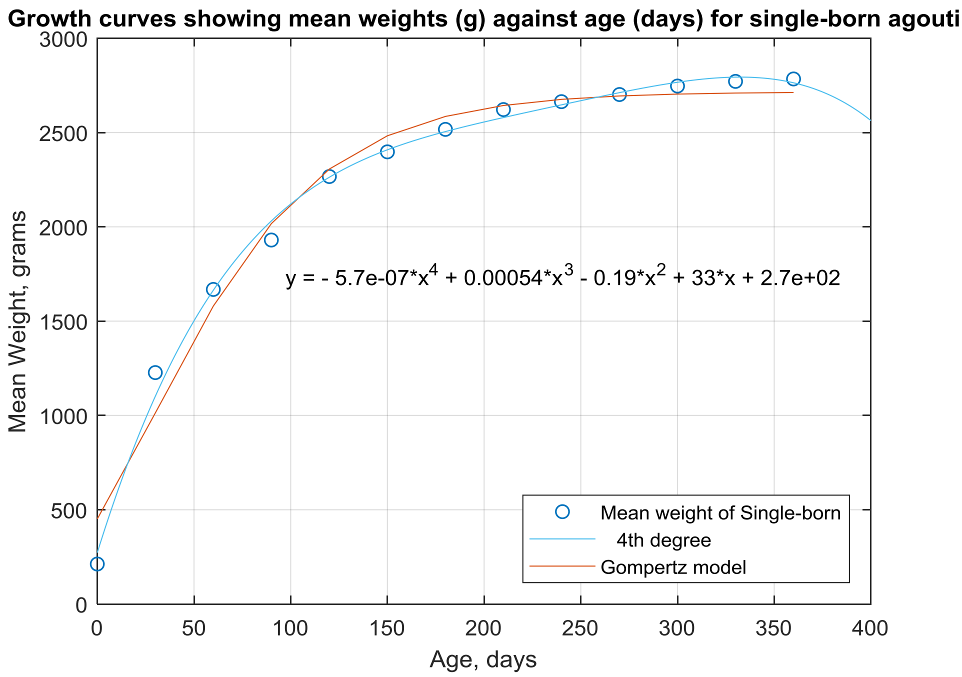

Figure-10. Gompertz model fitted to curve of mean live weight of single born offspring from day 0 to day 360.

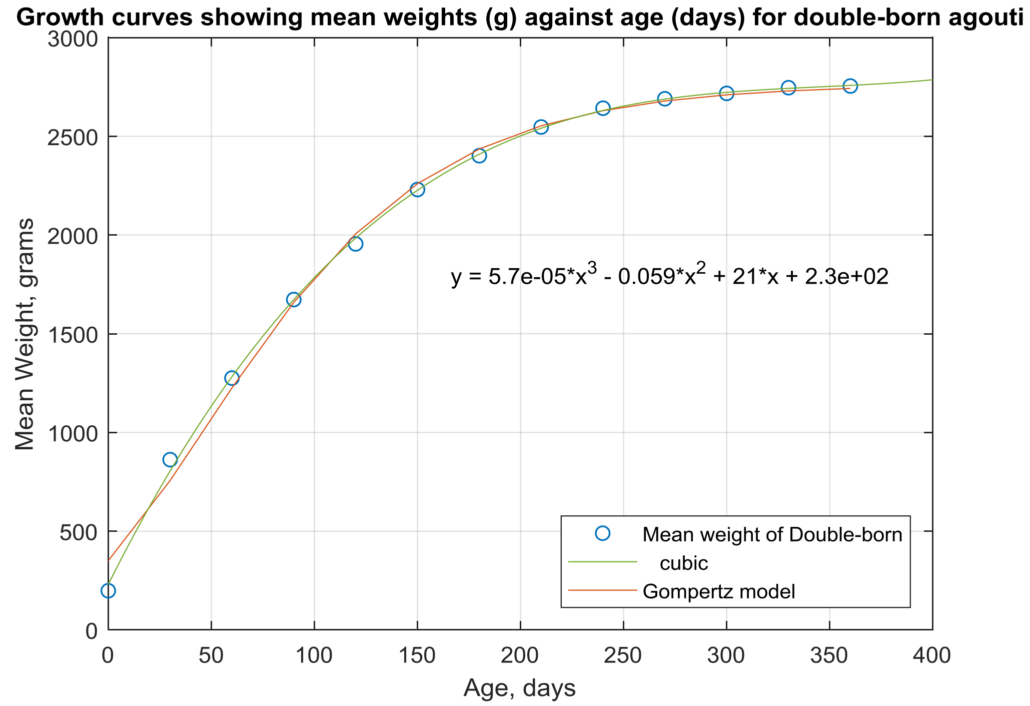

Figure-11. Gompertz model fitted to curve of mean live weight of double born offspring from day 0 to day 360.

