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GROWTH CURVE MODELING OF GARUT SHEEP AT UPTD-BPPTDK MARGAWATI GARUT

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Abstract

Growth curves can be used to reflect changes in the body structure due to genetic and environmental responses. This study evaluated six growth curve models - Gompertz, Logistic, Richard, Von Bertalanffy, and Weibull models – to analyze growth patterns in male and female Garut sheep at UPTD-BPPTDK Margawati Garut with the case study method. This research collected 211 samples of 67 male and 144 female lamb birth weight records. The average birth weights for male lambs were 2.96 ± 0.43 kg (single), 2.48 ± 0.42 kg (twins), and 2.27 ± 0.46 kg (triplets), while female lambs were 3.13 ± 0.46 kg (singles), 2.46 ± 0.40 kg (twins), and 2.01 ± 0.34 kg (triplets). Data were analyzed using the Curve Expert software to find similarities and curve shapes. The results showed that each parameter measured had a sigmoid growth curve. The curve model with the best accuracy to determine the growth rate of Garut sheep at UPTD-BPPTDK Margawati Garut was the Weibull model. The Weibull growth curve model is the most appropriate model to determining growth rate of male and female Garut sheep at UPTD-BPPTDK with coefficient of Determination (R^2) ± Standard Error (SE) were 0.999 ± 0.089; 0.999 ± 0.217 (Single), 0.999 ± 0.069; 0.999 ± 0.243 (Twin), and 0.999 ± 0.069; 0.999 ± 0.243 (Triplet), respectively. The value of the determination coefficient is getting higher, close to 1 (one), indicating that the model is as accurate as a predicted model.
Keywords: Sheep, Growth Curve, Genetic

MODEL KURVA PERTUMBUHAN DOMBA GARUT DI UPTD-BPPTDK MARGAWATI GARUT

Abstrak

Kurva pertumbuhan dapat digunakan untuk menjelaskan perubahan struktur tubuh karena pengaruh genetik dan lingkungan. Penelitian ini mengevaluasi model kurva pertumbuhan - model Gompertz, Logistic, Richard, Von Bertalanffy, dan Weibull untuk menganalisis pola pertumbuhan domba Garut jantan dan betina di UPTD-BPPTDK Margawati Garut dengan metode studi kasus. Penelitian ini menggunakan data sebanyak 211 sampel, yang terdiri atas 67 catatan berat lahir domba jantan dan 144 betina. Rata-rata berat lahir domba jantan adalah 2,96 ± 0,43 kg (kelahiran tunggal), 2,48 ± 0,42 kg (kelahiran kembar dua), dan 2,27 ± 0,46 kg (kelahiran kembar tiga), sedangkan untuk domba betina adalah 3,13 ± 0,46 kg (kelahiran tunggal), 2,46 ± 0,40 kg (kelahiran kembar dua), dan 2,01 ± 0,34 kg (kelahiran kembar tiga). Data selanjutnya dianalisis menggunakan perangkat lunak Curve Expert untuk menemukan kesamaan dan bentuk kurva. Hasil penelitian menunjukkan bahwa setiap parameter yang diukur memiliki kurva pertumbuhan sigmoid. Model kurva dengan akurasi terbaik untuk menentukan laju pertumbuhan domba Garut di UPTD-BPPTDK Margawati Garut adalah model Weibull. Model kurva pertumbuhan Weibull merupakan model yang paling tepat untuk menentukan laju pertumbuhan domba Garut jantan dan betina pada UPTD-BPPTDK dengan koefisien Determinasi (R^2) ± Standar Error (SE) berturut-turut sebesar 0,999 ± 0,089; 0,999 ± 0,217 (kelahiran tunggal), 0,999 ± 0,069; 0,999 ± 0,243 (kelahiran kembar), dan 0,999 ± 0,069; 0,999 ± 0,243 (kelahiran kembar tiga). Nilai koefisien determinasi semakin tinggi, mendekati nilai 1 (satu), menandakan bahwa model tersebut akurat sebagai model penduga.
Kata Kunci: Domba, Model Kurva Pertumbuhan, Genetik

INTRODUCTION

Garut sheep is a livestock genetic resource from West Java, Indonesia, that needs to be preserved and bred because of their high environment adaptability and relatively fast growth. Garut sheep can serve multiple purposes, such as breeding, meat production, fancy, and as a form of investment. Garut sheep have a strategic importance both traditionally and commercially due to their contributions to food security. The characteristic of Garut sheep is a combination of *rumpung* or *hiris* ears with a tail in the shape of a *beurit* tail or a *bagong* tail (Heriyadi, 2011). Evaluating the growth rate of Garut Sheep is crucial for farmers to determine the main growth characteristic that contributes to the desired production performance.

