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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

The Prediction of Brody, Logistik and Von Bertalanffy Models By Using The Bayesian Approach for Modeling The Growth Curves in Holstein Calves

Siyah Alaca Irkı Buzağılarda Büyüme Eğrisinin Modellenmesinde Kullanılan Brody, Logistik ve Von Bertalanffy Modellerinin Bayesci Yaklaşım ile Tahmini

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Abstract

In cattle breeding, growth curves are used for determining the most appropriate slaughter age, obtaining information about the general health status of animals, estimating the age of sexual maturity and the age of use in breeding, and selection studies. The aim of this study is to estimate the growth curves of Holstein calves using the Bayesian Approach of Brody, Logistik, and Von Bertalanffy models. The live weight data was collected from 34 Holstein calves raised at the cattle research farm of Niğde Ömer Halisdemir University, Ayhan Şahenk Agricultural Research and Application Center in 2019. Furthermore, for estimating the frequency modeling of the Holstein breed the predicted parameter values and standard deviation of parameters were used as the prior information. The Bayesian approach was used for making the statistical analysis. Monte Carlo Method Markov Chains (MCMC) algorithms were used to estimate the posterior distributions and it was 900,000 in total while excluding the 8000 burn-up periods. Random distribution graphs and autocorrelation graphs were used to control the iterations for the detection of posterior distributions. In this study, no problems arising from iteration were found. Moreover, the distribution information of the Brody, Logistic, and Von Bertalanffy model was calculated for the results. The Brody, Logistik and Von Bertalanffy model parameters distributions results can be used for modeling studies of the Holstein cattle breed. In addition, the compatibility of Brody, Logistik and Von Bertalanffy models was investigated by using data set, mean information of the posterior distributions estimated at the end of the study. The information for Brody, Logistik, and Von Bertalanffy model parameters was calculated, and the results of the posterior distributions showed the Deviation Information Criteria (DIC) values. For the comparison between the three models DIC values were calculated as 55.19, 33.17 and 38.02, respectively, and it was decided that the most compatible model was the Bayesian Logistics Model. The Bayesian Logistic Model, which is decided to be the most compatible, is a study-specific result.

Keywords: Bayesian approach, Calve, Cattle, Growth curves, Live weight, Non-linear model

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Öz

Sığır yetiştiriciliğinde en uygun kesim yaşının belirlenmesi, hayvanların genel sağlık durumu hakkında bilgi edinilmesi, eşeysel olgunluk yaşının belirlenmesi, damızlıkta kullanma yaşının belirlenmesi ve seleksiyon uygulamaları gibi konularda büyüme eğrileri kullanılmaktadır. Bu çalışmanın amacı Siyah Alaca ırkı buzağıların büyüme eğrilerinin modellenmesinde sıklıkla kullanılan Brody, Logistik ve Von Bertalanffy modellerinin Bayes Yaklaşımı ile tahmin edilmesidir. Çalışmada Niğde Ömer Halisdemir Üniversitesi, Ayhan Şahenk Tarımsal Araştırma ve Uygulama Araştırma Merkezi Büyükbaş Hayvan Yetiştirme Birimi'nde 2019 yılında yetiştirilen 34 baş Siyah Alaca buzağılara ait canlı ağırlık verileri kullanılmıştır. Bayes Yaklaşımı ile yapılan tahminleme çalışmasında literatürde Siyah Alaca ırkı için yapılan Frekanscı yaklaşım modelleme çalışmalarında tahmin edilen parametre değerlerinden ve parametrelere ait standart sapmalardan önsel bilgi olarak yararlanılmıştır. Sonsal dağılımların tahmininde, Monte Carlo Yöntemi Markov Zincirleri (MCMZ) algoritmaları için zincir uzunluğu, 8000 yanma periyodu hariç, toplam 900 000 olarak belirlenmiştir. Sonsal dağılımların tespiti için gerçekleştirilen iterasyonların kontrolünde rassal dağılım grafikleri ve otokorelasyon grafikleri kullanılmıştır. Çalışmada iterasyondan kaynaklı herhangi bir probleme rastlanmamıştır. Çalışma sonucunda Brody, Logistik ve Von Bertalanffy model parametrelerine ait dağılım bilgileri tahmin edilmiştir. Brody, Logistik ve Von Bertalanffy model parametrelerine ait bilgiler Siyah Alaca sığır ırkına ait yapılacak modelleme çalışmaları için kullanılabilir sonuçlardır. Ayrıca çalışma sonucunda tahmin edilen sonsal dağılımların ortalama bilgilerinin kullanılması ile elde edilen Brody, Logistik ve Von Bertalanffy modellerinin çalışmada kullanılan veri seti ile uyumları araştırılmıştır. Üç model arasındaki kıyaslama için Sapma Bilgi Kriteri (DIC) değerleri sırasıyla 55.19, 33.17 ve 38.02 olarak hesaplanırken uyumlu modelin Bayesci Logistik Modeli olduğuna karar verilmiştir. En uyumlu olduğuna karar verilen Bayesci Logistik Modeli çalışmaya özgü bir sonuçtur.