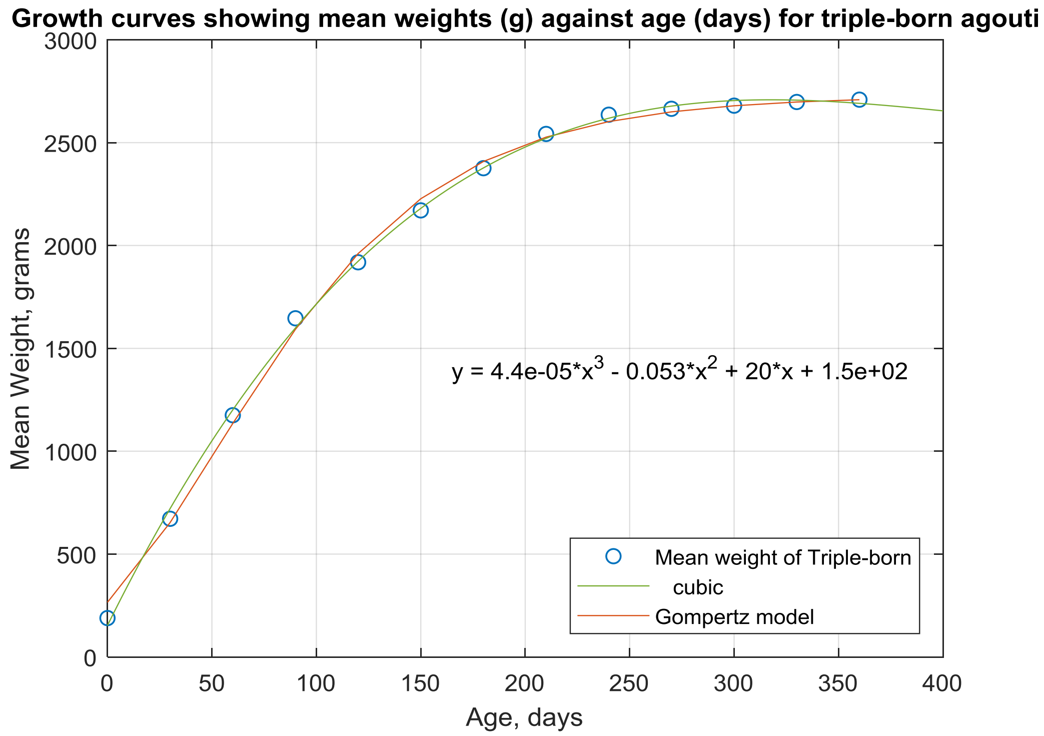

Figure-12. Gompertz model fitted to curve of mean live weight of triple born offspring from day 0 to day 360.

- Percentage Weight Gain (%) = $\frac{(Final\ Weight - Initial\ Weight)}{Initial\ Weight} * 100$

- Average Daily Weight Gain = $\frac{(Final\ Weight - Initial\ Weight)}{Total\ no.\ of\ days}$

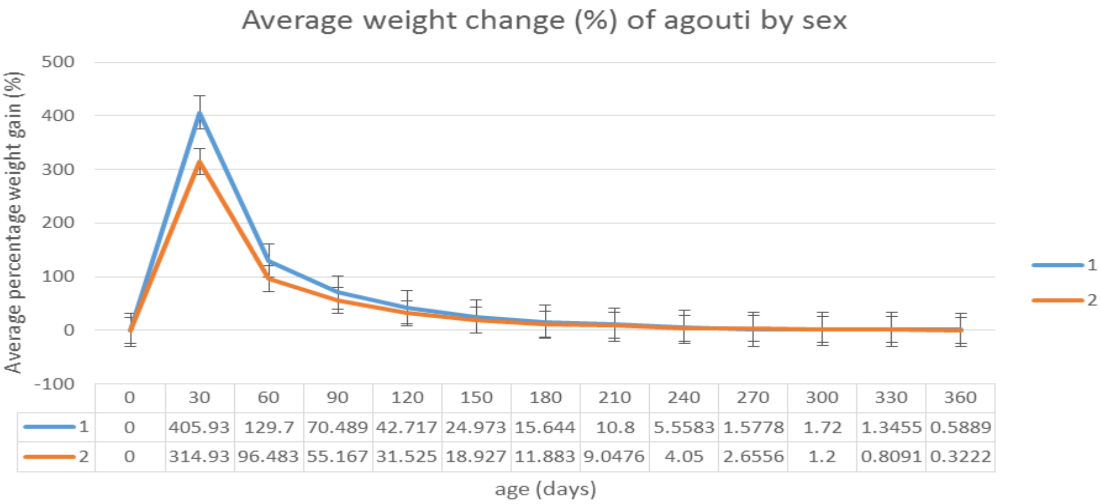

Figure-13. Percentage change of mean live weight gain of offspring from day 0 to day 360 by sex.