Growth is typically assessed through changes in body weight and size per time unit. The increase in body weight and body size of the sheep is related to the proportion of their meat, bone, and carcass fat. Changes in body size is a good indicator and fairly correlated with live weight. The animal growth rate can be determined by monitoring body size changes and body weight. In addition to physical weighing, live weight at specific time can be predicted by analyzing growth curves. A growth curve is a tool to evaluate and predict periods of fast or slow growth during livestock rearing, to obtain better production efficiency and future rearing management. Growth rate displays the animal's genetic potential and body growth towards maturity under environmental conditions.

Growth rate is generally modeled using nonlinear regression equations, but various models of growth curves can be used to reflect changes in body measurement due to genetic and environmental responses. Nonlinear regression curve equations widely used in observing growth rates include Gompertz, Logistic, Richards, Morgan-Mercer-Flodin (MMF), Weibull, and Von Bertalanffy models. These models have been widely used in researches and studies, and are excellent for quantitative longitudinal data in animals and plants. They also have good accuracy in determining growth inflection points.

Sheep rearing at UPTD-BPPTDK includes rams and ewes. Rams have a faster growth rate than ewes. The performance of livestock production is greatly affected by sex, and sheep farming depends on the availability of highbred rams and ewes. The availability of these highbred sheep is inseparable from breeding selection programs, that are important to produce good quality offspring with maximum performance. Sheep selection can be carried out on quantitative traits, including birth weight, weights at 30, 60, and 30 days, and weaning weight. The birth type (litter size) influences the birth weight of the lamb based on sex.

Phenotypic growth analysis in the sheep farming industry is essential to determine which biological growth trait is the main factor in achieving optimal production performance. This is what underlies the need for an effective livestock selection program based on the growth curve, to evaluate the results of Garut sheep breeding at UPTD-BPPTDK Margawati. UPTD-BPPTDK already has a good data recording system that can support research on the growth curve models for Garut sheep.

MATERIAL AND METHOD

The method used in this research was the case study. The research was carried out to give a general review of the characteristics of the population using instruments or interviews, observation, and recording to obtain data. The main variables measured in this research were age and body weight. The data was collected by purposive sampling, after which the data was tabulated and analyzed. The data collected or observed from a recording system was on birth weight, weights at 30, 60, 90, and up to 365 days. The total data sampled was 211 individuals, consisting of 147 single births, 54 twin births, and 10 triplet births. To make it easier to analyze, the data was tabulated, including sex, birth type (litter size), age (days), birth weight, and weights at 30, 60, 90, and up to 365 days.

RESULTS AND DISCUSSION

Birth weight is an important factor that shows the production performance of ewes. A high birth weight can indicate a high weaning weight in a lamb. Birth weight correlates with the growth and live weight of adult sheep. It also correlates with the survivability of the lamb. The birth weights of Garut sheep by sex corrected by sex and birth type can be seen in Table 1.

Table 1. The Birth Weights of Garut Sheep

Birth Type	Sex	Quantity	Average Weight (kg)	Standard Deviation	Coefficient of Variation
Single	Male	43	2.96	0.43	14.64
	Female	104	3.13	0.46	14.71
Twin	Male	21	2.48	0.42	16.75
	Female	33	2.46	0.40	16.19
Triplet	Male	3	2.27	0.46	20.38
	Female	7	2.01	0.34	17.06

Table 1. Average Weight, Standard Deviation, and Coefficient of Variation in Birth WeigThis research used records of birth weight and weights at 30, 60, 90, and 365 days, for the lambing year from 2012 to 2019. In total, 211 records were analyzed, consisting of 67 records of male and 144 records of female lamb birth weights. The average male lamb birth weight was 2.96 ± 0.43 kg for singleton, 2.48 ± 0.42 kg for twin, and 2.27 ± 0.46 kg for triplet. The average female lamb birth weight was 3.13 ± 0.46 kg for singleton, 2.46 ± 0.40 kg for twin, and 2.01 ± 0.34 kg for triplet.