Anahtar Kelimeler: Bayesci yaklaşım, Buzağı, Büyüme eğrileri, Canlı ağırlık, Doğrusal olmayan model, Sığır

1. Introduction

Holstein cattle breed is the most farmed cattle breed around the globe. It is originated in Netherland and its name Friesian is given due to its origin in the Frisia region Netherland. The leading countries for Holstein breeding include the USA, Germany, Netherland, England, and Canada (Ozhan, 1991; Göven, 2019). Live weight change per unit time is considered the most important trait in cattle husbandry (Bayram and Akbulut, 2009). The increase in the live weight of the animal is called growth (Akbaş et al., 1999). Growth trait depends upon the genetic potential in the genome of the animal and its interaction with the environment in which it is raised (Akbaş, 1995; Göven, 2019).

The changes occurring in the animal growth during its lifespan are described using the mathematical growth curves (Kocabaş et al., 1997; Bayram and Akbulut, 2009). Models that explain the biological information through growth curves and their parameters are known as growth functions or growth models (Akbulut et al., 2004). The most preferred growth curve models for the Holstein cattle breed in the literature are Richards, Brody, Gompertz, Logistics, and Von Bertalanffy models, which were estimated by the frequency approach prediction methods (Wada et al., 1983; Nadarajah et al., 1984; Perotto et al., 1992; Koenen and Groen, 1996; Akbaş et al., 2001; Bayram et al. 2004; Bayram and Akbulut, 2009; Göven, 2019). The point value prediction is done using the model parameters from the available data sets through the frequency approach. In the study published in recent years, the growth curve models in Rabbits (Blasco et al., 2003), Hani Fish, (Alós et al., 2010); Japanese quail (Fırat et al., 2016; Lázaro et al., 2017; Mohammadi et al., 2019) and sheep (Hojjati ve Hossein-Zadeh, 2018; Salles et al., 2020) are predicted by using Bayesian approach.

In the present study, the posterior distribution information of Brody, Logistik, and Bertalanffy model parameters with the Bayesian Approach was investigated by using the current live weight data and the predicted growth model data based on the literature. The aim of the study is to use priory information data obtained by Bayseian approach of parameter estimation to get more generalized results by going beyond the likelihood function knowledge.

2. Material and Method

The animal material in this study consists of 13 female and 21 male Holstein calves having different birth dates in the year 2019 in Ayhan Şahenk Agricultural Research and Application Research Center of Cattle Breeding Unit. Their body weight information was determined by taking measurements of animals every two weeks. The recorded age difference present due to different birth dates was eliminated by using the interpolation method (Akın, 1998), and the average live weight data of the first 16 weeks of 34 calve was used. Three nonlinear models were used for bodyweight modeling: Brody, Logistic, and Von Bertalanffy models. A growth model for a single experimental unit was assumed as:

$$y_j = f(t_j, \theta) + \varepsilon_j, \qquad j = 1,2,\dots,n \qquad \text{(Eq.1)}$$