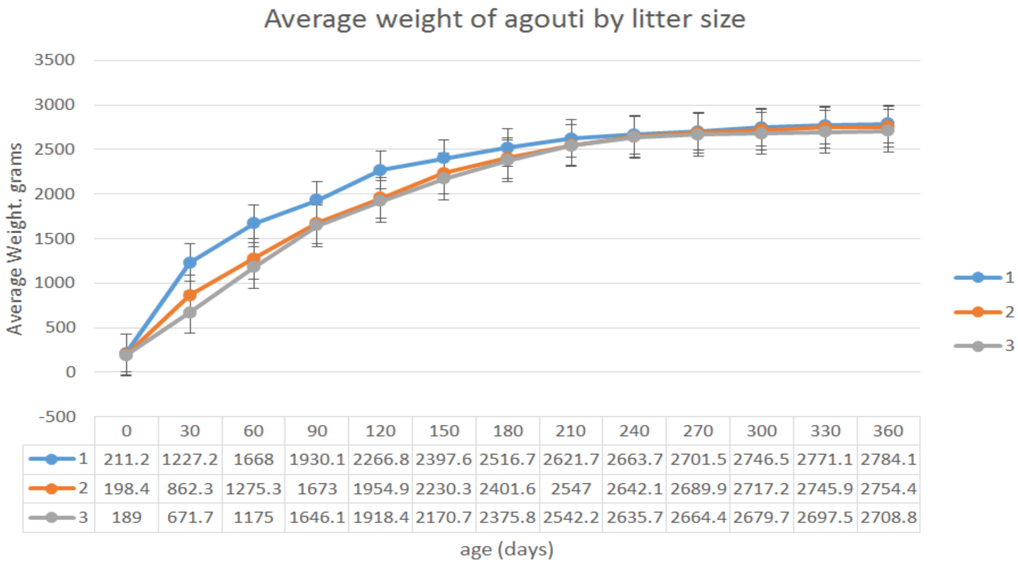

Figure-14. Mean live weight gain of offspring from day 0 to day 360 by litter size.

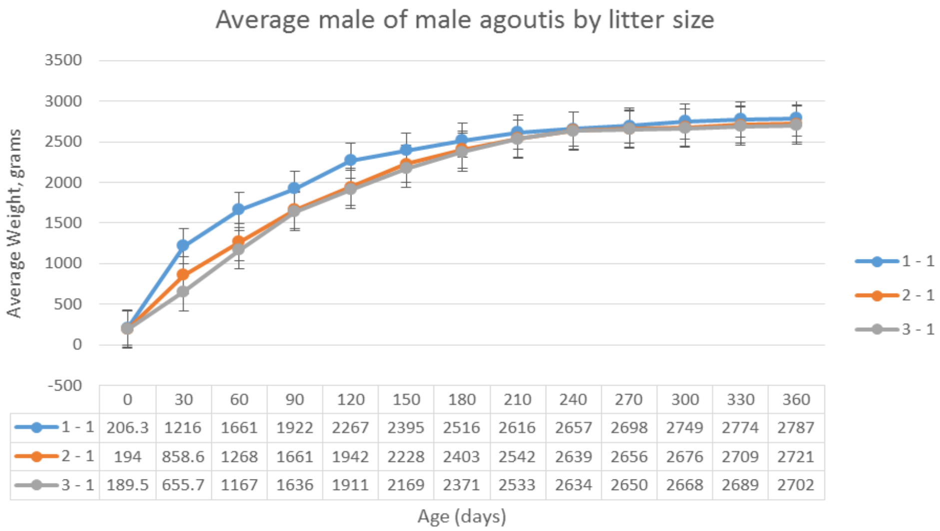

Figure-15. Average live weight gain of male offspring from day 0 to day 360.