The average birth weights of male lambs are higher than female lambs for both singletons and twins. Ewe age also affects the birth weight of lambs, with younger ewes giving birth to lambs with lower weights compared to older ewes. According to Inounu (2003), ewes with low weights will give birth to lambs with low average birth weights as well. These results are higher than the results obtained by Dudi (2023) in the same place using data from 1993 to 2011, who recorded an average birth weight of male lambs of 1.93 kg and an average weaning weight of 8.39 kg. The increase in weight is due to periodical selection processes held by UPTD-BPPTDK Margawati, which increased the birth and weaning weight of the next generation.

Differences in birth weight due to livestock growth and development factors can occur from both the genetic and environmental factors effect. This is in line with the findings of Faid *et al*. (2016) and Boujenane and Diallo (2017), that sex impacts birth weight, pre-weaning weight gain, and weaning weight. On average, the body weight of 365-day-old male lambs is higher than that of female lambs. While intrinsic factors such as sex, age, and physiological status are influential, extrinsic factors such as maternal and other environmental factors also determine the phenotypic expression of growth (Arango and Van Vleck, 2002).

The analysis results presented in Table 1 indicate that the average weight of rams is higher than ewes. Ewes have a higher sensitivity to the insulin hormone compared to rams, which results in a lower need for insulin hormone to regulate blood sugar. According to Carr et al. (2015), the birth weight of female lambs is lower than that of male lambs, because female lambs have lower insulin hormone levels, which are responsible for transporting glucose and amino acids needed to synthesize protein (meat).

The birth weights of male and female lambs were analyzed by sex and birth type. The coefficients of variation in single births were 14.64 for male lambs and 14.71 for female lambs. In the twin births, the coefficients of variation were 16.75 for male lambs and 16.19 for female lambs; in the triplet births, they were 20.38 for male lambs and 17.06 for female lambs. The highest coefficient of variation in birth weight was observed in the triplet birth type. The triplet birth type's coefficient of variation was higher than 10%, meaning an equation with one independent variable can be considered accurate if the standard error does not exceed 25%.

The higher the litter size, the lower the average body weight of the sheep produced. The single birth type has a higher birth weight than the twin birth type due to no competition for nutrients during the prenatal and lactation periods. This allows lambs with single birth type to consume milk according to their nutritional needs.

Growth Curve Model

The growth observed was based on data obtained from 1,626 rams born between 2012 and 2019. The data was used after a correction process. The correction was meant to equalize or standardize certain conditions when the data was not equal so that the corrected livestock had the same genetic chance. The corrected livestock were then divided by birth type. The curve models used in each birth type are the same: Gompertz, Logistic and Richards, Morgan-Mercer-Flodin, Weibull, and Von Bertalanffy models.

The growth curve shows that the average weight of the rams increases daily. The blue dots show the actual body weights obtained from the records that have been corrected by a correction factor. The red lines show the estimated average body weight based on the growth curve model. By obtaining the equation for the Gompertz model, it is expressed in the equation. The accuracy of the curve model was observed based on the highest coefficient of determination (R^2) and the smallest standard error (SE). The coefficient of determination can show the accuracy of the data against the regression line. The accuracy (r) between the points and the curve has a value of 0.99, which means that the accuracy of the data is significantly higher. The results of the accuracy values can be seen in Tables 2, 3, 4, 5, 6, and 7.