Where y_j is the observed weight, $f(t_j, \theta)$ is the model-specific function, θ is the unknown parameter vector, n is the total number of observations, and ε_j is the random independent error term. $f(t_j, \theta)$ are functions for growth models used in the study

Brody $$f_1(t_j, \theta_1) = A(1 - B\exp(-Kt)) \qquad \text{(Eq.2)}$$

Logistic $$f_2(t_j, \theta_2) = A/(1 + B\exp(-Kt)) \qquad \text{(Eq.3)}$$

Von Bertalanffy $$f_3(t_j, \theta_3) = A(1 - B\, exp(-Kt))3 \qquad \text{(Eq.4)}$$

Where y represents body weight at age t (day), A represents asymptotic weight, which is interpreted as mature weight, and B indicates the proportion of the asymptotic mature weight to be gained after birth, established by the initial values of W (weight) and t. K is a function of the ratio of maximum growth rate to mature weight, normally referred to as maturing rate. Large K values indicate early maturing animals and vice versa (Soysal et al., 2001; Aggrey, 2002; Kizilkaya et al., 2006; Yıldız et al., 2009).

Two basic functions are required for the Bayesian Approach, which is used for the estimation of model parameters (Eğrioğlu, 2002). The first is the likelihood function and the second is the prior distribution information.

$$\mathcal{L}(y|\theta_k, t, \sigma^2) = \frac{1}{(2\pi)^{\frac{n}{2}}\sigma^n} exp\left[-\frac{1}{2\sigma^2}\sum_{j=1}^{n}\{y_j - f_k(t_j, \theta_k)\}^2\right] \quad \text{(Eq.5)}$$

The likelihood function for growth models $t = \{t_j, j = 1,2, \ldots, n\}$, $y = \{y_j, j = 1,2, \ldots, n\}$ and k=1.2.

While determining the prior distribution information of the parameters, the information on the parameters is presented in *Table 1* for the Brody, Logistic and Von Bertalanffy models' estimation the Frequency Method in Holstein breed was used. The prior distribution information used is presented in *Table 1*.

Table 1. Parameter information of some modeling studies on Holstein cattle and prior distribution information used in the current study

References	Brody			Logistics			Von Bertalanffy		
	A	B	K	A	B	K	A	B	K
Wada et al. (1983)	456		0.09	432		0.22	450		0.10
Nadarajah et. al. (1984)	491	0.92	0.07						
Koenen and Groen (1996)							667	0.59	0.00
Perotto et al. (1992)				525.57	6.33	0.01			
Akbaş et al. (2001)	478		0.05	437	5.89	0.14	454	0.561	0.08
Bayram and Akbulut (2009)	508	0.94	0.04	452	5.58	0.12	471	0.55	0.08
Mean	483.25	0.92	0.06	461.64	5.93	0.09	510.50	0.56	0.05
Variance	360.690	0.00	0.00	1416.51	0.095	0.003	8226.250	0.000	0.001
Prior Distribution	*N(483; 361)	*N(0.93; 0.1)	*N(0.6; 0.1)	*N(462; 10000)	*N(6; 0.1)	*N(0.09; 0.1)	*N(510; 10000)	*N(0.6; 0.1)	*N(0.05; 0.1)

For the standard distributions of the models, the prior distribution is taken as gamma (0.01, scale=0.01). *Normal Distribution (Mean;Variance)

The mean and variance information given in *Table 1*, was used as a priori distribution for Bayesian approach analysis. While the mean information is used directly, 10,000 for variance information over 1000 and 0.1 for values less than 0.01 are preferred.

After the mathematical multiplication of the probability functions obtained with the prior determining distributions, the MCMC procedure of the SAS 9.4 program was used to obtain the posterior distributions of the parameters separately (SAS Institute, 2005). The MCMC iteration length used in the prediction of posterior distributions was determined as 908000 and the warming period length as 8000.