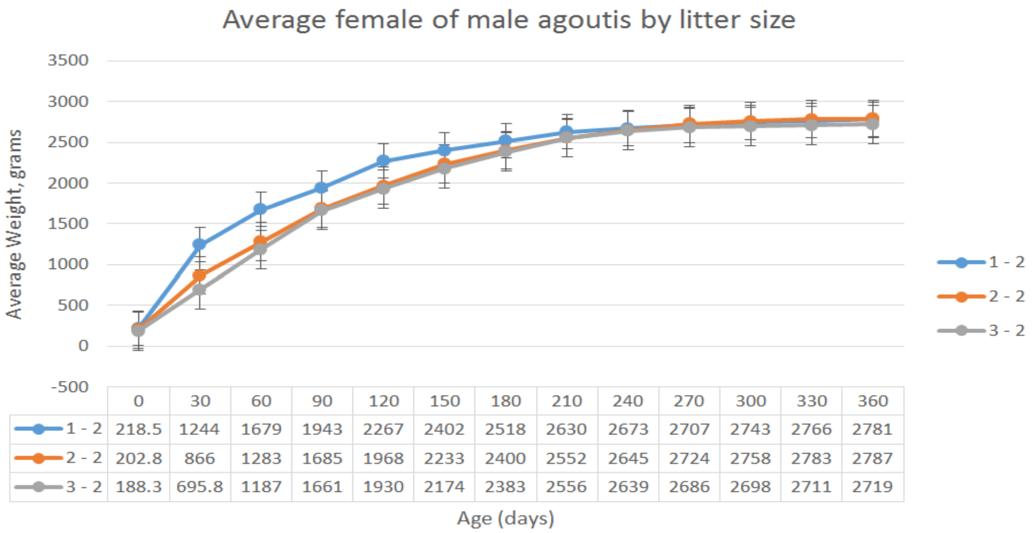

Figure-16. Average live weight gain of female offspring from day 0 to day 360.

4. DISCUSSION

Results showed that Agouti offspring can be weaned at day 7 post-partum with a survivability of 100% (30/30). This result was also confirmed by the paper written by Mohammed, et al. [7] which indicated the same survivability rate from 136 offspring from 80 parturitions regardless of litter size or dams' body condition. Average daily gains (Final weight- Initial weight/ No. of days) for all 3 litter sizes were compared for 4 periods within the 360 day data collection period. At day 90, offspring grew at an average rate of 18.89 g/d, 17.61 g/d and 17.57 g/d for single, double and triple born respectively. At day 180 offspring grew at an average rate of 2.75 g/d, 3.78 g/d and 4.17 g/d for single, double and triple born respectively. At day 270 offspring grew at an average rate of 0.87 g/d, 1.21 g/d and 1.25 g/d for single, double and triple born respectively. At day 360 offspring grew at an average rate of 0.41 g/d, 0.41 g/d and 0.38 g/d for single, double and triple born respectively. From the ADG values, single born offspring grew fastest in the early quarter (0- 3months) of life while double and triple born offspring showed compensatory growth in the second (4-6 months) and third quarters (7-9 months) of life and all 3 litter sizes plateaued at day 360 (month 12).

Table 1 and Figure 14 showed that single, double and triple born offspring weighed significantly different at each time point from day 0 to day 360. Table 2 showed the rate of change by live weight gain between sexes were similar at every interval except the period of 241-270 days where females were heavier. Figure 1 showed the mean weights between sexes, where females were heavier at day 360. Figure 2 showed mean weights for single, double and triple born offspring where single born offspring were the heaviest at day 360. Figure 3 and Figure 4 showed live weight gain of males and females respectively from day 0 to 360 comparing all 3 curves. Figure 5, Figure 6 and Figure 7 show the mean live weight of single, double and triple born offspring from day 0 to 360 comparing all 3 curves. Figure 8 and Figure 9 show the Gompertz model fitted to the curve of mean live weights of male and female offspring from 0 to 360 days old. Figure 10, Figure 11 and Figure 12 shows the Gompertz model fitted to the curve of mean live weights of single, double and triple born offspring from 0 – 360 days old. Table 3 summarized the comparison of Gompertz, Logistic and Von Bertalanffy equations on offspring by litter size and sex. Here it was seen that the Gompertz curve fits closest to the growth of agouti offspring by sex and litter size.

Figure 13 showed the rate of live weight change by sex and both male and female offspring showed the highest growth rate within the period of day 0 to 30, hence early nutrition is very important. Figure 14 illustrated that all 3 birth types seemed to plateau between days 240 to day 270 and grew differently until day 360. Figure 15 and 16 showed the live weight gain of all males and females were similar in weight at day 240 to day 270 regardless of litter size. Figure 14, 15 and 16 showed that agouti males can be harvested and utilized for meat from 8 to 9 months of age, where the average live weight is 2616g and 2685g.

5. CONCLUSION

- Male and female offspring grew at the same rate from day 0 to 360 except the period of 241-270 days, hence no sexual dimorphism by live weight was seen at day 360.
- Single born offspring grow faster than double and triple born offspring in the first 6 months of life, but double and triple born offspring exhibited a form of compensatory growth after 6 months of age.
- The average weight for optimum utilization (harvest) by live weight is no less than 2600g which can be achieved as early as 8 months of age.
- The Gompertz growth model best describes the growth of Agouti offspring as compared to the Logistic and Von Bertalanffy models.

6. RECOMMENDATIONS FOR FUTURE WORK

- How do agouti offspring grow by allometric growth/scaling?
- What is the age and live weight for female agouti to reach puberty and first estrus?
- What is the dressing percentage of agouti males harvested at day 240 in an intensive production system?

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Competing Interests: The authors declare that they have no competing interests.
Contributors/Acknowledgement: All authors contributed equally to the conception and design of the study.

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