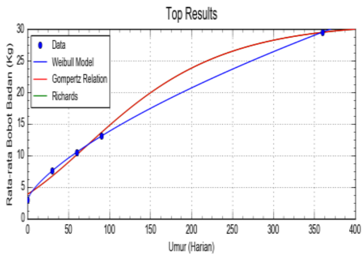

Figure 1. Growth Curve of Rams with Single Birth Type

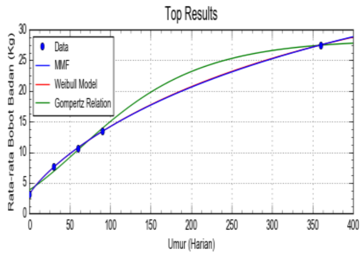

Figure 2. Growth Curve of Ewes with Single Birth Type

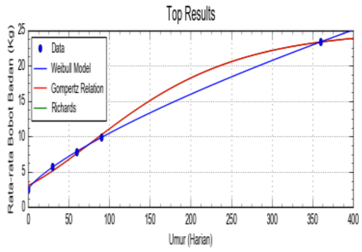

Figure 3. Growth Curve of Rams with Twin Birth Type

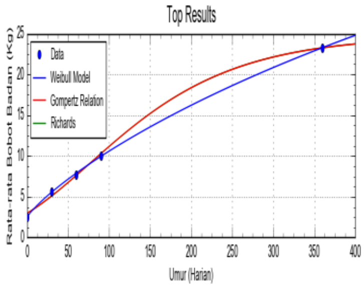

Figure 4. Growth Curve of Ewes with Twin Birth Type

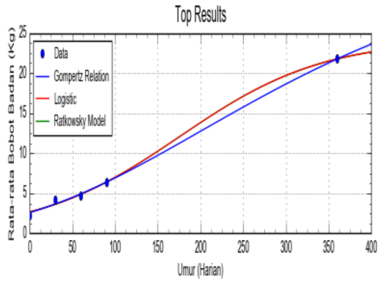

Figure 5. Groth Curve of Rams with Triplet Birth Type

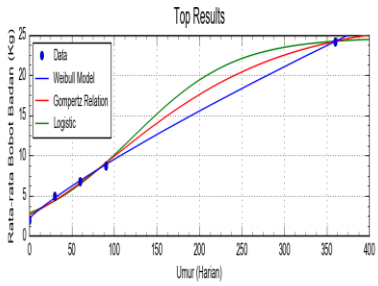

Figure 6. Growth Curve of Ewes with Triplet Birth Type

Table 2. Accuracy Value of the Curve Model for Male Lambs with Single Birth Type

Curve Model	Standard Error (SE)	Coefficient of Determination (R^2)
Gompertz	0.984733	0.997629
Logistic	1.277731	0.996006
Von bertalanffy	1.277734	0.996009
Richards	1.393443	0.997626
Weibull	0.089354	0.999990

Table 3. Accuracy Value of the Curve Model for Female Lambs with Single Birth Type

Curve Model	Standard Error (SE)	Coefficient of Determination (R^2)
Gompertz	0.829280	0.997978
Logistic	1.139276	0.996181
Von Bertalanffy	1.139275	0.996180
Richards	1.173728	0.997975
Weibull	0.217017	0.999930

Table 4. Accuracy Value of the Curve Model for Male Lambs with Twin Birth Type

Curve Model	Standard Error (SE)	Coefficient of Determination (R^2)
Gompertz	0.635731	0.998431
Logistic	0.839058	0.997265
Von Bertalanffy	0.839058	0.997265
Richards	0.899792	0.998428
Weibull	0.069344	0.999990

Table 5. Accuracy Value of the Curve Model for Female Lambs with Twin Birth Type

Curve Model	Standard Error (SE)	Coefficient of Determination (R^2)
Gompertz	0.574607	0.998713
Logistic	0.773603	0.997666
Von Bertalanffy	0.773603	0.997666
Richards	0.813408	0.998710
Weibull	0.243107	0.999884

Table 6. Accuracy Value of the Curve Model for Male Lambs with Triplet Birth Type

Curve Model	Standard Error (SE)	Coefficient of Determination (R^2)
Gompertz	0.635731	0.998431
Logistic	0.839058	0.997265
Von Bertalanffy	0.839058	0.997265
Richards	0.899792	0.998428
Weibull	0.069344	0.999990

Table 7. Accuracy Value of the Curve Model for Female Lambs with Triplet Birth Type

Curve Model	Standard Error (SE)	Coefficient of Determination (R^2)
Gompertz	0.574607	0.998713
Logistic	0.773603	0.997666
Von Bertalanffy	0.773603	0.997666
Richards	0.813408	0.998710
Weibull	0.243107	0.999884

The standard error (SE) and coefficient of determination (R^2) show the accuracy of the curve model in estimating age and weight values that closely align with the actual weight. The higher the coefficient of determination, the higher the accuracy of the results. For the growth curve models (Gompertz, Logistic, Richards, Weibull, and Von Bertalanffy), the R^2 value represented the closeness of the actual age and body weight of rams and ewes to the predicted value. The combined average R^2 value of the models was 0.996-0.999, and the SE was between 0.069-1.393. Based on these results, the Weibull Model demonstrated high accuracy, as its average R^2 was close to 1.00, and its average SE was lower than other models.

Comparison of Curve Models

The curve models were compared based on two criteria: simplicity of calculation and the model's accuracy. The model's simplicity can be assessed based on the number of iteration processes performed by the software. The more iteration processes required, the more complex the model is for converging, which means the model is more difficult to calculate. Based on the results of the accuracy tables, the Richards model requires the most iteration processes, followed by the Gompertz model, and the

Logistic model has the least iteration processes. These results align with the findings of Suparyanto et al (2001), who compared the same models on cross-bred Sumatran sheep using population data.