The Deviation Information Criterion (DIC), which is frequently used to decide on the best fit model for the modeling studies based on the Bayesian method, will be used (Forni et al., 2009; Fırat et al., 2016; Pooley and Marion, 2018).

$$DIC = 2\bar{D} - D(\bar{\theta}_k) \quad \text{(Eq.6)}$$

where, $\bar{D} = -2\int \log[p(y_t|\theta_k)p(\theta_k|y_t)]\, d\theta_{k,}$ $D(\bar{\theta}_k) = -2\log[p(y_t|\widehat{\theta_k})]$, $t = \{t_j = 1,2,\dots,n\}$, $y = \{y_j, j = 1,2,\dots,n\}$, k=1,2 and, y_t is the observed weight, θ_k is the unknown parameter.

In model comparison, the smaller DIC model fits better to the data set (Spiegelhalter et al., 2002; Forni et al., 2009). In practical applications of DIC, Spiegelhalter et al. (2002) stated that just reporting the model with the lowest DIC could be misleading if the difference in DIC is small, for example less than 5, and the models make very different inferences. DIC gives a clear conclusion to support the null hypothesis or the alternative hypothesis similar to the Bayes factor, BIC, and AIC (Fırat et al., 2016).

3. Results and Discussion

In this study, descriptive statistics of the live weight of 13 female and 21 male Holstein calves were given in *Table 2*. The posterior distributions of the Brody, Logistic, and Von Bertalanffy model parameters were estimated by the MCMC method using the average of body weights, and a priori distribution information is given in *Table 2*. The posterior distribution, MCMC iteration, and correlation graphs of the parameters are presented in *Figure 1* for the Brody model, *Figure 2* for the Logistic model, and *Figure 3* for the Von Bertalanffy model.

Table 2. Adjusted live weights of calves (n=34)

Live Weight	Total		
	Mean	Std. Deviation	CV
LW1	37.00	4.570	12.40
LW14	42.60	4.150	9.70
LW 28	47.60	5.340	11.20
LW42	56.50	5.910	10.50
LW56	66.50	7.900	11.90
LW70	77.90	8.490	10.90
LW84	90.30	10.260	11.40
LW98	102.50	10.990	10.70
LW112	112.70	12.310	10.90

LW: Live wight, CV: coefficients of variation

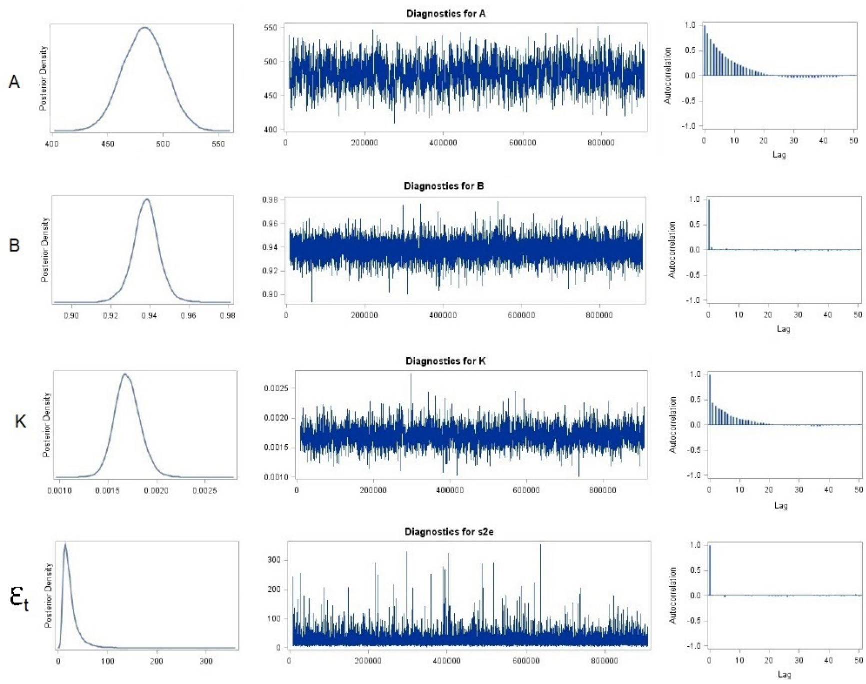

Figure 1. Posterior distribution, MCMC iteration, and autocorrelation plots of Brody model parameters

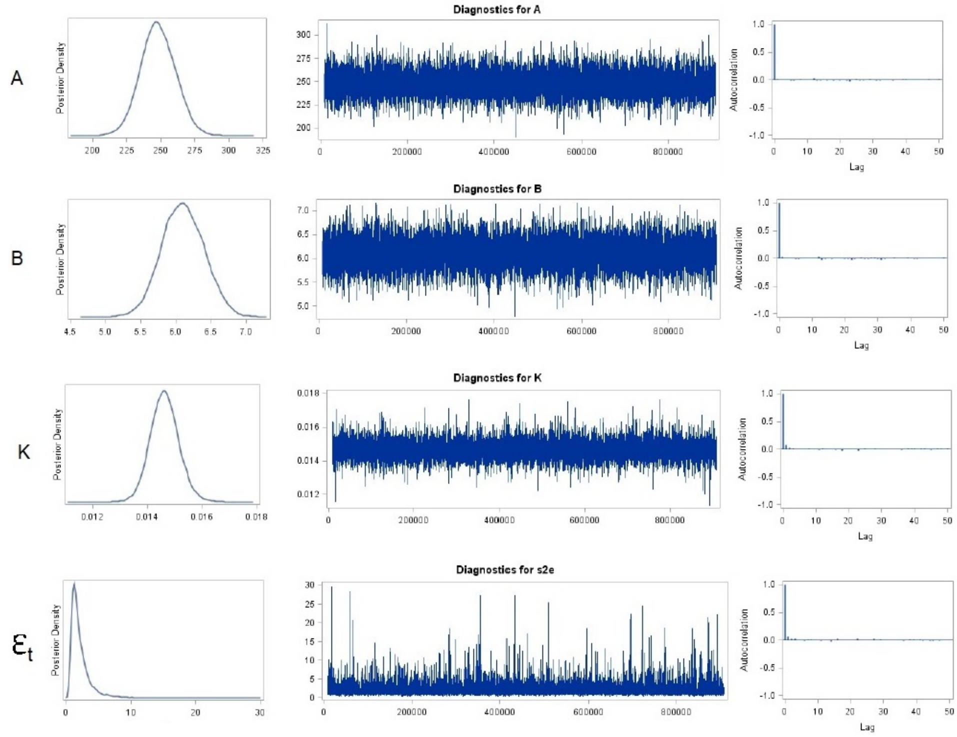

Figure 2. Posterior distribution, MCMC iteration and autocorrelation plots of Logistic model parameters