The accuracy of the models was compared based on the deviation between the field data and estimates from models at various ages to find out the trend of deviation of each model in estimating field data. The cause of the iteration processes that occur more in the Richards model, followed by the Morgan-Mercer-Flodin (MMF) model, is the discrepancy with the available data. It is proven by the error values generated by calculations using *CurveExpert*. Therefore, the mathematical equations of the models cannot be obtained. Meanwhile, the Weibull, Gompertz, Logistic, Richards, and Von Bertalanffy curve models produced mathematical equations.

Body Weight Gain

The research results at UPTD-BPPTDK Margawati showed that every year there is an increasing and decreasing phase in the body weight of rams and ewes. The average birth weight of Garut sheep from year to year tends to be stable, with the lowest in 2015 at 2.60 kg and the highest in 2019 at 3.07 kg. The lowest average birth weight was observed in 2016 due to the long drought, which prevented pregnant women from getting enough nutrients from forage. Nutrition plays a significant role in growth. Even if the sheep are highbred with good genetic traits, without being fed with the right and good quality nutrition, the advantages will not give significant added value. Appropriate and high-quality feeding can increase the potential of the genetic superiority of the sheep being raised to increase production performance to meet the predetermined target.

The increase in average birth weight that occurred in 2017, 2018, and 2019 was thought to be due to the response to selection held in the previous breeding center and better management. According to Ghasemi, et al (2019), birth weight is an important trait that affects the survival and growth of sheep throughout their life, meaning that high birth weight increases the survival and growth of the sheep. The highest average weight at the age of 90 days and weaning weight were also in 2014. The lowest average weights at the age of 30, 60, and 90 days were in 2015, 2016, and 2014. The lowest birth weight was also in the same year due to a long drought, causing reduced forage availability to affect sheep growth. However, sheep's high or low body weight is not merely due to genetics, seasons, and feed management. There are also non-genetic influences, including fixed effects such as sex and birth type, on body weight in the selection program.

The effect of sex and birth type on the body weight of sheep in the selection program for birth weight, weight at 30, 60, and 90 days, and weaning weight (100 days) in single birth type is higher than in twin, triple or multiple birth types (Faid, et al 2016; Boujenane and Diallo, 2017). It is in line with the results of research by Rahmat et al. (2007) that singleton sheep generally have higher weight than sheep with multiple birth types. The birth type also significantly influences the pre-weaning growth of sheep. Single birth type is better than twin birth type because there is no competition for singleton lambs to consume milk, so they can consume milk to their needs (Boujenane and Diallo, 2017).

Sex has an influence on birth weight, pre-weaning weight gain, and weaning weight. Birth weight, weights at 30, 60, and 90 days, and weaning weight in male lambs tend to be greater than in female lambs (Faid, et al, 2016; Boujenane and Diallo, 2017), According to Carr, et al, (2015), rams generally have a higher birth weight than ewes. Because ewes are more sensitive to the insulin hormone than rams, they will need less insulin hormone to lower blood sugar.

The birth weight of female lambs is lower than that of male lambs as the insulin hormone in female lambs is also lower than in male lambs. Insulin hormone is a hormone secreted by the pancreas and responsible for transporting glucose and amino acids needed as raw materials to synthesize protein (meat) is lower. The higher the raw materials for protein synthesis in the cells, the higher the body weight gain (Mukhtiani et al., 2013).

CONCLUSION

From the discussion above, it can be concluded that:

1. The best model for the growth curve for male and female lambs is the Weibull model, with the following equations:

- Singlet male lambs Y=31.0217850*exp (-exp (0.7360716-0.0103331x)).
- Singlet female lambs Y=28.368038*exp (-exp (0.68925481-0.01143034x)).
- Twin male lambs Y=24.98902*exp (-exp (0.743663-0.00950x)).
- Twin female lambs Y=24.745370*exp (-exp (0.7504513-0.009797x)).
- Triplet male lambs Y=34.895819*exp (-exp (0.953691-0.004734x)).
- Triple female lambs Y=27.066301*exp (-exp (0.849528-0.0084376x)).

2. The Weibull growth curve model is the most appropriate model to determining growth rate of male and female Garut sheep at UPTD-BPPTDK with coefficient of Determination (R^2) ± Standard Error (SE) were 0.999 ± 0.089; 0.999 ± 0.217 (Single), 0.999 ± 0.069; 0.999 ± 0.243 (Twin), and 0.999 ± 0.069; 0.999 ± 0.243 (Triplet).

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