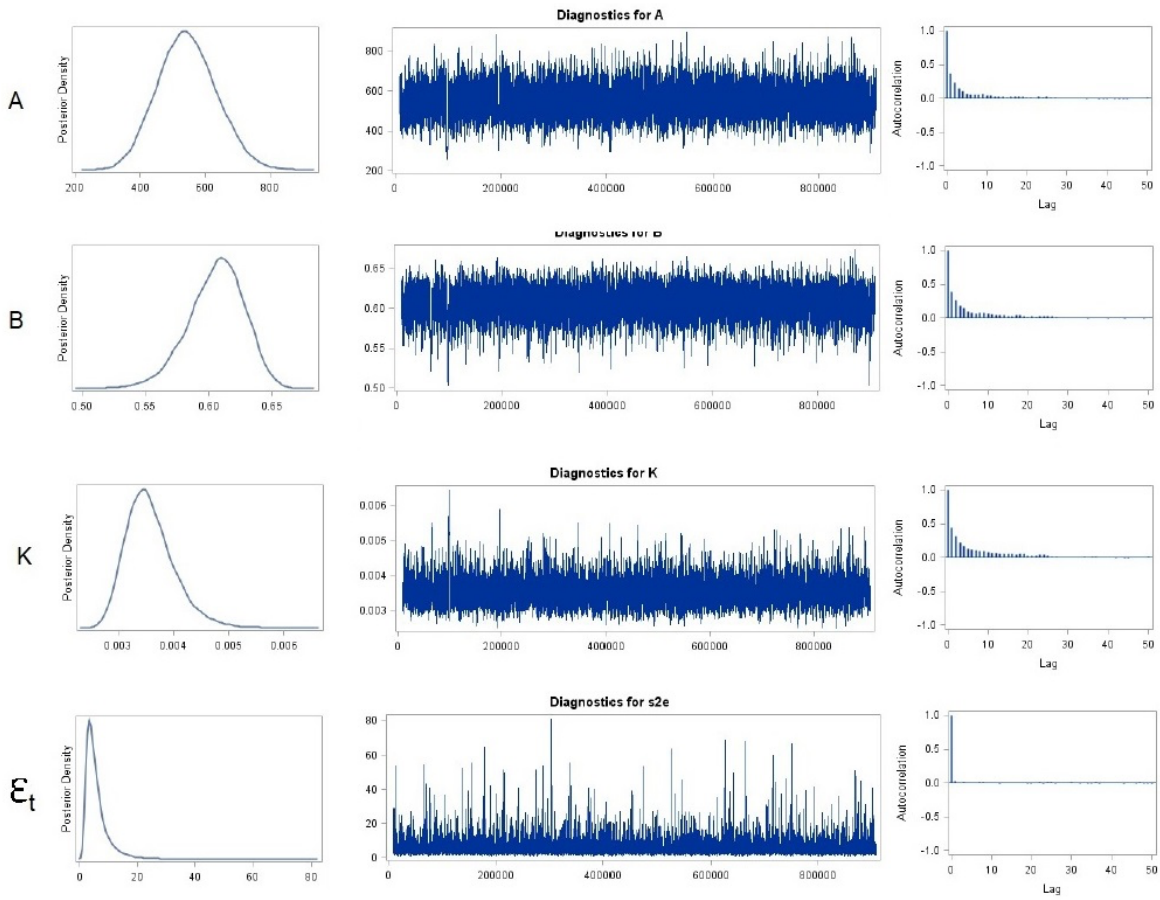

Figure 3. Posterior distribution, MCMC iteration, and autocorrelation plots of Von Bertalanffy model parameters

The fact that the iteration graph of the MCMC method in *Figures 1, 2,* and *3* has a random pattern and that no significant correlation is observed in the correlation graphs indicates that the predicted posterior distributions are valid. Descriptive statistics of model parameters are as given in *Table 3*.

Table 3. Descriptive statistics of Bayesian model parameters

Model	Parameter	Mean	SD	% 95 HPD interval	
				Lower	Upper
Brody	A	482.90	19.130	446	520.500
	B	0.94	0.007	0.938	0.952
	K	0.002	0.001	0.001	0.002
	ε_t	24.85	19.780	5.667	57.859
Logistic	A	248.20	12.834	222.600	272.700
	B	6.10	0.302	5.524	6.701
	K	0.01	0.001	0.014	0.016
	ε_t	2.19	1.756	0.458	5.106
Von Bertalanffy	A	544.80	89.998	376.200	725.000
	B	0.60	0.022	0.563	0.648
	K	0.004	0.000	0.003	0.004
	ε_t	6.01	4.830	1.133	14.113

The Brody model parameters for Holstein cattle breed with Frequency estimation methods, mature body weight (A) was reported as 456 kg (Wada et al., 1983), 491 kg (Nadarajah et al., 1984), 476 kg (Akbaş et al., 2001) and 508 kg in these reports (Bayram and Akbulut, 2009). The mean values of estimated mature body weights calculated in our study were 482.9 kg for the Brody model which was in cohesion with the reports mentioned above.

Furthermore, the logistic model parameters value estimation with Frequency estimation methods, mature body weight (A) was 432 kg (Wada et al., 1983), 525.6 kg (Perotto et al., 1984), 437 kg (Akbaş et al., 2001), and 452 kg (Bayram and Akbulut, 2009) in these reports. However, in the present study, it is seen that the mature live weight value of 248.2 kg or the Logistic model is different from the reported studies and is outside the standard deviation values. . It can be said the results of before mentioned estimation parameter studies precision is variable and the fact is it is due to data.

The Von Bertalanffy model parameters with Frequency estimation methods, mature body weight (A) were reported as 450 kg (Wada et al., 1983), 454 kg (Akbaş et al., 2001), 471 kg (Bayram and Akbulut, 2009), and 667 kg (Koenen and Groen, 1996) in the above-mentioned studies. Koenen and Groen, (1996) reported that the difference in the estimated parameter value reduces the priory information strength. Furthermore, the current study has the posterior distribution mean value from Von Bertalanffy 544.8 for the mature body weight which is in range according to the previous results reported. However, the relatively high standard deviation value decreases the confidence in the mean live weight value.

In the present study, the compatibility of the predicted models with the data set was investigated. The curve plots and estimated DIC statistics for this review are presented in *Figure 4.*

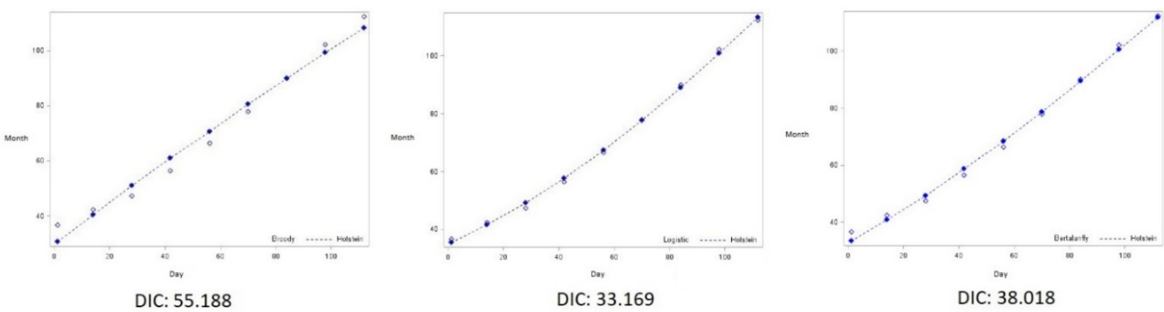

Figure 4. The Bayesian model graphs with real values and DIC values of models

The logistic model is more compatible with the data set when compared with other models. According to DIC values of the Bayesian models estimated in Figure 4, it was decided that the Logistic model is more compatible with the other two models for our data. It is thought that this selection may have arisen from the data set used. In their report, Wada et al. (1983) and Bayram and Akbulut (2009) predicted the Von Bertalanffy model, which was reported to be more compatible with the data set than the Logistic model.

4. Conclusion

The present study was designed for the predictions of Brody, Logistic, and Von Bertalanffy models, which are frequently used in the modeling of growth curves of Holstein cattle in the literature, and was investigated with the Bayesian approach. The present study also included the prediction, and there was no problem arising from iteration in the estimation of the posterior distributions of the model parameters.

In this study, the posterior distribution estimation of parameters for three different models were estimated. To study the coefficient interpretation, the mean value of posterior distribution was used. The estimated Brody parameters in the study contain a high priory information strength provided from the literature. Logistic model parameters are more affected by the likelihood function and model formulation combined with weak prior information. Due to mathematical model structures, the weak prior information used for the estimation in Von Bertalanffy helped to calculate the expected average value for an adult body weight of Holstein cattle.

Using the parameters obtained as a result of the present study, weight estimation can be performed for the Holstein breed. Periodic body weights can be estimated if the cattle are fattened at the youngest possible age. Considering that fattening activities in the Holstein cattle sector have an important place in animal husbandry, it can be said that the results obtained from this research together with specific studies will be useful in planning optimum feeding programs and determining the most appropriate breeding weight for heifer and slaughter age for a male.

The compatibility of the estimated curves with the data set used in the present study was investigated graphically and statistically. According to the results of the analysis of graphics and DIC values, the logistic model was found to be more compatible with this study data set. Therefore, the logistic model was selected for making the data analysis due to its compatibility with the data.

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